POLITECHNIKA
GDAŃSKA

imię i nazwisko autora rozprawy: mgr inż. arch. Szymon Kowalski
Dyscyplina naukowa: Architektura i urbanistyka

ROZPRAWA DOKTORSKA

Tytuł rozprawy w języku polskim:
Technologia wirtualnej rzeczywistości w dziedzictwie architektonicznym i jej wpływ na konserwację.

Tytuł rozprawy w języku angielskim:
Virtual reality technology in architectural heritage and its impact on conservation

Promotor	Drugi promotor
podpis	podpis
prof. dr hab. inż. arch. Jakub Szczepański	
Promotor pomocniczy	Kopromotor
podpis	podpis
dr hab. inż. arch. Piotr Sarnol	

Gdańsk,

GDAŃSK UNIVERSITY OF TECHNOLOGY

The author of the doctoral dissertation: mgr inż. arch. Szymon Kowalski
Scientific discipline: Architecture and urban planning

DOCTORAL DISSERTATION

Title of doctoral dissertation:
Virtual reality technology in architectural heritage and its impact on conservation.

Title of doctoral dissertation (in Polish)
Technologia wirtualnej rzeczywistości w dziedzictwie architektonicznym i jej wpływ na konserwację

Supervisor signature	Second supervisor signature
prof. dr hab. inż. arch. Jakub Szczepański	
Auxiliary supervisor signature	Cosupervisor signature
dr hab. inż. arch. Piotr Sarnół	

Gdańsk, 2025

POLITECHNIKA GDAŃSKA

OŚWIADCZENIE

Autor rozprawy doktorskiej: mgr inż. arch. Szymon Kowalski

Ja niżej podpisany(a), oświadczam, że jestem świadomy(a), że zgodnie z przepisem art. 27 ust. 1 i 2 ustawy z dnia 4 lutego 1994 r. o prawie autorskim i prawach pokrewnych (t.j. Dz.U. z 2021 poz. 1062), uczelnia może korzystać z mojej rozprawy doktorskiej zatytułowanej
Virtual reality technology in architectural heritage and its impact on conservation
do prowadzenia badań naukowych lub w celach dydaktycznych.[1]

Świadomy(a) odpowiedzialności karnej z tytułu naruszenia przepisów ustawy z dnia 4 lutego 1994 r. o prawie autorskim i prawach pokrewnych, konsekwencji dyscyplinarnych określonych w ustawie Prawo o szkolnictwie wyższym i nauce (Dz.U.2021.478 t.j.), a także odpowiedzialności cywilno-prawnej oświadczam, że przedkładana rozprawa doktorska została napisana przeze mnie samodzielnie.

Oświadczam, że treść rozprawy opracowana została na podstawie wyników badań prowadzonych pod kierunkiem i w ścisłej współpracy z promotorem prof. dr hab. inż. arch. Jakubem Szczepańskim, promotorem pomocniczym dr hab. inż. arch. Piotrem Samolem.

Niniejsza rozprawa doktorska nie była wcześniej podstawą żadnej innej urzędowej procedury związanej z nadaniem stopnia doktora.

Wszystkie informacje umieszczone w ww. rozprawie uzyskane ze źródeł pisanych i elektronicznych, zostały udokumentowane w wykazie literatury odpowiednimi odnośnikami, zgodnie z przepisem art. 34 ustawy o prawie autorskim i prawach pokrewnych.

Potwierdzam zgodność niniejszej wersji pracy doktorskiej z załączoną wersją elektroniczną.

Gdańsk, dnia 04.07.2025 .

Szymon Kowalski
podpis doktoranta

Ja, niżej podpisany(a) wyrażam zgodę/~~nie wyrażam zgody~~ na umieszczenie ww. rozprawy doktorskiej w wersji elektronicznej w otwartym, cyfrowym repozytorium instytucjonalnym Politechniki Gdańskiej.

Gdańsk, dnia 04.07.2025

Szymon Kowalski
podpis doktoranta

*niepotrzebne skreślić

[1] Art. 27. 1. Instytucje oświatowe oraz podmioty, o których mowa w art. 7 ust. 1 pkt 1, 2 i 4–8 ustawy z dnia 20 lipca 2018 r. – Prawo o szkolnictwie wyższym i nauce, mogą na potrzeby zilustrowania treści przekazywanych w celach dydaktycznych lub w celu prowadzenia działalności naukowej korzystać z rozpowszechnionych utworów w oryginale, w tłumaczeniu oraz zwielokrotniać w tym celu rozpowszechnione drobne utwory lub fragmenty większych utworów.
2. W przypadku publicznego udostępniania utworów w taki sposób, aby każdy mógł mieć do nich dostęp w miejscu i czasie przez siebie wybranym, korzystanie, o którym mowa w ust. 1, jest dozwolone wyłącznie dla ograniczonego kręgu osób uczących się, nauczających lub prowadzących badania naukowe, zidentyfikowanych przez podmioty wymienione w ust. 1.

POLITECHNIKA GDAŃSKA

STATEMENT

The author of the doctoral dissertation: mgr inż. arch. Szymon Kowalski

I, the undersigned, declare that I am aware that in accordance with the provisions of Art. 27 (1) and (2) of the Act of 4th February 1994 on Copyright and Related Rights (Journal of Laws of 2021, item 1062), the university may use my doctoral dissertation entitled:
<title>
for scientific or didactic purposes [1]

Gdańsk, 04.07.2025 ...

Szymon Kowalski
signature of the PhD student

Aware of criminal liability for violations of the Act of 4th February 1994 on Copyright and Related Rights and disciplinary actions set out in the Law on Higher Education and Science (Journal of Laws 2021, item 478), as well as civil liability, I declare, that the submitted doctoral dissertation is my own work.

I declare, that the submitted doctoral dissertation is my own work performed under and in cooperation with the supervision of: prof. dr hab. inż. arch. Jakub Szczepański, the auxiliary supervision of: dr hab. inż. arch. Piotr Samól.

This submitted doctoral dissertation has never before been the basis of an official procedure associated with the awarding of a PhD degree.

All the information contained in the above thesis which is derived from written and electronic sources is documented in a list of relevant literature in accordance with Art. 34 of the Copyright and Related Rights Act.

I confirm that this doctoral dissertation is identical to the attached electronic version.

Gdańsk, 04.07.2025 ...

Szymon Kowalski
signature of the PhD student

I, the undersigned, agree/do not agree* to include an electronic version of the above doctoral dissertation in the open, institutional, digital repository of Gdańsk University of Technology.

Gdańsk, 04.07.2025

Szymon Kowalski
signature of the PhD student

**delete where appropriate*

Art. 27. 1. Educational institutions and entities referred to in art. 7 sec. 1 points 1, 2 and 4–8 of the Act of 20 July 2018 – Law on Higher Education and Science, may use the disseminated works in the original and in translation for the purposes of illustrating the content provided for didactic purposes or in order to conduct research activities, and to reproduce for this purpose disseminated minor works or fragments of larger works.

2. If the works are made available to the public in such a way that everyone can have access to them at the place and time selected by them, as referred to in para. 1, is allowed only for a limited group of people learning, teaching or conducting research, identified by the entities listed in paragraph 1.

POLITECHNIKA GDAŃSKA

OPIS ROZPRAWY DOKTORSKIEJ

Autor rozprawy doktorskiej: mgr inż. arch. Szymon Kowalski
Tytuł rozprawy doktorskiej w języku polskim: Technologia wirtualnej rzeczywistości w dziedzictwie architektonicznym i jej wpływ na konserwację
Tytuł rozprawy w języku angielskim: Virtual reality technology in architectural heritage and its impact on conservation.
Język rozprawy doktorskiej: angielski
Promotor rozprawy doktorskiej: prof. dr hab. inż. arch. Jakub Szczepański
Promotor pomocniczy rozprawy doktorskiej: dr hab. inż. arch. Piotr Samól
Data obrony:

Słowa kluczowe rozprawy doktorskiej w języku polskim: Wirtualna rzeczywistość, rekonstrukcja cyfrowa, dziedzictwo architektoniczne, teoria konserwatorska, autentyczność, iluzja, technologie immersyjne, skanowanie laserowe, fotogrametria, inwentaryzacja cyfrowa, modelowanie 3D, teledetekcja, symulacja, dziedzictwo kulturowe

Słowa kluczowe rozprawy doktorskiej w języku angielskim: Virtual reality, digital reconstruction, architectural heritage, conservation theory, authenticity, illusion, immersive technologies, laser scanning, photogrammetry, digital survey, 3D modeling, remote sensing, simulation, cultural heritage.

Streszczenie rozprawy w języku polskim:
Niniejsza rozprawa podejmuje zagadnienie roli wirtualnej rzeczywistości (VR) jako niematerialnego medium w ochronie dziedzictwa architektonicznego. Konfrontując napięcie pomiędzy społecznymi oczekiwaniami dotyczącymi rekonstrukcji materialnej a konserwatorską zasadą autentyczności, dowodzi, że VR stanowi alternatywę dla rekonstrukcji fizycznej. Opierając się na badaniach interdyscyplinarnych, łączących historię architektury, doktrynę konserwatorską, genealogię iluzji i immersji w sztuce i architekturze, cyfrową inwentaryzację oraz modelowanie 3D, praca rozwija metodologiczne ramy rekonstrukcji immersyjnych. Trzy studia przypadku w różnych skalach: zakrystia kościoła św. Mikołaja (wnętrze), fortyfikacje Westerplatte (obiekt) oraz zespół dworski Heiligenbrunn (skala urbanistyczna) pokazują, w jaki sposób rekonstrukcje VR oparte na skanach mogą łączyć warsztat historyczny z precyzyjną dokumentacją cyfrową. Wyniki badań dowodzą, że środowiska immersyjne wspierają analizę naukową i poszerzają możliwości edukacji oraz upowszechniania wiedzy, ujmując rekonstrukcję jako praktykę transparentną i niematerialną. Pomimo wyzwań, takich jak przestarzałość danych, ryzyka interpretacyjne czy dostępność technologii, rozprawa konkluduje, że VR stanowi wiarygodne nowe medium konserwatorskie. Poprzez syntezę teorii, technologii i praktyki praca rozwija dyskurs konserwatorski i wyznacza podstawy dla przyszłych zastosowań technologii immersyjnych w dziedzictwie.

POLITECHNIKA GDAŃSKA

OPIS ROZPRAWY DOKTORSKIEJ

Streszczenie rozprawy w języku angielskim:
This dissertation investigates the role of virtual reality (VR) as an immaterial medium in the conservation of architectural heritage. Confronting the tension between public demands for material reconstruction and the conservation principle of authenticity, it argues that VR offers an alternative to physical reconstruction. Grounded in interdisciplinary research combining architectural history, conservation doctrine, the genealogy of illusion and immersion in art and architecture, digital surveying and 3D modelling, the study develops a methodological framework for immersive reconstructions. Three case studies at different scales: the sacristy of St. Nicholas Church (interior), the Westerplatte fortifications (object) and the Heiligenbrunn manor landscape (urban) demonstrate how scan based VR reconstructions can integrate historical scholarship with precise digital documentation. The findings show that immersive environments support scholarly analysis and expand opportunities for education and public engagement, reframing reconstruction as a transparent and immaterial practice. While challenges remain, including data obsolescence, interpretive risks and technological accessibility, the study concludes that VR constitutes a credible new conservation medium. By synthesising theory, technology and practice, this thesis advances conservation discourse and establishes a foundation for future applications of immersive technologies in heritage.

GDAŃSK UNIVERSITY OF TECHNOLOGY

DESCRIPTION OF DOCTORAL DISSERTATION

The author of the doctoral dissertation: Szymon Kowalski
Title of doctoral dissertation: Virtual reality technology in architectural heritage and its impact on conservation.
Title of doctoral dissertation in Polish: Technologia wirtualnej rzeczywistości w dziedzictwie architektonicznym i jej wpływ na konserwację
Language of doctoral dissertation: english
Supervisor: prof. dr hab. inż. arch. Jakub Szczepański
Auxiliary supervisor: dr hab. inż. arch. Piotr Samól
Date of doctoral defense:

Keywords of doctoral dissertation in Polish: Wirtualna rzeczywistość, rekonstrukcja cyfrowa, dziedzictwo architektoniczne, teoria konserwatorska, autentyczność, iluzja, technologie immersyjne, skanowanie laserowe, fotogrametria, inwentaryzacja cyfrowa, modelowanie 3D, teledetekcja, symulacja, dziedzictwo kulturowe

Keywords of doctoral dissertation in English: Virtual reality, digital reconstruction, architectural heritage, conservation theory, authenticity, illusion, immersive technologies, laser scanning, photogrammetry, digital survey, 3D modeling, remote sensing, simulation, cultural heritage.

Summary of doctoral dissertation in Polish:
Niniejsza rozprawa podejmuje zagadnienie roli wirtualnej rzeczywistości (VR) jako niematerialnego medium w ochronie dziedzictwa architektonicznego. Konfrontując napięcie pomiędzy społecznymi oczekiwaniami dotyczącymi rekonstrukcji materialnej a konserwatorską zasadą autentyczności, dowodzi, że VR stanowi alternatywę dla rekonstrukcji fizycznej. Opierając się na badaniach interdyscyplinarnych, łączących historię architektury, doktrynę konserwatorską, genealogię iluzji i immersji w sztuce i architekturze, cyfrową inwentaryzację oraz modelowanie 3D, praca rozwija metodologiczne ramy rekonstrukcji immersyjnych. Trzy studia przypadku w różnych skalach: zakrystia kościoła św. Mikołaja (wnętrze), fortyfikacje Westerplatte (obiekt) oraz zespół dworski Heiligenbrunn (skala urbanistyczna) pokazują, w jaki sposób rekonstrukcje VR oparte na skanach mogą łączyć warsztat historyczny z precyzyjną dokumentacją cyfrową. Wyniki badań dowodzą, że środowiska immersyjne wspierają analizę naukową i poszerzają możliwości edukacji oraz upowszechniania wiedzy, ujmując rekonstrukcję jako praktykę transparentną i niematerialną. Pomimo wyzwań, takich jak przestarzałość danych, ryzyka interpretacyjne czy dostępność technologii, rozprawa konkluduje, że VR stanowi wiarygodne nowe medium konserwatorskie. Poprzez syntezę teorii, technologii i praktyki praca rozwija dyskurs konserwatorski i wyznacza podstawy dla przyszłych zastosowań technologii immersyjnych w dziedzictwie.

GDAŃSK UNIVERSITY OF TECHNOLOGY

DESCRIPTION OF DOCTORAL DISSERTATION

Summary of doctoral dissertation in English:
This dissertation investigates the role of virtual reality (VR) as an immaterial medium in the conservation of architectural heritage. Confronting the tension between public demands for material reconstruction and the conservation principle of authenticity, it argues that VR offers an alternative to physical reconstruction. Grounded in interdisciplinary research combining architectural history, conservation doctrine, the genealogy of illusion and immersion in art and architecture, digital surveying and 3D modelling, the study develops a methodological framework for immersive reconstructions. Three case studies at different scales: the sacristy of St. Nicholas Church (interior), the Westerplatte fortifications (object) and the Heiligenbrunn manor landscape (urban) demonstrate how scan based VR reconstructions can integrate historical scholarship with precise digital documentation. The findings show that immersive environments support scholarly analysis and expand opportunities for education and public engagement, reframing reconstruction as a transparent and immaterial practice. While challenges remain, including data obsolescence, interpretive risks and technological accessibility, the study concludes that VR constitutes a credible new conservation medium. By synthesising theory, technology and practice, this thesis advances conservation discourse and establishes a foundation for future applications of immersive technologies in heritage.

PhD Thesis

VIRTUAL REALITY TECHNOLOGY IN ARCHITECTURAL HERITAGE AND ITS IMPACT ON CONSERVATION

Author: Szymon Kowalski

Supervisor: prof. dr hab. inż. arch. Jakub Szczepański
Auxiliary Supervisor: dr hab. inż. arch. Piotr Samól

Faculty of Architecture, Gdańsk University of Technology.

GDAŃSK UNIVERSITY
OF TECHNOLOGY

PhD Thesis

Virtual reality technology in architectural heritage and its impact on conservation.

Author: Szymon Kowalski

Supervisor: prof. dr hab. inż. arch. Jakub Szczepański
Auxiliary Supervisor: dr hab. inż. arch. Piotr Samól

Faculty of Architecture, Gdańsk University of Technology.

Table of contents

Items

Table of contents 3
1. Introduction 6
1.1 Motivation and background 6
1.2 Problem scope 6
1.3 Research Aim 10
1.4 Research questions 10
1.5 Thesis Statement 11
1.6 Research methodology 12
1.7 Structure of the work 13
1.8 Conceptual Framework: Extended Reality 14
1.9 State of the Art 19
1.9.1 Philosophical and Theoretical Background 19
1.9.2 Heritage digitalisation and digital reconstruction practices 24
1.10 Scope limitations 27
2. Concept of the reconstruction 29
2.1 Early authenticity 29
2.2 Rediscovery of Antiquity. From the Renaissance to the Enlightenment 33
2.3 Romantism and the 19th century 41
2.4 Development of current doctrine 56
2.5 Reconstruction in the post-war approach 62
2.6 Modern Rebuilding 80
2.7. Ruins as witnesses 83
2.8 Postmodernism in reconstruction 88
3. From Artistic Illusion to Digital Immersion 101
3.1 Illusory art in the history of architecture 102
3.1.1. Antics 102
3.1.2. Medieval Art, and Proto-Renaissance 107
3.1.3. Renaissance rediscovery of perspective 113
3.1.4. Baroque illusion 130
3.1.5. Vedutive Paintings 145
3.1.6. Panoramic Painting 147
3.2 Emerging of Virtual Reality in the pre-digital Era 153

3.3 Digital Illusion and Virtual Reality 161
3.4 Summary of the chapter 170
4. Applications and technological aspects of immersive scan based digital reconstruction. 175
4.1. Applications of Virtual Reality in Heritage Conservation 175
4.1.1 Before Virtual Reconstruction 175
4.1.2. Virtual Reconstruction 180
4.1.3 Gaming with Virtual Reconstruction aspect 183
4.1.4. Immersive virtual reconstructions 186
4.2. Technological Foundations for scan based VR Applications 192
4.2.1. Survey and Inventory Methods 192
4.2.2. Immersive visualization methods. 205
4.3. Summary of the chapter 210
5. Immersive Virtual Reconstructions in Architectural Heritage: Case Studies and Applications ... 211
5.1. Introduction 211
5.2. Interior Scale - Saint Nicolaus Church in Gdańsk. 215
5.2.1 Introduction 215
5.2.2. Invasive architectonical investigations. 221
5.2.3. Digitalisation of the interior 224
5.2.4. Virtual Reconstruction 227
5.3. Object scale - Westerplatte 236
5.3.1. Introduction 236
5.3.2. Conservation, authenticity and shifting memory politics 241
5.3.3 Guardhouse No. 1 and the Fort emplacement – Scan-Based Digitalisation and Virtual Sightseeing of Inaccessible Spaces 249
5.3.4. Officers' Villa, Guardhouse No. 5, and Warehouse No. 10 – Excavated Remains and Partial Virtual/AR Reconstructions 251
5.3.5. New Barracks 259
5.4. Urban Scale *Royal Valley - Heiligenbrunn* 269
5.4.1. Introduction 269
5.4.2. Historical urban development 276
5.4.3. Digital survey 281
5.4.4. Virtual Reconstruction 289
5.5. Cross-Case Conclusions 293
5.5.1 Conclusions at the Interior Scale (St. Nicholas Church) 293
5.5.2 Conclusions at the Object Scale (Westerplatte) 294
5.5.3 Conclusions at the Urban Scale (Heiligenbrunn) 297

5.5.4 Cross-Case Conclusions and Methodological Implications 298
6. Summary and final conclusions 301
Bibliography 305
Literature 305
Charters 318
Digital & Online Sources 318
Online Models (developed by author) 324
Online Models 325
List of Illustrations 326
Acknowledgements 333

1. Introduction

1.1 Motivation And Background

The author's research interest in virtual reconstruction is rooted in a long-standing engagement with multiple disciplines, including architecture, architectural history, military history, and art history. This motivation is further enriched by a strong interest in contemporary computational methods such as virtual reality, 3D modelling, 3D graphics, and game design. Over the course of the research, additional areas of fascination emerged, particularly in the field of digital surveying, including laser scanning, drone operation, and photogrammetry. This doctorate thus represents a natural progression of these evolving and interconnected interests.

First attempt to address the subject began in 2018 with a master's thesis in architecture titled Protection of the Historic Landscape of the Battlefield: Open-Air Museum of Westerplatte[1]. In this project, the author explored the concept of virtual reconstruction alongside the idea of a virtual architectural guide, contributing to the ongoing discourse on digital approaches to heritage interpretation at the time[2]. In addition to the standard architectural panels presenting the design proposal, the MSc diploma was extended to include a functional application featuring an intangible reconstruction in virtual reality[3].

Upon being admitted to the doctoral programme at Gdańsk University of Technology in 2019, the author was able to further develop and scientifically investigate the original concept of applying virtual reality technology in the context of architectural heritage. This progress was made possible through increased access to funding opportunities, participation in multiple research internships at various universities, and the acquisition of advanced equipment—including VR headsets, high-performance computer workstations, a Faro Focus 70 laser scanner, DJI Mavic drones, and other necessary tools. These resources, combined with the global expertise gained in operating such equipment and managing post-production workflows, significantly advanced the depth and scope of the research.

In addition to examining technological advancements, the research led to a series of peer-reviewed international publications. These addressed the application of virtual reality in education, architectural surveying, and remote sensing methodologies, as well as the outcomes of architectural investigations and historical studies, contributing to the objectives outlined in this dissertation.

1.2 Problem Scope

To present the problem statement for this work, it is important to emphasise the complexity of architectural heritage, which comprises objects that undergo multiple phases of evolution from

[1] The project, completed under the supervision of Prof. dr hab. inż. arch. Jakub Szczepański and dr hab. inż. arch. Piotr Samól, was awarded the Main Prize for Innovative Design by the Association of Monument Conservators and the Main Prize for a master's Thesis by the President of Gdańsk. It was also cited in a scientific journal for its creative application of virtual reality in the field of architectural education.

See Agnieszka Gębczyńska-Janowicz, "Virtual Reality Technology in Architectural Education," *World Transactions on Engineering and Technology Education* 18 (2020): 24–28.

[2] This discussion is further developed in chapter 5.

[3] Initially, only a small portion of the main concept was realised, which included static spherical renders representing an intangible reconstruction based on early-stage research. These were visualised using Google Cardboard in combination with a smartphone. The limited scope of this implementation was primarily due to financial constraints and restricted access to dedicated equipment.

creation and use to transformation, destruction, repair, and eventual restoration or reconstruction. This process requires careful consideration of the complex contexts that have shaped their transformation over time. The duration of these changes can be represented as a form of timeline divided into specific phases of transformation. These phases can be grouped along a timeline that maps the potential stages of an object's evolution, regardless of the type of object, its period of origin, or its complex history.

A key moment in the life of an architectural object is its destruction, not always total or intentional but often the result of neglect. This disruption can break the continuity of the structure and place its survival at risk. Complete destruction is often regarded as a form of "death," a permanent rupture in the historical timeline. In architecture, however, true death is rare. More typically, buildings enter a prolonged state of decline, a condition described here as *architectural agonia*. When a structure exists as a ruin or has significantly deteriorated, there is often pressure to restore it to its former state. Each case is unique, shaped by different patterns of deterioration and distinct principles of restoration. This is frequently driven by a social desire to return to a "glorious past," a romanticised vision of the building's previous appearance, even if that vision lacks historical accuracy. Such reconstruction efforts are frequently influenced by political motivations, with restoration employed as a means of constructing historical memory and reinforcing collective identity.

Tensions frequently arise between the public and heritage conservators, reflecting divergent views on the purpose and meaning of reconstruction. While each case requires individual evaluation, society tends to favour reconstructions, driven by emotional attachment and the desire to restore an idealised vision of past splendour. In contrast, conservators emphasise the importance of safeguarding authenticity and the material integrity of heritage structures[4].

Architectural reconstructions involve a range of complex challenges and dilemmas, including questions of authenticity, the selective recreation of history, the mythologisation of the past, and the political and economic pressures that often shape their trajectory. Consequently, architectural heritage becomes not only a medium for historical, political, and cultural narratives but also a strategic resource in tourism and economic development[5]. This divergence in perspectives contributes to the aestheticisation or thematisation of space[6], particularly in historic city centres, which results in the Disneyization of urban space[7], where reconstructions frequently prioritize visually impressive and symbolically charged results. Emotionally motivated interpretations may result in reconstructions that portray a version of the past which never truly existed[8]. Such efforts are inherently constrained by concerns over authenticity, financial limitations, the irreversible nature of interventions, and the interpretive boundaries of historical evidence.

[4] Jukka Jokilehto, "Considerations on Authenticity and Integrity in World Heritage Context," *City & Time* 1 (2006): 1–16.

[5] Sharon Zukin, *Naked City: The Death and Life of Authentic Urban Places* (New York: Oxford University Press, 2010).

[6] Piotr Lorens, *Tematyzacja przestrzeni publicznej miasta* (Gdańsk: Wydawnictwo Politechniki Gdańskiej, 2006).

Lorens, Piotr, and Justyna Martyniuk-Pęczek. "Od *City Beautiful Movement* do nowego urbanizmu." In *Wybrane teorie współczesnej urbanistyki*, edited by Izabela Mironowicz and Piotr Lorens. Gdańsk: Wydawnictwo Politechniki Gdańskiej, 2013.

[7] Alan Bryman, *The Disneyization of Society* (Thousand Oaks, CA: SAGE Publications, 2004).

[8] Tomasz Torbus, *Rekonstrukcje, dekonstrukcje, (nad)interpretacje: studia o losach architektury środkowoeuropejskich miast i rezydencji w aspekcie politycznym (XIX–XXI wiek)* (Gdańsk: słowo/obraz terytoria, 2019).

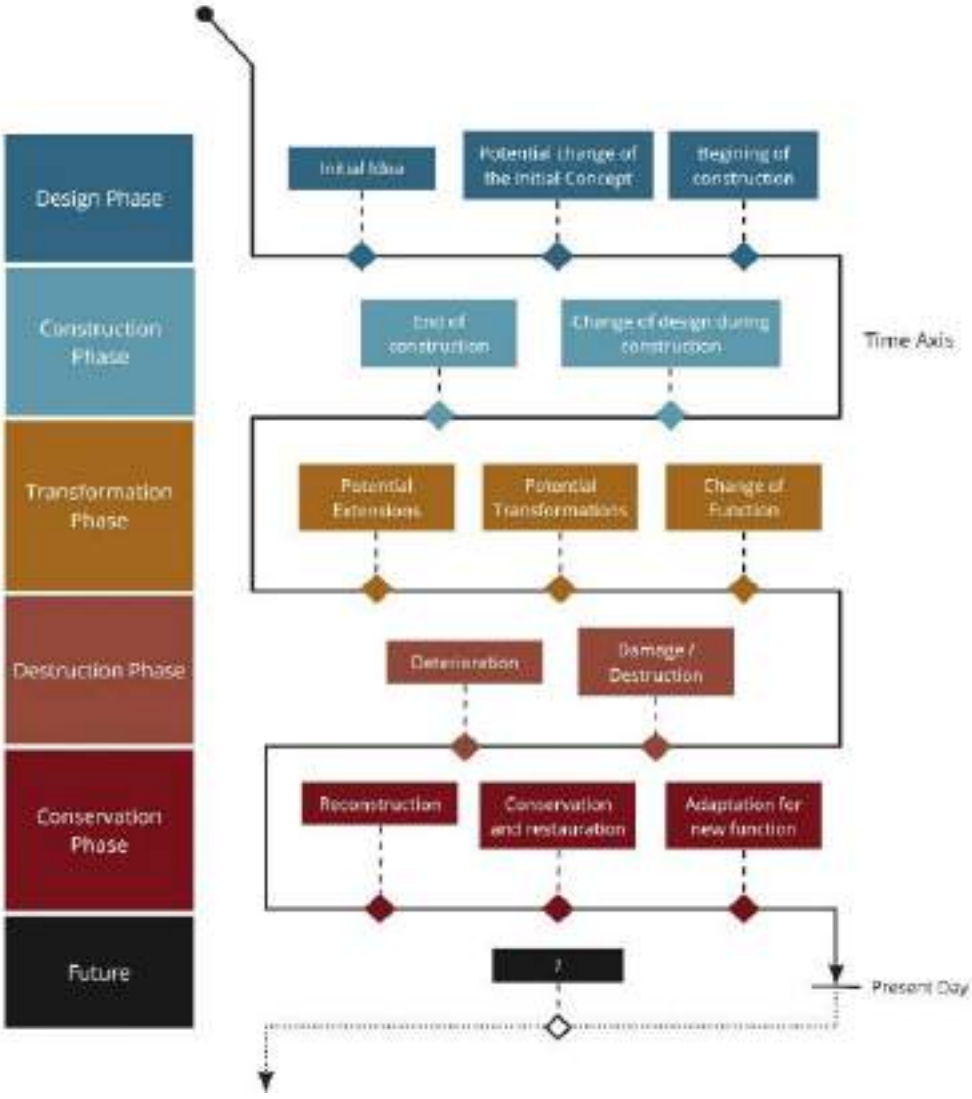


Fig. 1. General Timeline of architectural objects. Source: author.

In contrast, heritage conservators advocate for more restrained approaches that preserve ruins, fragments, and remnants in their existing condition in order to avoid distorting historical reality. Their methodology relies on rigorous architectural research, detailed documentation, and strict adherence to internationally recognised conservation standards.

Reconstructions such as those of Bobolice Castle[9] and Poznań Castle[10] exemplify cases of dilatant creation[11], where new structures are erected on historic sites under the guise of restoration without

[9] Michał Żemła and Matylda Siwek, "Between Authenticity of Walls and Authenticity of Tourists' Experiences: The Tale of Three Polish Castles," *Cogent Arts & Humanities* 7, no. 1 (2020): 1763893, https://doi.org/10.1080/23311983.2020.1763893

Michał Zębik, "Jak odbudowano zamek Bobolice," Forum Akademickie, November 2010, accessed December 2, 2024, https://prenumeruj.forumakademickie.pl/fa/2010/11/jak-odbudowano-zamek-bobolice/.

[10] *The Royal Castle in Poznań: History and Restitution*, ed. Włodzimierz Łęcki, Jacek Wiesiołowski, Hanna Kóćka-Krenz, and Andrzej Zarzycki (Poznań: Bogucki Scientific Publishers, 2014).

[11] Tomasz Torbus, *Rekonstrukcje, dekonstrukcje, (nad)interpretacje: studia o losach architektury środkowoeuropejskich miast i rezydencji w aspekcie politycznym (XIX–XXI wiek)* (Gdańsk: słowo/obraz terytoria, 2019), 126–51.

respect for the authentic substance, resulting in devastation[12]. These projects often serve the interests of tourism and national identity more than they reflect historical accuracy or adhere to conservation ethics. By prioritising visual appeal and symbolic representation, such reconstructions risk diminishing the value of authenticity. They may mislead the public into believing that the rebuilt structures are original, thereby distorting historical understanding and contributing to a simplified or romanticised narrative of the past.

Fig. 2. Dilatant Reconstruction. Left: Bobolice Castle (source: Zamek Bobolice website[13]). Right: Poznań Castle (source: Muzeum Narodowe w Poznaniu[14]).

Contemporary conservation theory increasingly emphasises authenticity, defined as the preservation of original material substance and historical accuracy. It cautions against speculative reconstructions that may distort the past and undermine the cultural value of heritage. Foundational international charters such as the Venice Charter (1964)[15] and the Nara Document on Authenticity (1994) advocate for restraint in reconstruction efforts, permitting them only in exceptional cases where there is sufficient documentation and a clear symbolic or educational purpose.

In light of growing public demand for the rebuilding of heritage sites and the expanding capabilities of digital technologies, a fundamental question arises: must reconstruction necessarily take material form? Can digital or virtual immersive reconstructions provide meaningful alternatives, preserving the authenticity of what survives while enabling a deeper, more nuanced engagement with the past? Technologies such as 3D scanning, photogrammetry, and particularly virtual reality (VR) now allow for the creation of immersive, non-invasive simulations that can illustrate various stages in the architectural evolution of heritage structures without altering the physical remains.

Although digital tools such as laser scanning, photogrammetry, and VR are increasingly applied in heritage documentation and visualisation, their use remains largely technology-driven rather than grounded in historical analysis, architectural methodology, or conservation theory[16]. This limits their

[12] PAR, "Lokalny biznesmen i polityk przegrywa proces z historykiem. Poszło o wywiad na Slazag.pl," *Press.pl*, December 2, 2024, accessed June 8, 2025, https://www.press.pl/tresc/84847,lokalny-biznesman-i-polityk-przegrywa-proces-z-historykiem_-poszlo-o-wywiad-na-slazag_pl.

[13] "Zamek Bobolice – materiały," accessed November 30, 2024, https://www.zamekbobolice.pl/materialy/gal/big_cropped/857.jpg.

[14] Muzeum Narodowe w Poznaniu, "Muzeum Sztuk Użytkowych w Zamku Królewskim," accessed November 30, 2024, https://mnp.art.pl/wp-content/uploads/2022/10/Muzeum-Sztuk-Uz%CC%87ytkowych-w-Zamku-Kro%CC%81lewskim.jpg.

[15] ICOMOS, *International Charter for the Conservation and Restoration of Monuments and Sites (the Venice Charter 1964)* (Venice: ICOMOS, 1964).

[16] Massimiliano Pieraccini, Gabriele Guidi, and Carlo Atzeni, "3D Digitizing of Cultural Heritage," *Journal of Cultural Heritage* 2, no. 1 (2001): 63–70, https://doi.org/10.1016/S1296-2074(01)01108-6; Naci Yastikli, "Documentation of Cultural Heritage Using Digital Photogrammetry and Laser Scanning," *Journal of Cultural Heritage* 8, no. 4 (2007): 423–27, https://doi.org/10.1016/j.culher.2007.06.003; Luigi Barazzetti et al., "HBIM and Augmented Information: Towards a Wider

critical and scholarly potential. At present, there is no framework that fully integrates digital reconstruction with rigorous historical interpretation, architectural investigation, and conservation ethics. This unresolved issue constitutes a research gap in contemporary heritage studies.

Addressing this gap forms the central justification for this dissertation. The study investigates how virtual reality (VR) can function as an immaterial medium for simulating the transformation, decay, and restoration of historic architectural forms across time. It demonstrates that, when grounded in architectural scholarship and supported by precise digital documentation, VR simulations can serve not only as tools for visualisation but also as instruments of research, interpretation, and public dissemination, thus contributing substantively to contemporary conservation discourse and practice.

1.3 Research Aim

This thesis investigates virtual reality as an immaterial medium for immersive simulation of historic architecture, developed through digital inventory methods, with particular emphasis on diachronic evolution and transformation. A central objective is to demonstrate how simulations, grounded in architectural research, can capture the changing appearance of buildings over time. By integrating historical research, digital documentation, and 3D modelling, the study explores how virtual environments can represent processes of change, decay, and restoration across different periods, offering a rigorous alternative to materially based reconstruction.

Beyond visualisation, the thesis evaluates virtual reality as a medium for the mediation, interpretation, and dissemination of architectural heritage to diverse audiences, including researchers, conservators, educators, and the public. In doing so, it contributes to debates on authenticity, transparency, and the role of emerging technologies in cultural heritage preservation and education, while situating them within contemporary conservation doctrine.

1.4 Research Questions

Based on the state of the art and the scientific aim of this study, the main research questions were formulated as follows:

> **(MQ1)** How can virtual reality visualisation be effectively implemented in scan-based digital reconstructions of architectural heritage?
>
> **(MQ2)** What impact might this have on conservation theory and the reconstruction practice?

By dividing the research problem into these two key questions, the overall narrative of the thesis is established. The first question focuses on the technical aspects of virtual reconstruction, addressing both data acquisition and the presentation of virtual models. The analysis considers a range of technologies and their applicability to different categories of heritage objects, revealing the diverse ways in which these tools can interact with and represent cultural heritage. The second question examines the theoretical dimension of virtual reconstruction, focusing on its impact on conservation principles. It evaluates how VR may shape debates on reconstruction, emphasising its potential as an ethically grounded alternative to material rebuilding.

User Community of Image and Range-Based Reconstructions," *ISPRS International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XL-5/W7 (2015): 35–42, https://doi.org/10.5194/isprsarchives-xl-5-w7-35-2015.

To deepen the study and position it within conservation doctrine, art history, technical practice, and their combined influence, a series of sub-questions was developed:

> **(SQ1)** How has the idea of reconstruction and authenticity been reflected in conservation doctrine?
>
> **(SQ2)** How has the concept of illusion been historically applied in art and architecture to manipulate perception and construct visual experiences?
>
> **(SQ3)** What methodological approaches enable the creation of accurate digital copies of heritage structures using contemporary scanning technologies?
>
> **(SQ4)** What technical and interpretive challenges arise when integrating 3D-scanned heritage structures into virtual reality environments?
>
> **(SQ5)** How do digital reconstructions of heritage sites at different scales shape their presentation and inform contemporary conservation theories related to authenticity and preservation?
>
> **(SQ6)** Can the actual risks of the virtual approach be identified in the course of the research?

1.5 Thesis Statement

This dissertation argues that virtual reality simulation, when grounded in rigorous historical research, architectural analysis, and digital documentation, provides a credible and ethically digital alternative to material reconstruction in heritage conservation.

By synthesising immersive visualisation with established conservation principles, VR-based reconstructions:

> **Thesis 1.** When grounded in rigorous interdisciplinary research, immersive virtual reconstructions can convey historical states of heritage in an immaterial form, offering reversible and modifiable simulations that preserve the integrity of authentic remains. This makes them an ethically preferable approach in contested heritage contexts, where material reconstructions risk distortion through conjecture or political pressures.
>
> **Thesis 2**. Remote sensing and digital inventory tools enable the transformation of heritage from the material to the virtual domain, providing a basis for immersive simulations that function both as instruments of scholarly interpretation and as platforms for public engagement through accessible, shared, and interactive experiences.

Rather than merely reproducing lost forms, virtual reconstructions function as epistemological tools, enhancing both scholarly and public understanding of architectural transformation across time while respecting the integrity of original fabric and established conservation ethics.

This thesis thus challenges conventional paradigms of heritage reconstruction and advances the rethinking of authenticity, memory, and digital presence in contemporary conservation theory. It further addresses the absence of an integrated framework linking digital reconstruction with conservation ethics, demonstrates applicability across multiple scales of architectural heritage, from interior through object to urban, and offers a foundation for future applications of immersive technologies in conservation and heritage interpretation.

1.6 Research Methodology

The general methodology employed in this dissertation is an original, mixed, and interdisciplinary approach developed by the author, combining methods traditionally associated with architecture, geodesy and geomatics, computing, and historical research. It integrates qualitative research techniques, such as archival queries and the analysis of historical sources, including written documents, architectural plans, technical drawings, iconographic materials, maps, and photographs, with spatial analysis and documentation methods drawn from the fields of architecture, urban planning, and cultural heritage, with directional analysis of literature studies.

Due to the structure of the dissertation, the methodology applied in Chapters 2 and 3 is based on a series of site visits and direct analyses of selected structures that exemplify either reconstructions or original works of art. These first-hand investigations are essential for understanding the material, spatial, and stylistic characteristics of the objects in question. The fieldwork is supplemented by comprehensive literature studies, which provide historical, theoretical, and critical context, ensuring a well-rounded and in-depth understanding of each analysed subject.

A central component of the methodology is in situ architectural investigations, carried out across objects of varying scales, with each studied site treated as a primary source of information. This includes both direct physical examination of built structures and the application of digital tools such as photogrammetry, laser scanning, and the processing of open-source spatial data. The research further involves the construction of surface-based 3D models of digitally reconstructed objects, which are subsequently contextualised within their broader heritage and historical environments.

Fig. 3. General methodological scheme. Source: author.

The primary research methodology adopted in this dissertation is the deductive method, grounded in a detailed study and analysis of three historical case studies located in Gdańsk. These examples were deliberately selected to represent different scales of architectural intervention—ranging from interior to building, to urban scale—thus allowing for a comprehensive and multi-layered exploration of virtual reconstruction methodologies. The first case focuses on the Gothic interior of the sacristy in the Dominican Church of Saint Nicholas, representing the architectural interior scale. The second examines a series of architectural structures, with particular emphasis on the New Barracks on the Westerplatte Peninsula, which date from the 19th century and are strongly connected to the events of the Second World War. The third case explores the development of the district and urban structure in Królewska Dolina (King's Valley), serving as a representative example at the urban scale.

The research also examines the interaction between virtual reconstruction and contemporary conservation theory, considering how digital methodologies may support, challenge, or redefine established principles of heritage preservation. The complexity of the methods employed—drawing from architecture, conservation theory, digital technologies, and historical research—renders the project inherently interdisciplinary. This multifaceted approach enables a comprehensive and nuanced

understanding of historical architectural forms and their transformation over time, effectively combining empirical site data with critical historical interpretation.

1.7 Structure Of The Work

The structure of this dissertation reflects the adopted methodological approach and is organised around the main and subsidiary research questions. The structure reflects a progression from theoretical analysis to practical case studies. It is divided into six chapters, forming a cohesive and progressively unfolding narrative. The overall layout consists of four main parts: Introduction, General Study, Detailed Study, and Final Summary.

Fig. 4. Structure of the work scheme. Source: author.

Chapter	Focus	Main / Sub-Questions Addressed
1. Introduction	Research context, aims, and structure	Presents **MQ1** and **MQ2**; explains link to sub-questions
2. Reconstruction and Authenticity in Conservation Doctrine	Conservation theory and authenticity debates	**SQ1** (authenticity in doctrine) → contributes to **MQ2**
3. Illusion, Perception, and Immersion in Art and Architecture	Historical applications of illusion and immersion	**SQ2** (illusion in art/architecture) → contributes to **MQ2**
4. Methodologies of Digital Documentation and Reconstruction	Survey methods, scanning technologies and VR integration	**SQ3** (digital copies with scanning) & **SQ4** (VR integration challenges) → contribute to **MQ1**
5. Immersive Virtual Reconstructions in Practice	Case studies at multiple scales; theoretical impact; risks	**SQ5** (scale & impact on conservation theory), **SQ6** (risks of virtual approach) → contribute to **MQ1 and MQ2**
6. Summary and Conclusions	Synthesis of findings, answers to main questions, contributions and outlook.	**Explicitly answers MQ1 and MQ2**

Fig. 5. Structure of the work table in relation to research questions. Source: author.

The General Study comprises two interrelated sections: a literature review and a methodological review. The literature review establishes the state of current knowledge, supported by the author's fieldwork and site visits. It explores key theoretical concepts, including reconstruction, authenticity, immersive experience in art history, and the early development of immersive environments. The methodological review discusses the application of contemporary remote sensing technologies—such as laser scanning and photogrammetry—alongside the technical foundations of virtual reality.

At the core of the dissertation is the Detailed Study, comprising a series of case studies. Each illustrates a complete workflow: from data acquisition and architectural investigation to digital processing, 3D modelling, and virtual reconstruction.

The final chapter, Summary and Conclusions, synthesises the research findings, reflecting on methodological insights and evaluating the broader implications of the study for architectural heritage, conservation practice, and digital interpretation.

Chapter 1 Introduction

The dissertation opens by defining the central research problem, outlining its scientific objectives, and detailing the methodological approach. It also includes a preliminary literature review, establishing the theoretical and philosophical context for the investigation.

Chapter 2 Reconstruction and the authenticity in conservation doctrine

A chronological exploration of reconstruction practices within the Western tradition is presented here, charting their evolution from antiquity to contemporary times. The chapter highlights shifts in theory and practice as they relate to changing societal values and conservation ethics, and tries to partially answer the detailed question “How has the idea of reconstruction and authenticity been reflected in conservation doctrine?”

Chapter 3: From Artistic to Digital Immersion

Focusing on the historical development of immersive visual culture, this chapter traces the transition from artistic illusionism to technological immersion. It follows a trajectory from painting and panoramic formats through photography and early cinema, leading up to digital immersive environments.

Chapter 4 Digitalisation of heritage and immersive digital reconstructions

Attention then turns to the technologies underpinning digital heritage. Through examples drawn from the author’s own fieldwork, the chapter examines techniques such as laser scanning and photogrammetry, along with immersive platforms like virtual reality HMD and CAVE systems.

Chapter 5 Case studies

At the core of the dissertation lies a trio of detailed case studies, each representing a different scale of architectural heritage: interior, architectural, and urban. The selected examples, St. Nicholas Church Sacristy, the Westerplatte fortifications, and the King’s Valley in Wrzeszcz, demonstrate how virtual reconstruction can address diverse historical contexts and conservation challenges. Each study is based on in-depth research, including archival work, architectural investigation, primary source analysis, digital documentation, and 3D modelling. It also outlines potential directions for future research and application within the field of digital heritage.

Chapter 6 Summary

Concluding the dissertation, this chapter synthesises insights from the preceding sections and reflects on the implications of immersive technologies for conservation theory and practice.

1.8 Conceptual Framework: Extended Reality

To understand the theoretical and practical foundations of this thesis, it is essential to define the core concepts of Virtual Reality (VR) and immersive environments in the context of architectural heritage conservation[17]. Although an early prototype of contemporary VR was introduced by Ivan Sutherland

[17] The historical and technical background of virtual reality is addressed in Chapter 3.3, Emergence of Virtual Reality in the Pre-Digital Era, and further developed in Chapter 4.3, Immersive Visualisation Methods. The present section provides only a brief overview, which will be expanded upon in subsequent chapters.

with his Ultimate Display[18] (commonly referred to as the Sword of Damocles project), the term has since evolved to encompass various modalities of interaction with computer-generated spatial environments, extending well beyond visual simulation into multi-sensory, spatially responsive, and embodied experiences[19].

Extended Reality (XR)

Extended Reality (XR) is an umbrella term that encompasses technologies that digitally augment or fully replace physical perception. It includes Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), enabling interaction with digital content in either fully virtual spaces or contextually blended environments[20]. XR technologies are now increasingly used in cultural heritage visualisation, interpretive storytelling, and non-invasive documentation practices.

To illustrate the conceptual spectrum of XR, Milgram and Kishino's Reality–Virtuality Continuum (1994)[21] is frequently referenced. It offers a fluid model for understanding how real and virtual elements coalesce, with VR at one end (complete immersion) and the real environment at the other, connected by MR and AR.

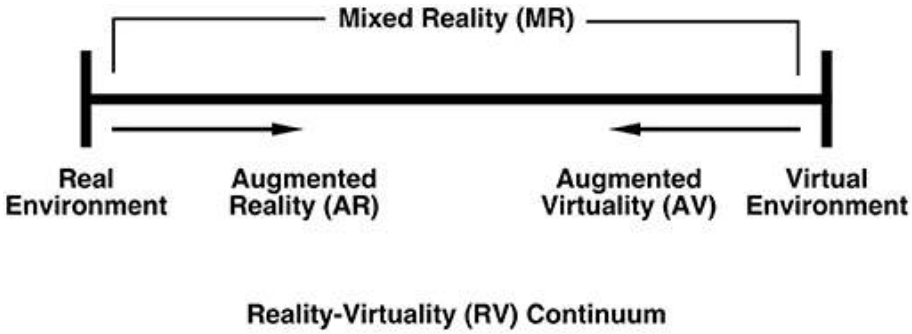


Fig. 6. Reality–Virtuality Continuum, adapted from Paul Milgram and Fumio Kishino, 1994[22].

[18] The project is widely covered in the chapter 3.3 "Emerging of Virtual Reality in the pre-digital Era" of this thesis.

[19] It should be noted that these technologies are evolving rapidly, and emerging devices or applications may alter the comparisons currently presented. Ongoing advancements in the field of Extended Reality (XR) continue to influence a wide range of specialised domains, contributing to the development of increasingly sophisticated tools, user experiences, and implementation strategies.

[20] Christoph Anthes, Rubén Jesús García-Hernández, Markus Wiedemann, and Dieter Kranzlmüller, "State of the Art of Virtual Reality Technology," in *2016 IEEE Aerospace Conference* (Big Sky, MT, March 5–12, 2016), 1–19, (Piscataway, NJ: IEEE, 2016), https://doi.org/10.1109/AERO.2016.7500674; Arzu Çöltekin, Ian Lochhead, Marguerite Madden, Sidonie Christophe, Alexandre Devaux, Christopher Pettit, Oliver Lock, et al., "Extended Reality in Spatial Sciences: A Review of Research Challenges and Future Directions," *ISPRS International Journal of Geo-Information* 9, no. 7 (2020): 439, https://doi.org/10.3390/ijgi9070439; Minna Vasarainen, Sami Paavola, and Liubov Vetoshkina, "A Systematic Literature Review on Extended Reality: Virtual, Augmented and Mixed Reality in Working Life," *International Journal of Virtual Reality* 21, no. 2 (2021): 1–28; Philipp A. Rauschnabel, Reto Felix, Chris Hinsch, Hamza Shahab, and Florian Alt, "What Is XR? Towards a Framework for Augmented and Virtual Reality," *Computers in Human Behavior* 133 (2022): 107289, https://doi.org/10.1016/j.chb.2022.107289.

[21] Paul Milgram and Fumio Kishino, "A Taxonomy of Mixed Reality Visual Displays," *IEICE Transactions on Information and Systems* 77, no. 12 (1994): 1321–29.

[22] Ibid.

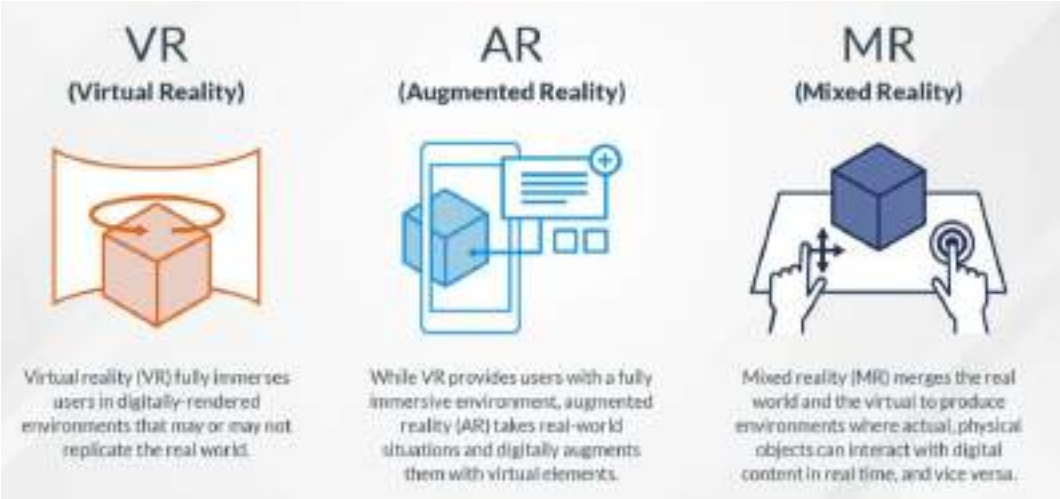


Fig. 7. Types of Extended Reality (XR), differentiating VR, AR, and MR (source: Vation Ventures website[23])

Technology	Extended Reality (XR)		
	Virtual Reality (VR)	**Augmented Reality (AR)**	**Mixed Reality (MR)**
Definition	A fully immersive digital environment that replaces the real world.	Overlays digital content onto the real world, enhancing reality without replacing it.	Combines elements of AR and VR, allowing digital and real-world objects to interact in real-time.
Interaction	Users interact through motion-tracked controllers or hand-tracking in a completely virtual space.	Typically uses smartphones or AR glasses; digital images or objects appear over the real-world view.	Uses advanced devices (e.g., MS HoloLens) where digital objects respond to real-world cues.
Perception /Immersion	Total immersion; the user's perception is entirely within the digital world.	Augments perception of the real world by adding digital elements.	Blends perception, with digital and real objects co-existing and interacting.
Devices	Oculus Rift, Oculus Quest, HTC Vive, PlayStation VR, Apple Vision Pro	Smartphones, tablets with AR emulation possibilities. Microsoft HoloLens, Google Glass, Apple Vision Pro	Microsoft HoloLens, Magic Leap

Fig. 8. Synthetic comparison between different technologies, with a narrowing of the topic to just Virtual Reality. Source: author.

Virtual Reality[24]

Virtual Reality (VR), as a central modality within the broader field of Extended Reality (XR), refers to a technology that immerses users in a fully simulated, computer-generated environment. In VR, the physical world is entirely replaced by a digital realm designed to replicate or reimagine spatial experience. Typically accessed through specialised hardware such as Head-Mounted Displays (HMDs) for individual use or CAVE systems (Cave Automatic Virtual Environment)[25] for individual and group interaction, VR environments employ stereoscopic visuals to produce depth perception and a

[23] Vation Ventures. "XR Trends: What Is Extended Reality?" November 1, 2022. Accessed May 25, 2025. https://www.vationventures.com/research-article/xr-trends-what-is-extended-reality

[24] This section focuses specifically on the conceptual aspects of augmented reality within the broader framework of Extended Reality (XR), while the technical foundations and interactivity are examined in detail in Chapter 4.

[25] Jacek Lebiedź and Mariusz Szwoch, "Virtual Sightseeing in Immersive 3D Visualization Lab," in *Proceedings of the 2016 Federated Conference on Computer Science and Information Systems* (FedCSIS 2016), *Annals of Computer Science and Information Systems* 8 (2016): 1641–45, https://doi.org/10.15439/2016F227

compelling sense of realism. Motion-tracking sensors, cameras, and marker-based systems monitor users' movements, enabling real-time interaction in which physical gestures directly correspond to virtual actions. Interaction is usually facilitated through hand controllers or data gloves, while spatial audio and additional tracking technologies further enhance immersion and the embodied experience of the virtual space[26].

Fig. 9. Virtual reality emulated via VR HMD and CAVE VR. Source: photos by the author.

Augmented Reality

While Virtual Reality (VR) fully immerses the user in a digital environment, Augmented Reality (AR) enhances the physical world by overlaying virtual objects, graphics, audio, or other multimedia elements onto it, allowing the user to remain situated within their real-world surroundings. Unlike VR, AR does not replace reality but supplements it, typically through the use of lenses or screens capable of real-time tracking and digital augmentation. The term "augmented reality" is generally attributed to Tom Caudell and David Mizell, who introduced it in 1990[27]. A central objective of AR is to achieve a seamless integration between virtual content and the physical environment. However, interaction within AR is often limited to observation and basic navigation, such as moving around a digitally projected model within a physical space. This functionality is commonly delivered through devices such as smartphones, tablets, or AR glasses. AR systems employ technologies including image recognition, positional tracking, and motion sensing to accurately determine the spatial and contextual placement of virtual elements within the augmented environment[28].

[26] Howard Rheingold, *Virtual Reality: The Revolutionary Technology of Computer-Generated Artificial Worlds—and How It Promises to Transform Society* (New York: Simon & Schuster, 1992); Roy S. Kalawsky, *The Science of Virtual Reality and Virtual Environments: A Technical, Scientific, and Engineering Reference on Virtual Environments* (Wokingham, England; Reading, MA: Addison-Wesley, 1993).

[27] Donna R. Berryman, "Augmented Reality: A Review," *Medical Reference Services Quarterly* 31, no. 2 (2012): 212–18, https://doi.org/10.1080/02763869.2012.670604

[28] Ronald Azuma, Yohan Baillot, Reinhold Behringer, Steven Feiner, Simon Julier, and Blair MacIntyre, "Recent Advances in Augmented Reality," *IEEE Computer Graphics and Applications* 21, no. 6 (2001): 34–47, https://doi.org/10.1109/38.963459; Steve Aukstakalnis, *Practical Augmented Reality: A Guide to the Technologies, Applications, and Human Factors for AR and VR* (Boston: Addison-Wesley Educational, 2016); Rick van Krevelen, "Augmented Reality: Technologies, Applications, and Limitations" (VU University Amsterdam, 2007), https://doi.org/10.13140/RG.2.1.1874.7929

Fig. 10. Example of use of AR directly in situ and remotely. Source: photos by the author.

Mixed Reality

Mixed Reality (MR) is the most advanced form of Extended Reality, combining real and virtual environments to enable physical and digital objects to coexist and interact in real time. It extends the capabilities of Virtual Reality (VR) and Augmented Reality (AR) by adding dynamic interactivity and context awareness. Unlike AR, MR allows virtual elements to respond to and integrate with the physical environment, creating a hybrid space that supports fluid, two-way interaction. Users can manipulate and embed digital objects within real-world settings, enhancing immersion and usability. MR relies on advanced devices such as the HoloLens 2 or Magic Leap 2, which use depth-sensing and environmental tracking to accurately detect spatial positions and movements, offering a high level of precision and responsiveness beyond what AR alone can provide[29].

Fig. 11. Example of use of MR in the architectural design process (source: Adobe webpage[30])

Metaverse

The concept of the metaverse extends beyond traditional Virtual Reality (VR) by enabling not only individual immersion in digital environments but also shared, persistent, and interactive virtual spaces inhabited by multiple users. It denotes an expansive, immersive, and networked digital ecosystem in which individuals can socialise, work, play, and participate in a variety of activities through Extended Reality (XR) technologies. Increasingly, the metaverse is regarded as a potential next stage in the

[29] Maximilian Speicher, Brian D. Hall, and Michael Nebeling, "What Is Mixed Reality?" in *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (New York: ACM, 2019), 1–15, https://doi.org/10.1145/3290605.3300767.

[30] Adobe, "Substance 3D," accessed March 12, 2023, https://www.adobe.com/pl/products/substance3d

evolution of the internet, integrating elements of spatial computing, avatar-based communication, and real-time interaction within a unified and continuous digital framework. Users within the metaverse are represented by avatars, digital embodiments that navigate across interconnected platforms and environments. These virtual spaces support seamless transitions, enabling synchronous communication, collaborative engagement, and the co-creation of content across diverse contexts. However, despite significant interest and ongoing technological investment, the metaverse remains, at present, largely a conceptual and developmental framework rather than a fully operational or universally accessible system[31].

1.9 State of the Art

1.9.1 Philosophical And Theoretical Background

The definition of Virtual Reality

Virtual Reality:

> *A set of images and sounds, produced by a computer, that seem to represent a place or a situation that a person can take part in*[32]

> *Virtual reality (VR), the use of computer modelling and simulation that enables a person to interact with an artificial three-dimensional (3-D) visual or other sensory environment.*[33]

Simulation:

> *the artificial reproduction of the properties of an object or phenomenon by using a model of it*[34]

Mimesis:

> *The act of representing or imitating reality in art, especially literature*[35]

To fully establish a working definition of virtual reality, it is necessary to examine both the etymological origins and the philosophical background of the term. The modern definition of virtual, as given by the Cambridge Dictionary—"created by computer technology and appearing to exist but not existing in the

[31] A. S. Hovan George, Fernando Maschio, A. Shaji George, T. Baskar, and Digvijay Pandey, "Metaverse: The Next Stage of Human Culture and the Internet," *International Journal of Advanced Research Trends in Engineering and Technology* 8, no. 12 (2021): 1–10, https://doi.org/10.5281/zenodo.6548172; Jothi Prakash Venugopal, Arul Antran Vijay Subramanian, and Jegathesh Peatchimuthu, "The Realm of Metaverse: A Survey," *Computer Animation and Virtual Worlds* 34, no. 5 (2023): e2150, https://doi.org/10.1002/cav.2150; Valentin Kuleto, Milena P. Ilić, Marko Ranković, Mladen Radaković, and Aleksandar Simović, "Augmented and Virtual Reality in the Metaverse Context: The Impact on the Future of Work, Education, and Social Interaction," in *The Metaverse as a Virtual Form of Existence: Emerging Trends and Design Practices*, ed. Dalibor Radovanović (Cham: Springer Nature Switzerland, 2024), 3–24.

[32] "Virtual Reality," *Cambridge English Dictionary*, accessed May 20, 2025, https://dictionary.cambridge.org/dictionary/english/virtual-reality.

[33] "Virtual Reality," *Encyclopaedia Britannica*, accessed May 20, 2025, https://www.britannica.com/technology/virtual-reality

[34] "Symulacja," *Słownik Języka Polskiego* (PWN), accessed May 20, 2025, https://sjp.pwn.pl/slowniki/symulacja.html

[35] "Mimesis," *Cambridge English Dictionary*, accessed May 20, 2025, https://dictionary.cambridge.org/dictionary/english/mimesis?topic=representation-in-art-and-in-general

physical world"[36]—accurately reflects the context in which the term is used throughout this dissertation. However, the concept has deeper historical roots. As noted by Etymonline.com, the term virtual can be traced back to the 14th century, where it was understood as "having the essence or effect of something without being physically real"[37]. Although this earlier usage lacks any technological connotation, it nonetheless resonates with the theoretical framework of this research, particularly in its emphasis on the intangible yet perceivable nature of virtual environments.

The modern term virtual reality emerged in the late 20th century. It is widely credited to Jaron Lanier, a pioneer in computer science and human-computer interaction, who helped popularise the concept in the context of immersive, computer-generated environments. The phrase encapsulates a central paradox: an experience that feels real, despite lacking material substance. It defines a space where simulation achieves perceptual authenticity, allowing users to engage with reconstructed realities that are experientially convincing but physically absent[38].

Philosophical background

In an age increasingly defined by immersive technologies and digital environments, the relationship between knowledge and reality is undergoing a profound transformation. Epistemology, the philosophical study of knowledge, finds itself tested by the emergence of virtual reality, which challenges long-standing assumptions about perception and truth. Traditionally, knowledge has been grounded in the correlation between sensory experience and an objective external world. Yet virtual environments construct experiences that feel real while remaining entirely artificial, undermining the reliability of perception as a direct conduit to truth. This development aligns with post-Kantian epistemology, which understands reality not as something passively received but as actively shaped by the structures of perception, cognition, and mediation. Adding further complexity, Jean Baudrillard's theory of simulacra proposes that in contemporary media and virtual systems, representations may become untethered from any original referent, where simulations replace the real altogether. In this conceptual landscape, virtual reality does not merely imitate reality but reconfigures the very foundations through which authenticity, presence, and knowledge are defined.

Foundational theories

The concept of virtual reality can be traced back to classical philosophy, most notably in the works of Plato. His Allegory of the Cave[39] explores the relationship between representation and reality, presenting a philosophical framework in which perceived realities may differ significantly from the true nature of things. In the allegory, the shadows on the cave wall symbolise *mimesis*—the imitation of true reality. Similarly, both material and virtual reconstructions, due to their inherent lack of full authenticity, can be understood as imitations of the original, thus raising important questions about the nature of reality and truth in the context of heritage reconstruction.

[36] "Virtual," *Cambridge English Dictionary*, accessed May 20, 2025, https://dictionary.cambridge.org/dictionary/english/virtual

[37] "Virtual," *Etymology Online*, accessed May 20, 2025, https://www.etymonline.com/search?q=virtual.

[38] Aldo Faisal, "Computer Science: Visionary of Virtual Reality," *Nature* 551, no. 7680 (2017): 298–99.

[39] Plato's Allegory of the Cave, from The Republic, is a foundational metaphor illustrating the relationship between perception and reality. In the allegory, prisoners see only shadows on a wall, mistaking them for reality. When one escapes and discovers the world outside the cave, he realizes the shadows were illusions. This symbolizes the journey toward enlightenment and knowledge beyond sensory experience. The allegory contrasts the world of appearances with the world of forms, highlighting the value of education and philosophical inquiry in understanding truth.

The concept of reality was further developed by Descartes' concept of Evil Demon[40] in his *Meditations on First Philosophy*[41] published in 1641, which explores deception and manipulated realities that blur the real cognition. Building on this, Immanuel Kant, in his *Critique of Pure Reason,*[42] published in 1781 and corrected in 1787, argued that while we can never know things as they are in themselves, *the noumenon*, or true reality, our experience of the world is shaped by the mind's inherent structures: space, time, and the categories of understanding. What we know is the *phenomenon*—the way things appear to us through our senses and cognitive framework. In this way, Kant proposes that all perception is already a kind of constructed or "transcendental" reality[43], governed by the internal conditions that make experience possible. This philosophical insight anticipates the central problem of virtual reality: that what we perceive as "real" may be shaped, filtered, or even simulated through mediating systems, whether cognitive or, in the case of this work, technological.

Postmodern thought

While classical modernist philosophy was grounded in the belief that a single objective truth could be attained through scientific or philosophical reasoning[44], and that moral values and logical principles were universally applicable, postmodernist thought fundamentally challenged these assumptions. Postmodernism questioned the existence of a singular, absolute truth and instead introduced the idea of multiple, context-dependent truths, emphasising subjectivity, interpretation, and the relativity of knowledge fundamentals presented by Lyotard.

Building on this intellectual shift, Gilles Deleuze, in his 1968 work *Difference and Repetition*[45], introduced a new understanding of the concept of the virtual[46]. Deleuze defined the virtual as something real but not yet actual—a field of potentialities that may take shape in multiple ways. He argued that the virtual is not imaginary or false, but rather a real and integral part of the world, rich with possibilities waiting to be actualised. When applied to virtual reality, this perspective suggests that digital spaces are not mere imitations or illusions, but new, creative, real forms of experience born from existing potential. In this light, architectural reconstructions do not simply replicate the past; they reinterpret, transform, and recontextualise it, offering alternative ways of understanding, representing, and engaging with architectural heritage. These reconstructions thus possess the capacity to generate new realities and insights, rather than merely reproducing historical ones.

In parallel, Jean-François Lyotard presents in *Postmodern Condition,*[47] published in 1979, the grand narratives that once underpinned notions of truth and reality have lost their authority. In their absence,

---

[40] Descartes' Evil Demon thought experiment explores the form of idea of a virtual reality—a world that might be entirely deceptive or simulated. By doubting all sensory experience, Descartes anticipates modern questions about the blurred line between the actual and the virtual. He ultimately finds that, even if reality is an illusion, the act of thinking remains certain, grounding truth in self-awareness rather than perception, expressed in his famous dictum: Cogito, ergo sum ("I think, therefore I am").

[41] René Descartes, *Meditations on First Philosophy: With Selections from the Objections and Replies*, ed. John Cottingham (Cambridge: Cambridge University Press, 2013).

[42] Immanuel Kant, *Krytyka czystego rozumu*, trans. Romuald Ingarden (Warsaw: Państwowe Wydawnictwo Naukowe, 1957).

[43] Kant's transcendental idealism offered a resolution between rationalism and empiricism by transforming Descartes' skepticism into a framework that explains how knowledge is possible despite uncertainty. Rather than choosing between sense experience or pure reason, Kant argued that all knowledge arises from experience, yet is actively shaped by the mind's innate structures.

[44] As presented in Kant's transcendental idealism.

[45] Gilles Deleuze, *Difference and Repetition*, trans. Paul Patton (New York: Columbia University Press, 1994).

[46] Brian Massumi, "Envisioning the Virtual," in *The Oxford Handbook of Virtuality*, ed. Mark Grimshaw-Aagaard (Oxford: Oxford University Press, 2013), 55–70.

[47] Jean-François Lyotard, *Kondycja ponowoczesna: raport o stanie wiedzy* (Warszawa: Aletheia, 1997).

knowledge and meaning become increasingly localised, fragmented, and performative. This destabilisation of a unified truth resonates with how virtual spaces disrupt conventional understandings of reality, challenging the notion of a singular, universal truth.

Postmodern reflections on reality were further developed by Jean Baudrillard in his influential 1981 work *Simulacra and Simulation*[48]. Baudrillard argues that in contemporary society, symbols and representations, what he terms "simulacra", no longer simply reflect reality but come to replace and distort it to the point where they become more "real" than the original reality. He outlines four stages of simulation: faithful representation, persuasion of reality, pretence, and pure simulation. This progression culminates in hyperreality, a state in which simulations are so convincing that the boundary between reality and representation disappears.

Baudrillard's critique extends to environments such as Disneyland, which he identifies as a simulated world that feels "more real" due to its immersive design and idealised fantasy of American values. Disneyland's explicit artificiality masks the fact that much of modern life is similarly constructed, reinforcing the illusion that reality outside its gates remains authentic. This insight applies equally to historic city centres, where heritage sites are often commercialised and "beautified" to appeal to tourists, risking a disconnection from their genuine cultural significance and thereby contributing to the production of hyperreality.

Within this hyperreal condition, traditional concepts of truth and authenticity erode as people increasingly experience life through mediated symbols, media, and virtual environments. Architectural reconstruction exemplifies this phenomenon, as rebuilt structures often replicate originals that no longer exist or have lost their historical context. Rather than merely recalling the past, these reconstructions create new, self-contained realities that supplant historical authenticity, embodying Baudrillard's notion of hyperreality. This echoes his metaphor of the "desert of the real," describing a world saturated by simulations and façades without authenticity.

Baudrillard's concept of hyperreality highlights a condition where representations surpass reality, alienating individuals from genuine experience and immersing them instead in a constructed, image-mediated world. Virtual reality technologies can be seen as extensions of this process, producing immersive, interactive environments that blur distinctions between the authentic and the artificial. Together, these ideas illuminate evolving perceptions of truth, experience, and representation within contemporary culture.

With the evolution of postmodern thought and the growing integration of technology into everyday life, the convergence of these realms found increasing expression within contemporary philosophy. In his 1998 work *Becoming Virtual: Reality in the Digital Age*[49], author Pierre Lévy offers a comprehensive concept of virtualisation as a process not of replacing reality but of transforming it, extending it. This transformation and extension involves a shift from concrete existence to a more abstract and potential mode of being, thereby enabling new possibilities for interaction and meaning-making. Importantly, Lévy distinguishes this process from the notion of imitation or simulacrum, as advanced by Baudrillard. He challenges the conventional dualism between the "virtual" and the "real," proposing instead that the virtual constitutes a coexisting dimension of reality alongside the real, actual. This perspective provides a valuable framework for understanding virtuality today, not as a mere illusion or loss of authenticity, but as an evolving, generative space where reality is expanded and reconfigured through digital technologies. The concept of virtualisation is closely linked to remote sensing methods and the

[48] Jean Baudrillard, *Simulacra and Simulation*, trans. Sheila Faria Glaser (Ann Arbor: University of Michigan Press, 1994).

[49] Pierre Lévy, *Becoming Virtual: Reality in the Digital Age* (Boulder, CO: Perseus Books, 1998).

transformation of tangible, material heritage into intangible, immaterial representations. Aligned with Lévy's theory, this process has the potential to extend the realm of heritage into new forms of interaction and engagement and new forms of multimedia culture.

Cultural reflections

The concept of virtuality, virtual reality, computer simulation, and a general questioning of truth is not only a subject of philosophical discourse but has also been a persistent and dominant motif in science fiction. This motif has evolved in parallel with technological advancements and shifting cultural paradigms.

Ray Bradbury's The Veldt[50] (1954) introduced readers to immersive simulated environments with psychological depth, foreshadowing both the promise and the peril of substituting the real world with artificial projections. Shortly thereafter, Daniel F. Galouye's Simulacron-3[51] (1964) imagined a digital world indistinguishable from reality, marking one of the earliest literary explorations of simulated consciousness. Continuing along this trajectory, Stanisław Lem's Summa Technologiae[52] (1964) offered a profound theoretical reflection on future technologies. Within it, Lem introduced the concept of "phantomatics", a visionary precursor to modern virtual reality that proposed the creation of fully artificial sensory realities capable of deceiving the human mind. His philosophical inquiry presented virtual experience not merely as a form of entertainment, but as something potentially transformative.

The cyberpunk[53] literature of the 1980s and 1990s further redefined virtual reality by emphasising its dystopian potential. William Gibson's Neuromancer (1984)[54] and Neal Stephenson's Snow Crash (1992)[55] introduced the concept of cyberspace[56] as an expansive, fully navigable digital landscape. These virtual worlds were inhabited by avatars and dominated by powerful corporations, reflecting themes of disembodiment, identity, and systemic control. Such works helped establish the foundational metaphors of the internet age and have deeply influenced subsequent portrayals of virtual environments and digital culture.

In cinema, Ghost in the Shell (1995)[57] and, drawing inspiration from both this film and the philosophical ideas of Jean Baudrillard, The Matrix (1999)[58] further developed these themes. They examined the blurred boundaries between artificial environments, metanarratives, memory, and consciousness, encouraging viewers to question the nature of perceived reality itself[59].

---

[50] Ray Bradbury, "The Veldt," *The Saturday Evening Post*, September 23, 1950.

[51] Daniel F. Galouye, *Simulakron 3*, trans. Radosław Januszewski (Poznań: Dom Wydawniczy Rebis, 2003).

[52] Stanisław Lem, *Summa Technologiae* (Kraków: Wydawnictwo Literackie, 1964).

[53] Cyberpunk is a sci-fi subgenre set in dystopian, future, high-tech urban landscapes, focusing on themes like corporate power, social decay, and the blend of human and machine. Antiheroes, hackers, and AIs navigate gritty, neon-lit worlds where technology both empowers and dehumanizes. Most of the works highlights survival and rebellion in a dark, tech-dominated future.

[54] William Gibson, *Neuromancer* (London: Gollancz, 2016).

[55] Neal Stephenson, *Snow Crash* (New York: Bantam Books, 1992).

[56] Cyberspace is a virtual, digital realm where users can interact with data as if it were a physical space. Coined by William Gibson in novel Neuromancer, it represents a shared, immersive world that transcends the physical, blending technology with perception in a dynamic digital landscape.

[57] *Ghost in the Shell*, directed by Mamoru Oshii (Tokyo: Production I.G, 1995).

[58] *The Matrix*, directed by Lana Wachowski and Lilly Wachowski (Burbank, CA: Warner Bros., 1999).

[59] *The Matrix* reflects Jean Baudrillard's concept of simulacra, where signs no longer refer to any underlying reality, creating a hyperreality. The simulated world imposed by the Machines exemplifies this, presenting an illusion that conceals the absence of the real. This aligns with Lyotard's critique of metanarratives, as the rebels' resistance challenges the dominant simulation and reasserts postmodern scepticism toward universal truths.

More recently, Ready Player One (2018)[60] presented a gamified, immersive metaverse known as the OASIS, where users seek refuge from a deteriorating real world. This portrayal reflects both contemporary optimism about escapist digital technologies and growing concern over socio-economic inequality and the consequences of excessive immersion in virtual spaces.

Taken together, these works do more than entertain. They chart an intellectual trajectory that stretches from early speculative fiction to complex philosophical and sociotechnical critiques. Virtual spaces are portrayed as extensions of human desires and fears, raising fundamental questions about the boundaries between reality and illusion. These narratives critically examine themes such as technological control, the risks of immersive simulation, and the potential loss of authentic human experience in an increasingly digital world.

1.9.2 Heritage Digitalisation And Digital Reconstruction Practices[61]

The traditional approach to heritage documentation relied heavily on manual measurement techniques and skilled hand-drawn representations[62]. With the advent of digital technologies, these practices have undergone a significant transformation. The introduction of Computer-Aided Design (CAD) marked an early turning point, gradually giving way to increasingly advanced methods of documentation and preservation of cultural assets. Today, complex 3D documentation techniques often supplement, and in some cases replace, conventional measurement practices[63].

Key digital technologies currently used in heritage documentation include photogrammetry, terrestrial laser scanning (LiDAR), and drone-based aerial surveys. These methods are frequently integrated with Geographic Information Systems (GIS) and spatial data platforms, as well as Building Information Modelling (BIM)[64], particularly in its heritage-specific form, HBIM. Collectively, these tools enable the creation of highly accurate, scalable, and immersive representations of architectural and archaeological[65] assets, supporting not only preservation but also advanced analysis, interpretation, and public dissemination.

The emergence of digital reconstruction in heritage practice can be traced back to the early 1990s, a period marked by the increasing accessibility of personal computing and the development of basic 3D modelling software. Early virtual reconstructions, such as those developed within academic and museum contexts, were often limited by computational power and lacked the immersive interactivity found in contemporary platforms and technology[66]. Despite these limitations, pioneering projects laid

[60] *Ready Player One, directed by Steven Spielberg (Burbank, CA: Warner Bros., 2018).*

[61] This topic will be explored in greater detail in Chapters 3 and 4 of this thesis, which provide a comprehensive state-of-the-art overview of the subject.

[62] Maria Brykowska, *Metody pomiarów i badań zabytków architektury* (Warszawa: Oficyna Wydawnicza Politechniki Warszawskiej, 2003).

[63] Fabio Remondino and Stefano Campana, eds., *3D Recording and Modelling in Archaeology and Cultural Heritage: Theory and Best Practices*, BAR International Series 2598 (Oxford: BAR Publishing, 2014); Fabrizio I. Apollonio, "A Review of 3D Documentation of Heritage Structures," *Journal of Cultural Heritage* 23 (2017): 171–88.

[64] Giovanna Acampa, Fabiana Forte, and Pierfrancesco De Paola, "B.I.M. Models and Evaluations," in *Values and Functions for Future Cities*, ed. Giulio Mondini, Alessandra Oppio, Stefano Stanghellini, Marta Bottero, and Francesca Abastante, Green Energy and Technology, vol. 123 (Cham: Springer International Publishing, 2020), 351–63, https://doi.org/10.1007/978-3-030-23786-8_20

[65] Anastasia Dakouri-Hild and Bernard Frischer, eds., *Beyond Illustration: 2D and 3D Digital Technologies as Tools for Discovery in Archaeology*, BAR International Series S1805 (Oxford: BAR Publishing, 2008).

[66] Styliani Sylaiou, Fotis Liarokapis, Kostas Kotsakis, and Petros Patias, "Virtual Museums, a Survey and Some Issues for Consideration," *Journal of Cultural Heritage* 10, no. 4 (2009): 520–28, https://doi.org/10.1016/j.culher.2009.03.003; Fabio

the foundation for today's more sophisticated practices. A landmark initiative in this regard is the Rome Reborn Project[67], launched in the late 1996, but still advanced[68], which aimed to digitally reconstruct the city of ancient Rome at its urban development around 320 CE.

Other significant projects, such as Visualising Venice[69], Digital Karnak[70], and Virtual Palmyra[71] and others[72], similarly emphasise mapping historical data to visualise architectural transformations over time. Leveraging archaeological findings, historical records, and architectural studies, these projects offer comprehensive and visually engaging virtual models, enabling scholars and the public alike to explore and interpret complex historical environments and their layered narratives dynamically.

The methodological challenges raised by early virtual reconstructions prompted the development of international guidelines, most notably the London Charter (2009)[73] and the Seville Principles (2011)[74]. The London Charter established the first international framework for computer-based visualisation in cultural heritage, emphasising transparency, intellectual rigour, and sustainability, and introducing the concept of *paradata*[75] to document interpretive choices and uncertainties. The Seville Principles further stressed the need to communicate degrees of uncertainty and distinguish between different levels of reconstruction, thereby preventing seamless models from creating misleading impressions of certainty[76]. The Seville charter also proposed a taxonomy of practices in virtual heritage, which will be adopted in this thesis as a reference framework.

Bruno et al., "From 3D Reconstruction to Virtual Reality: A Complete Methodology for Digital Archaeological Exhibition," *Journal of Cultural Heritage* 11, no. 1 (2010): 42–49, https://doi.org/10.1016/j.culher.2009.02.006

[67] Bernard Frischer, Diane Favro, Dean Abernathy, and Monica De Simone, "The Digital Roman Forum Project of the UCLA Cultural Virtual Reality Laboratory," *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XXXIV-5/W10 (2003).

[68] Bernard D. Frischer, Dean Abernathy, Gabriele Guidi, Joel Myers, Cassie Thibodeau, Antonio Salvemini, Pascal Müller, H. Peter Hofstee, and Barry Minor, "Rome Reborn," *ACM SIGGRAPH 2008 New Tech Demos* (New York: ACM, 2008), https://doi.org/10.1145/1401615.1401649; Bernard Frischer and David Massey, "3D Urban Models as Tools for Research and Discovery: Two Case Studies of the Rostra in the Roman Forum Utilizing Rome Reborn," in *Critical Archaeology in the Digital Age*, ed. Kevin Garstki, Cotsen Digital Archaeology Series 2 (Los Angeles: Cotsen Institute of Archaeology Press, 2022), 23–48.

[69] Kristin L. Huffman, Andrea Giordano, and Caroline Bruzelius, eds., *Visualizing Venice: Mapping and Modeling Time and Change in a City* (London: Routledge, 2019).

[70] Elaine A. Sullivan and Lisa M. Snyder, "Digital Karnak: An Experiment in Publication and Peer Review of Interactive, Three-Dimensional Content," *Journal of the Society of Architectural Historians* 76, no. 4 (2017): 464–482, https://doi.org/10.1525/jsah.2017.76.4.464.

[71] Minna Silver, Gabriele Fangi, and Ahmet Denker, *Reviving Palmyra in Multiple Dimensions: Images, Ruins and Cultural Memory* (Caithness, UK: Whittles Publishing, 2018).

[72] More of the related studies will be presented in chapter 4 of this thesis.

[73] *The London Charter for the Computer-based Visualisation of Cultural Heritage, version 2.1 (London: Arts and Humanities e-Science Support Centre, February 2009), http://www.londoncharter.org.*

[74] *The Principles of Seville: International Principles of Virtual Archaeology* (Seville: Sociedad Española de Arqueología Virtual, 2011), http://smartheritage.com/seville-principles

[75] Paradata, as defined in *The London Charter for the Computer-based Visualisation of Cultural Heritage*, version 2.1 (London: Arts and Humanities e-Science Support Centre, February 2009), refers to the documentation of interpretive processes, assumptions, and reasoning that underpin computer-based visualisations of cultural heritage. Unlike metadata, which record technical aspects of a digital file, paradata make explicit the scholarly choices and degrees of uncertainty embodied in a reconstruction. This principle ensures transparency and accountability, preventing digital models from presenting a misleading impression of completeness.

[76] Víctor Manuel López-Menchero Bendicho and Alfredo Grande, "Hacia una Carta Internacional de Arqueología Virtual: El Borrador SEAV," *Virtual Archaeology Review* 2, no. 4 (2011): 71–75.

Virtual restoration: *this involves using a virtual model to reorder available material remains in order to visually recreate something that existed in the past. Thus, virtual restoration includes virtual anastylosis.*

Virtual anastylosis: *this involves restructuring existing but dismembered parts in a virtual model.*

Virtual reconstruction: *this involves using a virtual model to visually recover a building or object made by humans at a given moment in the past from available physical evidence of these buildings or objects, scientifically reasonable comparative inferences and, in general, all studies carried out by archaeologists and other experts in relation to archaeology and history.*

Virtual recreation: *this involves using a virtual model to visually recover an archaeological site at a given moment in the past, including material culture (movable and immovable heritage), environment, landscape, customs, and general cultural significance.*

Recent virtual heritage projects increasingly incorporate immersive and interactive technologies to create more engaging and meaningful experiences[77]. Many of these initiatives draw upon techniques from the gaming industry, using interactive storytelling and user-focused design to enrich narrative content and improve audience engagement[78]. Key developments in this field include immersive Virtual Reality (VR) and Augmented Reality (AR) applications[79], digital twin models, real-time interactive simulations, and the growing use of artificial intelligence in the documentation and interpretation of cultural heritage.

VR and AR technologies allow users to explore reconstructed heritage environments either on-site or remotely, offering multisensory experiences that provide deeper insight into historical contexts. VR can recreate past scenarios with a high degree of realism, enabling users to engage in contextual learning and develop an emotional connection with the past. AR, by contrast, superimposes digital content onto physical spaces, enhancing museum exhibitions and archaeological sites with additional layers of information and visual reconstructions.

The use of digital twins, especially with the HBIM technology, defined as data-rich virtual replicas of physical heritage environments, has gained traction in recent years[80]. These models integrate spatial data with ongoing updates, supporting activities such as structural monitoring, conservation planning, and interpretive storytelling[81].

Together, these advancements represent a fundamental shift in heritage practices. Rather than serving only as a method of static recording, digital documentation has evolved into an active, interactive, and

[77] Ayoung Suh and Jane Prophet, "The State of Immersive Technology Research: A Literature Analysis," *Computers in Human Behavior* 86 (September 2018): 77–90, https://doi.org/10.1016/j.chb.2018.04.019

[78] Erik Champion, *Critical Gaming: Interactive History and Virtual Heritage* (London: Routledge, 2024).

[79] Maria Economou, "Evaluating the Use of Virtual Reality and Multimedia Applications for Presenting the Past," in *Handbook of Research on Technologies and Cultural Heritage: Applications and Environments*, ed. Georgios Styliaras, Dimitrios Koukopoulos, and Fotis Lazarinis (New York: IGI Global, 2011), 223–39, https://doi.org/10.4018/978-1-60960-044-0.ch011; Mafkereseb Kassahun Bekele et al., "A Survey of Augmented, Virtual, and Mixed Reality for Cultural Heritage," *Journal on Computing and Cultural Heritage* 11, no. 2 (2018): 1–36, https://doi.org/10.1145/3145534.

[80] Simos Logothetis, Athina Delinasiou, and Efstratios Stylianidis, "Building Information Modelling for Cultural Heritage: A Review," *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences* II-5/W3 (2015): 177–183, https://doi.org/10.5194/isprsannals-II-5-W3-177-2015

[81] Giovanna Acampa and Mariolina Grasso, "Heritage Evaluation: Restoration Plan through HBIM and MCDA," *IOP Conference Series: Materials Science and Engineering* 949, no. 1 (2020): 012061, https://doi.org/10.1088/1757-899X/949/1/012061.

accessible medium. These tools open new opportunities for research, education, conservation, and public engagement, enabling cultural heritage to be not only preserved but also explored and experienced in more dynamic and immersive ways, extending the concept of virtual reconstruction into immersive virtual reconstruction. s

1.10 Scope Limitations

The scope of this research is primarily limited to Virtual Reality (VR) technology, with only partial consideration given to Augmented Reality (AR) and the explicit exclusion of Mixed Reality (MR). This focus is shaped by both methodological objectives and practical constraints, particularly the availability of specialised hardware and infrastructure.

The study emphasises the direct application of VR within the context of architectural heritage, supported by access to Head-Mounted Display (HMD) systems, a CAVE VR environment, and high-performance computing infrastructure. This direction has been further developed through interdisciplinary collaboration with the Immersive 3D Visualisation Laboratory, led by Prof. Jacek Lebiedź at the Faculty of Electronics, Telecommunications and Informatics.

Augmented Reality (AR) is addressed only to a limited extent and solely within the Westerplatte Peninsula case study, where smartphone-based AR applications are used for interpretive purposes. However, AR does not constitute a core technological framework within this dissertation. Mixed Reality (MR) technologies, such as Microsoft HoloLens, are excluded entirely due to the lack of access to appropriate equipment, and the research focuses on fully immersive, non-material simulations made possible by VR.

The case studies selected for this dissertation are all located in Gdańsk, Poland. This geographic focus supports the research through direct access to material sites, which serve as primary sources and were easily documented and digitalised without the need for extensive travel. Additionally, most relevant archival materials and historical documentation are also housed in Gdańsk, allowing for efficient and comprehensive source-based research.

The study focuses on the representation of historical architectural phases, particularly those involving original existence, transformation, decay, and past reconstructions. It does not address speculative future scenarios, such as adaptive reuse or proposed restoration projects, as these fall beyond the scope of this research.

CHAPTER 2

CONCEPT OF THE RECONSTRUCTION

VIRTUAL REALITY TECHNOLOGY IN ARCHITECTURAL HERITAGE AND ITS IMPACT ON CONSERVATION

2. Concept Of The Reconstruction

The purpose of this chapter is to critically examine and present the author's perspective on the evolution of conservation doctrine, with particular attention to how the concepts of authenticity, reconstruction, and heritage interpretation have shifted over time. The linear development of conservation has already been discussed and summarised by numerous scholars, especially Jukka Jokilehto (A History of Architectural Conservation)[82], Giovanni Carbonara[83], Bernard Feilden[84], and interesting insight of historian of conservation thought Janusz Krawczyk[85].

Polish researchers have also contributed to the broader discourse on heritage conservation from a distinctly Polish perspective. Notable figures such as Jan Zachwatowicz[86], Edmund Małachowicz[87], and Bohdan Rymaszewski[88] have published foundational works that synthesise and develop Polish conservation theory. More recently, Tomasz Torbus[89] has critically addressed contemporary issues such as over-interpretation and dilettante approaches to heritage. The Polish perspective is especially crucial for this thesis, as the case studies presented in Chapter 5 are situated within the Polish context and reflect the complexities of Poland's approach to conservation.

Rather than simply repeating this chronology, this chapter explores how each era's approach, whether focused on preservation, restoration, or reconstruction, was regarded as both morally and culturally justified in its time, but was often later challenged or re-evaluated. Special attention is given to the inherent instability of conservation principles and the tensions that emerged, particularly after the Second World War, between material authenticity and interpretive representation. These tensions are highlighted through examples where similar conservation challenges produced divergent theoretical and practical responses.

This chapter argues that reconstruction, whether material or virtual, has always functioned as a visual and interpretive medium, shaping how the present understands the past. The analysis presented here provides the conceptual basis for evaluating the role of virtual reality within contemporary conservation, framing it as the latest phase in this ongoing evolution.

2.1 Early Authenticity

During antiquity, most buildings were primarily utilitarian in nature; if a structure required adaptation or modification, it was simply rebuilt to meet new requirements. Likewise, when a building was no longer needed or had become structurally unsound, it was often dismantled and replaced with a new one on the same site. The concept of routine maintenance was clearly present, aimed at prolonging

[82] Jukka Jokilehto, *A History of Architectural Conservation*, 2nd ed. (New York: Routledge, 2017).

[83] Giovanni Carbonara, *Avvicinamento al restauro: teoria, storia, monumenti* (Napoli: Liguori, 1997).

[84] Bernard M. Feilden, *Conservation of Historic Buildings*, 3rd ed. (Oxford: Architectural Press, 2003).

[85] Janusz Krawczyk, *Nazwać, żeby ocalić. Klasycy myśli konserwatorskiej wobec reliktów przeszłości* (Toruń: Wydawnictwo Naukowe Uniwersytetu Mikołaja Kopernika, 2020).

[86] Jan Zachwatowicz, *Ochrona zabytków w Polsce* (Warszawa: Polonia, 1965).

[87] Edmund Małachowicz, *Konserwacja i rewaloryzacja architektury w środowisku kulturowym* (Wrocław: Oficyna Wydawnicza Politechniki Wrocławskiej, 2007).

[88] Bohdan Rymaszewski, *Polska ochrona zabytków* (Warszawa: Wydawnictwo Naukowe Scholar, 2005).

[89] Tomasz Torbus, *Rekonstrukcje, dekonstrukcje, (nad)interpretacje: studia o losach architektury środkowoeuropejskich miast i rezydencji w aspekcie politycznym (XIX–XXI wiek)* (Gdańsk: Słowo/Obraz Terytoria, 2019).

the existence of structures, and was often perceived as purely utilitarian; therefore, it cannot be equated with the protection and safeguarding of heritage[90].

However, even from the earliest stages of human civilisation, the concept of memory emerged as a means to preserve cultural elements from oblivion. This foundational idea is deeply entwined with the origins of architectural heritage, shaping how societies have perceived and valued the built environment, not merely as a functional necessity but also as a carrier of collective memory and identity.

The continuity of symbolic meaning in antiquity was frequently expressed through practices such as the reuse of architectural elements - spolia, syncretism, and the appropriation of past forms to serve new imperial ideologies. These acts allowed societies to establish a sense of connection with their predecessors, embedding traces of the past within new constructions and reaffirming collective memory. In such contexts, authenticity was often defined not by the preservation of original material, but by the continuity of function, symbolic resonance, and shared cultural memory embodied within the built environment. The use of spolia, in particular, went far beyond mere practicality. Integrating authentic fragments from previous eras functioned as a powerful tool of collective memory and cultural symbolism, providing tangible links to tradition while also enabling reinterpretation for new political and ideological purposes[91]. Thus, authenticity in Roman architecture was often rooted in the meaningful preservation and transformation of cultural memory, rather than in strict material originality[92].

An early example of heritage preservation can be found in a clay cylinder inscribed by Nebuchadnezzar II (605–562 BCE), commemorating the reconstruction of a temple dedicated to the god Lugal-Marda in Marad. The inscription records the king's restoration activities and his rediscovery of a foundation deposit left by the Akkadian king Naram-Sîn (2254–2218 BCE), which he incorporated into the new temple alongside his own deposit[93]. The temple, Eigikalamma ("temple, eye of the country"), reflects the Mesopotamian reverence for the past. The cylinder itself likely served as a commemorative object and was probably buried in the temple's foundation for ritual protection and to preserve the memory of both rulers[94].

[90] Jukka Jokilehto, *A History of Architectural Conservation*, 2nd ed. (New York: Routledge, 2017), 11–13, 18–21; David Lowenthal, *The Past Is a Foreign Country* (Cambridge: Cambridge University Press, 1985), 244.

[91] Dale Kinney, "Spolia: *Damnatio* and *Renovatio Memoriae*," *Memoirs of the American Academy in Rome* 42 (1997): 117–48, https://doi.org/10.2307/4238749.

[92] Dale Kinney, "Roman Architectural Spolia," *Proceedings of the American Philosophical Society* 145, no. 2 (2001): 138–61.

[93] Andrew George, *Babylonian Topographical Texts* (Leuven: Peeters Publishers, 1992), 343–44.

[94] *Cylinder of Nebuchadnezzar II*, Vatican Museums, via Vatican Museums online collections, accessed July 12, 2022, https://www.museivaticani.va/content/museivaticani/en/collezioni/musei/museo-gregoriano-egizio/sala-viii--antichita-del-vicino-oriente-antico/cilindro-di-nabucodonosor-ii.html; Andrew George, *House Most High: The Temples of Ancient Mesopotamia* (Winona Lake, IN: Eisenbrauns, 1993), 104.

Fig. 12. Inscribed clay cylinder Inv. D723. of Nabuchadnezar II, Maradda, southern Iraq, Neo-Babylonian Period, Vatican Museum. Source: author, 2022.

A compelling example of authenticity as continuity and symbolic resonance is the Temple of Jupiter Optimus Maximus, dedicated to the chief Roman deity. After Sulla's sack of Athens in 86 BCE, several incomplete Corinthian columns from the Temple of Zeus[95] were brought to Rome and incorporated into Jupiter's temple[96]. This use of spolia reflected not only pragmatic reuse but also the Roman practice of appropriating the cultural legacy of conquered peoples to reinforce their own identity. The temple underwent repeated destruction and reconstruction, including major restoration by Emperor Vespasian after fires and political upheaval. These efforts focused not just on rebuilding the structure, but on preserving its symbolic authority and role within Roman society. Vespasian's work earned him the title "Conservator of Public and Restorer of Private Buildings," highlighting a Roman view of authenticity cantered on the continuity of memory, function, and meaning, rather than material originality[97].

The Arch of Constantine in Rome, located near the Colosseum, stands as one of the most iconic and well-preserved Roman triumphal arches. Erected to commemorate Emperor Constantine I's victory over Maxentius at the Battle of Milvian Bridge in 312 AD. Beyond its immediate commemorative function, the Arch is an another example of how the concepts of memory, authenticity, and symbolic continuity were expressed through architecture. Its eclectic design incorporates decorative reliefs, statues, and architectural components deliberately taken from monuments of earlier emperors such as Trajan, Hadrian, and Marcus Aurelius[98]. This intentional use of spolia went beyond the practical advantage of sourcing high-quality materials; it was a conscious effort to associate Constantine's reign with the legacy of Rome's most esteemed rulers. Through this visual narrative of continuity and legitimacy, according to Jas Elsner, the arch constructed a sense of imperial identity and historical authenticity grounded not only in material survival but also in the selective appropriation and reinterpretation of the past[99].

---

[95] The temple has partially survived to the present day and continues to inspire admiration as a prime example of ancient Greek architecture and the Corinthian order. Despite the looting of Athens, it was ultimately completed during Roman rule.

[96] The Temple of Jupiter has undergone multiple reconstructions since its original dedication, and it was rebuilt several times after the disasters. Today, only fragments of its foundations and a few architectural elements survive, visible at the Capitoline Museums and the Piazza del Campidoglio.

[97] Edmund Małachowicz, *Konserwacja i rewaloryzacja architektury w środowisku kulturowym* (Wrocław: Oficyna Wydawnicza Politechniki Wrocławskiej, 2007), 27.

[98] Mark Wilson Jones, "Genesis and Mimesis: The Design of the Arch of Constantine in Rome," *Journal of the Society of Architectural Historians* 59, no. 1 (2000): 50–77, https://doi.org/10.2307/991562

[99] Jas Elsner, "From the Culture of Spolia to the Cult of Relics: The Arch of Constantine and the Genesis of Late Antique Forms," *Papers of the British School at Rome* 68 (2000): 149–84, https://doi.org/10.1017/S0068246200003901.

Fig. 13. Arc of Constantine in Rome, Italy. Source: author, 2022.

A similar example of reusing elements and repurposing spolia can be seen in how the early Church transformed and appropriated the legacy of Rome's classical past in the Basilica of Santa Maria in Trastevere. Founded around 340 AD in the wake of the Edict of Milan in 313 AD, which granted freedom of worship, officially recognized Christianity, and initiated the widespread construction of Christian churches, the basilica demonstrates this process vividly. The interior of the three-nave basilica is marked by an assemblage of columns and capitals that differ in material, style, and proportion, many of which were repurposed from the nearby Baths of Caracalla. This deliberate reuse of architectural spolia illustrates the symbolic strategies employed by early Christian builders, as these materials acquired new significance within Christian contexts. In this instance, authenticity was articulated not through material originality but through the integration of classical elements into a redefined religious and cultural framework. By incorporating authentic relics of Rome's imperial past, the basilica affirmed both the continuity of divine authority and the Christian claim to the city's cultural heritage[100].

Fig. 14. Interior of Basilica di Santa Maria in Trastevere, Rome, Italy. Source: author, 2022.

[100] Dale Kinney, "Liturgy, Space, and Community in the Basilica Julii (Santa Maria in Trastevere)," *Acta ad archaeologiam et artium historiam pertinentia* 31 (2019): 81–100, https://doi.org/10.5617/acta.7801; Alfonso Ippolito, Cristiana Bartolomei, Davide Mezzino, Martina Attenni, and Rawan Darwa, "Digital Documentation Strategies for the Knowledge of the Basilica of Santa Maria in Trastevere," *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLVIII-M-2-2023 (2023): 735–42, https://doi.org/10.5194/isprs-archives-XLVIII-M-2-2023-735-2023; Amanda Reeves, "If Walls Could Talk: The Columns of Santa Maria in Trastevere," *In Medias Res* (Medium), 2018, accessed May 30, 2023, https://medium.com/in-medias-res/if-the-walls-could-talk-the-columns-of-santa-maria-in-trastevere-4c7e3bc0cbc2

Another significant example of authenticity in architectural elements is the transfer of column capitals from Ravenna to Aachen by Charlemagne. Originally brought from Constantinople to Ravenna as symbols of imperial succession, these capitals were later incorporated into Charlemagne's palace chapel[101], extending a tradition of repurposing significant architectural fragments[102] to express legitimacy and continuity of power[103]. In 805, Pope Leo III consecrated the chapel, five years after crowning Charlemagne as Holy Roman Emperor. The relocation of the Frankish capital to Aachen reflected Charlemagne's intent to revive the legacy of Roman rule in Europe. The design of the chapel itself was strongly inspired by the Byzantine architecture of San Vitale in Ravenna, and it later became an influential model in its own right[104]. Much like the Arch of Constantine, the incorporation of authentic elements into the chapel served to demonstrate continuity with Roman traditions, symbolising the cultural and spiritual revival of the Roman Empire in the form of the Holy Roman Empire. This conscious use of ancient material was thus integral to Charlemagne's broader vision of authority and identity, reinforcing the idea that authenticity in heritage often resides as much in symbolic continuity as in the material substance itself.

2.2 Rediscovery of Antiquity. From the Renaissance to the Enlightenment

Throughout history, the rediscovery of antiquity has profoundly shaped the development of architectural thought. The European Renaissance, in particular, was a pivotal era marked by renewed fascination with classical art and literature, which brought ancient Greek and Roman artefacts back into the cultural consciousness and established them as essential carriers of heritage value. A significant milestone in this process was the publication of De re aedificatoria (On the Art of Building)[105] by Leon Battista Alberti in the mid-15th century. Drawing heavily from Vitruvius's De architectura[106], Alberti's treatise was among the first comprehensive works on architecture since antiquity, systematically exploring building materials, urban planning, aesthetics, and conservation, while emphasising symmetry, proportion, and harmony as foundational principles[107].

The revival of classical forms during the Renaissance did more than influence architectural style; it also marked a fundamental shift in how the past was valued and engaged with. By introducing new

[101] The chapel, inspired by the Byzantine Church of San Vitale in Ravenna, is a key example of the Carolingian Renaissance, showcasing the classical revival style later defined as pre-Romanesque.

[102] Edmund Małachowicz, *Konserwacja i rewaloryzacja architektury w środowisku kulturowym* (Wrocław: Oficyna Wydawnicza Politechniki Wrocławskiej, 2007), 27; David Rollason, "Charlemagne's Palace," *Archaeological Journal* 172, no. 2 (2015): 443–48, https://doi.org/10.1080/00665983.2015.1040262

[103] Roland Prien, "The Copy of an Empire? Charlemagne, the Carolingian Renaissance and Early-Medieval Perceptions of Late Antiquity," in *The Transformative Power of the Copy: A Transcultural and Interdisciplinary Approach*, ed. Corinna Forberg and Philipp Wolfgang Stockhammer (Heidelberg: Heidelberg University Publishing, 2017), 309–29, https://doi.org/10.17885/heiup.195.260

[104] W. Eugene Kleinbauer, *Charlemagne's Palace Chapel at Aachen and Its Copies*, *Gesta* 4 (1965): 2–11, https://doi.org/10.2307/766678

[105] Leon Battista Alberti, *On the Art of Building in Ten Books*, trans. Joseph Rykwert, Neil Leach, and Robert Tavernor (Cambridge, MA: MIT Press, 1991).

[106] In 1416, the Italian humanist Poggio Bracciolini discovered a manuscript of Vitruvius' treatise in the library of Saint Gall, Switzerland. Vitruvius' ten-book work is the only surviving major text on classical architecture from antiquity, covering a broad range of topics, including urban planning, building materials, construction methods, hydraulics, and sundials.

[107] Alberti's other treaty "De Pictura", published in 1435, is a another treatise written by the Leon Battista Alberti, where he explores the principles of linear perspective and offers guidance on how to create the illusion of depth in painting. It is described in Chapter 3.2 .

frameworks for the appreciation, adaptation, and theoretical understanding of antiquity, Renaissance thinkers like Alberti helped lay the foundations for modern conservation doctrine[108]. Their approach shaped evolving notions of authenticity and cultural value, as well as new methods for recording and transmitting heritage, concerns that remain central to contemporary debates. In tracing these developments, this thesis situates digital practices within a broader historical continuum, viewing current approaches to virtual heritage as the latest stage in the ongoing reinterpretation and technological mediation of cultural memory.

Santa Maria degli Angeli e dei Martiri

Santa Maria degli Angeli e dei Martiri in Rome is an early example of the evolving principles that underpin modern conservation thought, reflecting a developing attitude toward the preservation, adaptation, and reinterpretation of historic structures. The church exemplifies respect for architectural history by illustrating the adaptive reuse of ancient fabric within a new cultural and religious context. Built within the remains of the Baths of Diocletian, it preserves significant elements of ancient Roman architecture, even after centuries of neglect and destruction. In 1561, Pope Pius IV entrusted Michelangelo with its transformation, envisioning the conversion of the ruins into a church dedicated to angels and to the memory of Christian martyrs. Adopting a philosophy of limited intervention, Michelangelo preserved the original Roman fabric while sensitively adapting the space for Christian worship. He retained much of the ruined exterior, emphasised the visual unity between the permanent ruin and the adapted interior, and allowed the building's layered history to remain visible[109].

The significance of this case for the topic of this thesis lies in its early embodiment of core conservation principles such as minimal intervention, respect for original fabric, and adaptive reuse, values that have come to define modern approaches to heritage. Michelangelo's work demonstrates that authenticity extends beyond material preservation to include the thoughtful integration of past and present, a notion central to contemporary debates. This example further illustrates how historical layering, reinterpretation, and the mediation of meaning remain key challenges not only in traditional conservation but also in the digital reconstructions and virtual heritage projects explored in this dissertation.

Fig. 15. The Church of Santa Maria degli Angeli e dei Martiri: exterior and interior. Source: author, 2024.

[108] Jukka Jokilehto, *A History of Architectural Conservation*, 2nd ed. (New York: Routledge, 2017), 26–27.

[109] James S. Ackerman, *The Architecture of Michelangelo*, 2nd ed. (Chicago: University of Chicago Press, 1986), 260–68; Jukka Jokilehto, *A History of Architectural Conservation*, 2nd ed. (New York: Routledge, 2017), 34-36.

Laocoon group

The case of the restoration of the Laocoön Group, an iconic ancient sculpture, offers a scholarly example of the evolving principles of conservation doctrine. The sculpture depicts Laocoön and his sons in a dramatic struggle with sea serpents. It exemplifies ancient Hellenistic artistry through its dynamic forms and emotional intensity[110]. The Laocoön Group's complex history reflects its enduring artistic and cultural significance. Likely created during the Hellenistic period and referenced by Pliny the Elder in his Natural History, the sculpture was originally displayed in Emperor Titus's palace and was later moved to Hadrian's Octagonal Court at the Vatican. Rediscovered in 1506 on Rome's Esquiline Hill, the work was acquired by Pope Julius II and installed in the Vatican Museums. Although largely intact, several key parts were missing, sparking centuries of debate and restoration attempts.

Early restoration efforts revealed diverging perspectives on authenticity and interpretation. Pope Julius II organised a competition to reconstruct the missing right arm, with Jacopo Sansovino proposing an outstretched pose, widely adopted in reproductions, while Michelangelo argued for a bent position. In 1532, Giovanni Antonio Montorsoli, a disciple of Michelangelo, attached a new arm to the sculpture, and later, Agostino Cornacchini added parts to the younger son[111]. Following the Napoleonic looting and the sculpture's return, Antonio Canova refrained from altering previous restorations despite doubts about their accuracy. A turning point came in 1906, when Ludwig Pollack discovered the original right arm at the site of excavation. This breakthrough resolved centuries of debate and revealed inaccuracies in earlier restorations[112]. The sculpture was subsequently reconfigured to incorporate the original arm while removing speculative later additions. Notably, the sons of Laocoön were left without arms to avoid conjectural restoration and the risk of misleading interpretation[113].

The history of the Laocoön Group vividly illustrates the challenges that remain central to both traditional and digital approaches to heritage conservation. Its evolving restoration, marked by debate, error, and eventual correction, highlights the tension between the desire for visual completeness and the ethical imperative to respect material authenticity and historical uncertainty. The shift towards cautious, reversible interventions established principles such as transparency, reversibility, and the acceptance of historical layering, which are now fundamental to modern conservation doctrine. These same issues are encountered in digital heritage practice, where decisions about reconstruction, documentation, and the treatment of uncertainty directly influence how heritage is perceived and understood. The Laocoön Group thus stands as both a methodological precedent and a conceptual metaphor for the evolving role of interpretation, authenticity, and ethical responsibility in the digital mediation of cultural memory, key themes at the heart of this dissertation.

---

[110] The Laocoön Group is widely acknowledged to have had a significant impact on the work of Baroque artists, including Michelangelo, Raphael, Giuliano da Sangallo, and Gian Lorenzo Bernini.

[111] The practice of supplementing the sculpture with missing parts in an attempt to restore its presumed original appearance can be described as a form of stylistic restoration, a concept closely associated with Eugène Viollet-le-Duc and the restoration approaches of the nineteenth century.

[112] The discovery in the early twentieth century, occurring long after the reattachment of the reproduced arm, reflected a shift from early stylistic restauration into scientific in attitudes toward the treatment of original material and the practice of reintegration.

[113] Margarete Bieber, *Laocoon: The Influence of the Group since Its Rediscovery* (New York: Columbia University Press, 1942); Seymour Howard, "On the Reconstruction of the Vatican Laocoon Group," *American Journal of Archaeology* 63, no. 4 (1959): 365–69, https://doi.org/10.2307/501788; Avi Lifschitz and Michael Squire, eds., *Rethinking Lessing's Laocoon* (Oxford: Oxford University Press, 2017); C. Richard Booher, review of *Rethinking Lessing's Laocoon: Antiquity, the Enlightenment, and the "Limits" of Painting and Poetry*, ed. Avi Lifschitz and Michael Squire (Oxford: Oxford University Press, 2017), *Classical World* 112, no. 3 (2019): 240–41.

Fig. 16. Laocoon Group. Source: author, 2022.

Raphael Santi

While the Renaissance is remembered as a period of rediscovery, its early stages were not closely associated with the conservation or protection of architecture[114]. Instead, many ancient Roman structures, such as the Colosseum and the Forum Romanum, were frequently treated as convenient quarries for materials to be used in new construction projects. Despite repeated attempts by various popes to curb this practice, it persisted until decisive action was taken. In 1515, Pope Leo X issued a papal bull granting Raphael Sanzio, the celebrated painter and architect, the authority to excavate ancient Roman ruins and claim any statues or artefacts uncovered within the city or up to a mile beyond its borders. The decree required excavators to report their findings to Raphael within three days, and stonemasons were forbidden from destroying inscriptions without prior approval. Raphael, in a letter to the pope, proposed measures to prevent further destruction of ancient monuments and suggested a systematic visual survey of Rome to document its antiquities[115]. This initiative aimed to ensure that ancient masonry could still be repurposed for the ongoing construction of St Peter's Basilica, but only after inscriptions were recorded and sculptures preserved[116].

Importantly, this act represents one of the earliest efforts to introduce systematic documentation and oversight in the management of historic material, anticipating key principles of conservation that remain relevant today. Raphael's approach, which combined scholarly recording with pragmatic reuse, not only shaped artistic practice but also laid the groundwork for the doctrines, standards, and ethical debates that now define the field of heritage conservation. These early initiatives in documentation, preservation, and conscious intervention form a clear historical precedent for both modern and digital inventory methods explored throughout this thesis.

[114] In Renaissance architecture was generally regarded as a mechanical or utilitarian art, lower in status than painting or sculpture. As a result, ancient Roman buildings were often valued more as convenient sources of building materials than as cultural artefacts worthy of preservation. This practical attitude reflected both the urgent construction needs of the period and the prevailing artistic hierarchy, which placed less importance on architectural heritage than on the revival of the visual arts. See Robert Williams, *Raphael and the Redefinition of Art in Renaissance Italy* (Cambridge: Cambridge University Press, 2017), 4, 32–34.

[115] The arrangement provided Raphael with a unique opportunity to study classical art and architecture directly. His findings profoundly influenced his artistic style and contributed to the broader Renaissance revival of classical ideals, marking a significant shift towards recognising the importance of preserving the heritage of antiquity.

[116] Roger Jones and Nicholas Penny, *Raphael* (New Haven, CT: Yale University Press, 1987), 199–206; Edmund Małachowicz, *Konserwacja i rewaloryzacja architektury w środowisku kulturowym* (Wrocław: Oficyna Wydawnicza Politechniki Wrocławskiej, 2007), 28.

Pompeii and archaeological excavations

The archaeological excavations of the eighteenth and nineteenth centuries, particularly at Pompeii (1737), Herculaneum (1748), and Stabia (1749), marked a significant development in the study of ancient architecture and artefacts and contributed to a renewed interest in classicism[117]. These sites were notable for their remarkable state of preservation, as the eruption of Vesuvius in AD 79 had buried the Roman cities under volcanic ash, resulting in minimal subsequent alteration. In contrast to cities such as Rome, which underwent substantial changes over time, Pompeii, Herculaneum, and Stabia provided opportunities to examine aspects of ancient Roman architecture, customs, and daily life with comparatively little later interference[118]. As a result, they were often perceived as invaluable sources of historical information[119].

This perception led to the notion of comprehensive preservation and encouraged detailed study of architectural history, sparking the development of archaeological and architectural investigations grounded in scientific methodology. The scientific study and exceptional preservation of sites such as Pompeii not only expanded the scope of archaeological research but also established principles of authenticity, integrity, and systematic documentation that remain foundational to modern conservation.

In some cases, structures at Pompeii were reconstructed to illustrate aspects of ancient life. Notable examples include the Villa of the Mysteries, the House of the Vettii[120], and portions of the forum and adjacent structures, where porticoes, colonnades, and walls were partially rebuilt. These interventions served both to protect the remains and, importantly, to provide visitors with a sense of the original spaces[121]. Consequently, Pompeii presents a complex blend of original remains, stabilised ruins, partial reconstructions, and some speculative restoration, reflecting changing attitudes towards authenticity, the presentation of the past, and the visitor experience[122].

---

[117] Paul Zanker, *Pompeii: Public and Private Life*, trans. Deborah Lucas Schneider (Cambridge, MA: Harvard University Press, 1999); Roger Ling, *Pompeii: History, Life & Afterlife* (Stroud: Tempus, 2005); Pedar Foss and John J. Dobbins, eds., *The World of Pompeii* (London: Routledge, 2009).

[118] Similar archaeological excavations were conducted in Egypt, in Englightment era, where the prevailing climate and historical circumstances contributed to the preservation of ancient artefacts. Following Napoleon's conquest, expeditions were organised to investigate these remains. As with the Roman sites, the well-preserved elements of Egyptian antiquity provided important sources of information about the cultural and architectural history of the ancient world.

[119] Jukka Jokilehto, *A History of Architectural Conservation*, 2nd ed. (New York: Routledge, 2017), 56–59.

[120] The topic of House of Vettii interior will reappear in chapter 3 with ancient Pompeii illusory art movement.

[121] Many visitors express a strong preference for reconstructed or complete forms of ancient structures, as such presentations help them to visualize and emotionally engage with the past. Reconstructed spaces can offer a tangible sense of scale, context, and atmosphere that fragmentary remains alone may not provide. This desire for wholeness often shapes conservation and reconstruction policies, balancing scholarly accuracy with the interpretive needs and expectations of the public.

[122] The example of Pompeii is particularly relevant to the Westerplatte case study, as it addresses both the challenges of presenting archaeological excavations and the potential of immaterial, virtual approaches to interpreting and displaying heritage sites.

Fig. 17. Remains of Ancient Pompeii. Source: author, 2020.

Piranesi

Parallel to these developments in archaeological practice, artists and scholars also began to explore new ways of engaging with ancient ruins through documentation and interpretation. While Giovanni Paolo Panini is regarded as one of the first artists to focus on the theme of ancient and fantastical Rome[123], it was Giovanni Battista Piranesi who had the greater influence on propagation the ruins of Rome[124] with the etching style known as *veduta ideata*[125]. His series of publications, Vedute di Roma (1749)[126] and Le Antichità Romane (1756), exemplify this approach. Piranesi's works are valuable not only for their precise documentation of the ruins of Rome in the mid-eighteenth century, as his publications have become invaluable resources for historians and archaeologists by offering insights into structures and landscapes that have since changed or disappeared, but also for their dramatic and evocative compositions, which captivated viewers and stirred renewed interest in the ancient world[127]. This approach inspired further engagement with classical antiquity and deepened appreciation for both the material presence and the atmospheric qualities of ancient ruins[128].

[123] Giovanni Paolo Panini, *Roman Capriccio: The Pantheon and Other Monuments*, 1735, oil on canvas, Indianapolis Museum of Art, Indianapolis.

[124] It was the replicative technique of etching that enabled the production of multiple copies from a single matrix, in contrast to Panini, who worked primarily as a painter.

[125] The *veduta ideata*, or "imagined view," refers to an idealized or invented scene that combines real and imaginary architectural elements, exemplified by Piranesi's composite and often fantastical engravings.

Veduta ideata, as understood in the context of this thesis, can be described as a form of immaterial and imaginative reconstruction. These views were often based on documented studies of similar structures and served to convey a visual impression of how the past might have appeared. This approach embodies a central idea explored in this work: the interplay between documentation and creative interpretation in representing lost or fragmentary heritage.

[126] Giovanni Battista Piranesi, *Vedute di Roma* (Paris: Firmin-Didot, 1839).

[127] Piranesi's depictions of Roman ruins often transcended objective documentation and moved well beyond the dominant Enlightenment approach of his time, foreshadowing many aspects of the Romantic era. His etchings evoke a sense of awe and melancholy, highlighting both the decay of antiquity and the fascination with ruins that would become central to nineteenth-century thought.

[128] David Watkin, *Historia architektury zachodniej* (Warszawa: Arkady, 2001), 312–15.

Fig. 18. Piranesi's engravings Antichita Romane 1756, left – Veduta di Campo Vaccino (source: Wikimedia Commons[129]), right – Colloseo (source: Wikimedia Commons[130]).

Winckelmann and the scientific approach towards the antiquities

The Enlightenment marked a profound transformation in how objects were perceived and valued as artefacts of human culture. Whereas earlier generations often prized works primarily for their artistic merit and collected them as curiosities, this era introduced early efforts at conservation and promoted a more systematic understanding of cultural heritage. The spirit of documentation exemplified by Piranesi laid the groundwork for the critical investigation of antiquity, a development further advanced by figures such as Johann Joachim Winckelmann. Winckelmann's pioneering studies of Greek and Roman art fundamentally shaped modern approaches to understanding and preserving cultural heritage. In his landmark work, *Geschichte der Kunst des Alterthums* (1764)[131], he argued that the careful study of ancient Greek art revealed essential principles of beauty, harmony, and idealisation. Supported by advancements in printing, his publications helped disseminate knowledge of art and antiquities to a broader audience and encouraged the direct observation and scientific analysis of authentic artefacts[132].

During this period, Voltaire advanced the idea of "monuments" as cultural creations worthy of investigation and preservation—a concept further developed by Aubin-Louis Millin de Grandmaison, who coined the term "historical monument" to describe structures of enduring cultural and historical significance[133].

The vast number of excavated artefacts in the eighteenth century contributed to the emergence of the modern museum as a public institution dedicated to preserving, studying, and displaying objects of cultural and historical significance. Enlightenment ideals, particularly those emphasising education and

---

[129] Giovanni Battista Piranesi, *Veduta di Campo Vaccino* (engraving), Wikimedia Commons, accessed June 13, 2025, https://upload.wikimedia.org/wikipedia/commons/thumb/8/86/Piranesi-17010.jpg/1099px-Piranesi-17010.jpg.

[130] Piranesi, Giovanni Battista. *The Colosseum*. Etching. Wikimedia Commons. Accessed June 13, 2025. https://upload.wikimedia.org/wikipedia/commons/6/66/Giovanni_Battista_Piranesi%2C_The_Colosseum.png.

[131] Johann Joachim Winckelmann, *History of the Art of Antiquity*, trans. Harry Francis Mallgrave (Santa Monica, CA: Getty Publications, 2006).

[132] Johann Joachim Winckelmann, "Sendschreiben von den Herculanischen Entdeckungen an den Reichsgrafen von Brühl," in *Kleine Schriften und Briefe*, ed. Wilhelm Senff (Weimar: H. Böhlaus Nachfolger, 1960), 242–62; Élisabeth Décultot, "Winckelmann's Model of Art Historiography and Its Reception in the Late 18th and 19th Century," in *Doing Humanities in Nineteenth-Century Germany*, 85–109 (Leiden: Brill, 2019), https://doi.org/10.1163/9789004416840_006; Janusz Krawczyk, *Nazwać, żeby ocalić. Klasycy myśli konserwatorskiej wobec reliktów przeszłości* (Toruń: Wydawnictwo Naukowe Uniwersytetu Mikołaja Kopernika, 2020), 36.

[133] Janusz Krawczyk, *Nazwać, żeby ocalić. Klasycy myśli konserwatorskiej wobec reliktów przeszłości* (Toruń: Wydawnictwo Naukowe Uniwersytetu Mikołaja Kopernika, 2020), 16.

public access, fostered the rise of scientific archaeology and museology[134]. Exhibitions of these collections introduced new ideas to a wider audience and underscored the need for preservation and restoration to ensure the longevity and value of artefacts[135]. Landmark institutions such as the Ashmolean Museum in Oxford and the British Museum in London embodied this new approach, focusing on the collection, documentation, and public display of authentic artefacts. By presenting these objects as carriers of cultural values and knowledge, early museums broadened the perception of material heritage and played a pivotal role in shaping preservation practices that continue to influence heritage conservation today.

French Revolution

The French Revolution (1789–1799) represents a turning point in the history of heritage, vividly illustrating how cultural monuments can become the focus of both ideological destruction and the birth of modern conservation. During this period, particularly in the Reign of Jacobin Terror, many historic buildings and monuments associated with the monarchy, aristocracy, and Catholic Church were deliberately targeted as symbols of oppression and inequality. Sites such as the medieval castle of Bastille were demolished, while numerous churches and monasteries were repurposed or vandalised[136], with some transformed into secular "Temples of Reason" reflecting revolutionary ideals of secularism and civic virtue[137]. This period was marked by a rare antagonism towards authentic heritage objects, with religious and royal symbols systematically removed or destroyed in an attempt to erase cultural memory[138].

Ironically, this wave of destruction prompted a fundamental shift in heritage management. Fears over the loss and dispersal of valuable artefacts led to the founding of the Commission des Monuments in 1790, later the Temporary Commission of Art. For the first time, heritage preservation became a national, public responsibility. The commission's main task was to inventory and collect works of art worthy of state protection, recognising their importance to France's identity. Despite financial difficulties, the commission issued detailed instructions for inventorying and safeguarding cultural objects. The collaboration between Félix Vicq-d'Azyr and Dom Germain Poirier exemplified a new interdisciplinary, systematic approach to documentation and preservation, laying the groundwork for modern heritage management[139].

The tension between loss and preservation persisted into the Napoleonic era and early nineteenth century, prompting further documentation efforts such as Alexandre de Laborde's 1816 survey of France's monuments titled "The Monuments of France: Chronologically Classified and Considered about Historical Facts and the Study of the Arts"[140].

---

[134] Edward P. Alexander and Mary Alexander, *Museums in Motion: An Introduction to the History and Functions of Museums*, 2nd ed. (Lanham, MD: AltaMira Press, 2007), 3–6, 11.

[135] Ibid. 32-36.

[136] The abbeys of Clairvaux and Cluny, among the most significant monastic complexes in medieval France, suffered extensive destruction during the French Revolution and its aftermath. Much of Cluny Abbey was dismantled for building materials, leaving only a fraction of the original structure standing, while Clairvaux Abbey was secularized and its buildings were repurposed as a prison.

[137] Notable examples include the forced takeover of Notre Dame Cathedral in Paris and the Cathedral of Our Lady in Strasbourg.

[138] Janusz Krawczyk, *Nazwać, żeby ocalić. Klasycy myśli konserwatorskiej wobec reliktów przeszłości* (Toruń: Wydawnictwo Naukowe Uniwersytetu Mikołaja Kopernika, 2020), 18-20.

[139] Ibid. 33-53.

[140] Alexandre de Laborde, *Les monuments de la France classés chronologiquement et considérés sous le rapport des faits historiques et de l'étude des arts* (Paris: Pierre Didot l'aîné, 1816).

2.3 Romantism And The 19th Century

Rise of national identity

The dawn of the nineteenth century in Europe witnessed a profound transformation in attitudes toward architecture, history, and cultural identity. Johann Wolfgang Goethe's essay "Von deutscher Baukunst" (On German Architecture, 1772)[141] captures this shift, as he moves beyond the universal European ideals of classicism to embrace the national, the German, the historic, and the emotional qualities of Gothic art. In this essay, Goethe, initially accustomed to the prevailing architectural style of Classicism, viewed Strasbourg Cathedral with scepticism[142]. However, upon closer examination, he came to appreciate the beauty and original genius of its master builder, Erwin von Steinbach, recognising his exceptional artistic skill in creating a pure Gothic[143] masterpiece and praising his contributions to the cathedral's façade[144]. He argues that such works should be appreciated for their documentary and heritage value[145], despite foreign criticism. In this context, Goethe references Giorgio Vasari's term "Gothic," which had long carried a pejorative meaning as the architecture of barbaric peoples[146] overshadowing classical Rome. Goethe, however, reinterprets Gothic as a positive, distinctly national style, seeing it as "ours" and valuing it for its authenticity, monumental character, and its role in

[141] Johann Wolfgang Goethe, "On German Architecture" (1772), in *Zabytek i historia – wokół problemów konserwacji i ochrony zabytków w XIX wieku*, ed. Piotr Kosiewski and Jarosław Krawczyk (Warszawa: Muzeum Pałac w Wilanowie, 2011), 241–50.

[142] Johann Wolfgang Goethe, *Von deutscher Baukunst* (1772), in *Goethes Werke: Kleine Schriften und Aufsätze*, vol. 13 (Weimar: Verlag der Goethe-Gesellschaft, 1887), 1–10, https://archive.org/details/goethe-von-deutscher-baukunst/mode/2up:

"Als ich das erstemal nach dem Münster gieng, hatt ich den Kopf voll allgemeiner Erkenntniß guten Geschmacks. Auf Hörensagen ehrt ich die Harmonie der Massen, die Reinheit der Formen, war ein abgesagter Feind der verworrnen Willkürlichkeiten sothischer Verzierungen. … und so graute mirs im Gehen vorm Anblick eines mißgeformten krausborstisen Ungeheuers."

Eng. trans.: "When I went to the cathedral for the first time, my head was full of a general appreciation of good taste. By hearsay I honoured the harmony of the masses, the purity of the forms, and was a sworn enemy of the confused arbitrariness of Gothic ornamentation. … and so, as I walked, I dreaded the sight of a misshapen, curly-bristled monster."

[143] In this context, Goethe references Giorgio Vasari's term "Gothic," which had long carried a pejorative meaning as the architecture of barbaric peoples overshadowing classical Rome. Goethe, however, reinterprets Gothic as a positive, distinctly national style, seeing it as "ours" and valuing it for its authenticity, monumental character, and its role in preserving cultural continuity.

[144] Johann Wolfgang Goethe, *Von deutscher Baukunst* (1772), in *Goethes Werke: Kleine Schriften und Aufsätze*, vol. 13 (Weimar: Verlag der Goethe-Gesellschaft, 1887), 1–10, https://archive.org/details/goethe-von-deutscher-baukunst/mode/2up:

Und nun soll ich nicht ergrimmen, heiliger Erwin, wenn der deutsche Kunstgelehrte, auf Hörensagen neidischer Nachbarn, seinen Vorzug verkennt, dein Werk mit dem unverstandnen Worte gotisch verkleinert. Da er Gott danken sollte, laut verkündigen zu können, das ist deutsche Baukunst, unsre Baukunst, da der Italiener sich keiner eignen rühmen darf, viel weniger der Franzos.

Eng. trans.: And now, holy Erwin, I should not be angry if the German art scholar, on the hearsay of envious neighbours, fails to recognise its merit and belittles your work with the incomprehensible word Gothic. Since he should thank God to be able to proclaim aloud that this is German architecture, our architecture, since the Italians cannot boast of their own, much less the French.

[145] The lengthy construction of Strasbourg Cathedral also becomes particularly relevant when considering another significant example, the Cathedral of Cologne, discussed later in this work.

[146] Giorgio Vasari, *Żywoty najsławniejszych malarzy, rzeźbiarzy i architektów*, vol. 1 (Warszawa: Państwowe Wydawnictwo Naukowe, 1985), 116–17.

preserving cultural continuity. He argues that such works should be appreciated for their documentary and heritage value[147], despite foreign criticism.

Goethe's publication aligns with the German Sturm und Drang movement, which challenged Enlightenment universalism in favour of localism and national identity. In architecture, this meant a rediscovery and renewed appreciation of the Gothic style, marking the beginning of the quest for a distinctive national style and authenticity. This appreciation marked a pivotal shift in architectural thought, paving the way for new doctrines of authenticity, monumentality, national style, and conservation that would come to define the nineteenth century[148].

In the wake of the Napoleonic Wars and the territorial expansions that followed the Congress of Vienna, Prussia inherited vast regions rich in historic buildings[149], monuments, and works of art. However, these assets faced neglect, damage, and the risk of further loss, especially after the widespread upheaval and secularisation of church properties. In response to this urgent situation, Karl Friedrich Schinkel[150] authored his memorandum in 1815[151], "For the Preservation of All Monuments and Memorials of Our Nation's Past." Schinkel's memorandum called for the establishment of a dedicated public office responsible for the care, documentation, and protection of historic monuments and artefacts across Prussia. He advocated systematic inventories, the involvement of qualified experts regardless of social class, and the retention of heritage objects in their original local context rather than centralising them in museums. This pioneering document laid the groundwork for state-sponsored heritage conservation in Germany, introducing principles of authenticity, locality, professional stewardship, and the importance of public responsibility in safeguarding national heritage[152].

Gothic revival Chorin – Cologne

In addition to Karl Friedrich Schinkel career in design, he is perhaps less widely recognised for his significant contributions to conservation and preservation. After publishing his, already mentioned in this work, influential memorandum, he became actively involved in numerous restoration projects across Prussia, including the Schlosskirche in Wittenberg, the conservation and adaptation of Moritzburg Castle in Halle for university use[153], and the preservation of Stolzenfels Castle[154]. Among

[147] It is worth noting the asymmetrical façade, where the southern tower was never completed, creating a somewhat incomplete appearance similar to that of the Cathedral of Antwerp in Belgium, the Basilica of Saint Denis, and other churches in Bourges, Soissons, Vézelay, and Chartres.

[148] Dorothea E. von Mücke, "Beyond the Paradigm of Representation: Goethe on Architecture," *Grey Room* 35 (2009): 6–27, https://doi.org/10.1162/grey.2009.1.35.6; Jukka Jokilehto, *A History of Architectural Conservation*, 2nd ed. (New York: Routledge, 2017), 111–14.

[149] While the Rhineland and part of the Saxon area were annexed to Prussia, the new German Confederation was established as a replacement for the dissolved Holy Roman Empire.

[150] Schinkel, celebrated as a Prussian architect, painter, and designer of furniture and stage scenery, began his career working in the Classical style under the influence of his mentor Friedrich Gilly. He later transitioned to Neo-Gothic, inspired by an appreciation for Gothic architecture and a desire to express Germany's national architectural identity. During the nineteenth century, Schinkel's prolific output included numerous projects across Prussia, most notably the renowned Altes Museum in Berlin.

[151] Karl Friedrich Schinkel, "Memorandum to the Prussian Authorities" (1815), in *Wokół problemów konserwacji i ochrony zabytków w XIX wieku*, ed. Piotr Kosiewski and Jarosław Krawczyk (Warszawa: Muzeum Pałac w Wilanowie, 2011), 263–68.

[152] Janusz Opaska, "U źródeł ochrony zabytków: rozwój systemowego konserwatorstwa w Niemczech w początkach XIX," *Ochrona Zabytków* 1, no. 4 (2010): 199–210; Jukka Jokilehto, *A History of Architectural Conservation*, 2nd ed. (New York: Routledge, 2017), 111-114

[153] Michael Snodin, *Karl Friedrich Schinkel: A Universal Man* (New Haven, CT: Yale University Press, 1991), 212.

[154] Ibid. 164-165.

these, Chorin Abbey in the Brandenburg region stands out as particularly relevant to the scope of this work.

Founded in 1258 by Margrave Johann I of Brandenburg and settled by Cistercian monks from the Lehnin monastery, Chorin Abbey flourished during the Middle Ages as a major religious, cultural, and economic centre. Its architecture exemplifies the brick Gothic style of the period. Like many monastic foundations, it faced significant challenges in the late Middle Ages and early modern era, including conflict, political upheaval, and economic decline. The abbey and monastery were dissolved during the Reformation in 1542. Subsequent misuse, devastation during the Thirty Years' War, and further demolition led to the loss of substantial portions of the church and cloister. By the nineteenth century, the complex had fallen into ruin, with portions used for agricultural purposes, and monastic church used as a cattle barn. To this day much of the structure survives to offer a glimpse of its former glory[155].

When Schinkel visited Chorin Abbey around 1817[156], he found the complex in a severely deteriorated state, with convent buildings used for agricultural purposes and the main church serving as a cattle barn. Undertaking thorough research into the origins of Gothic architecture, Schinkel advocated for the recognition of the ruins as a national monument, highlighting their exceptional artistic value and relatively well-preserved condition. His studies at Chorin resulted in approximately 300 sketches and drawings that would influence his later mastery of the Neo-Gothic style[157], and contributed to shaping a national architectural identity of German nation[158].

Fig. 19. Remains of Chorin Abbey. Source: author, 2022.

[155] Gunther Nisch, "Hospitals in Medieval Documents of the Cistercian Monastery Chorin," in *Festschrift für Gunther Nisch* (2018), 45–52; Cistercian Monastery, Chorin, *Europäische Route der Backsteingotik*, accessed March 21, 2023, https://www.eurob.org/item/chorin_cistercian-monastery/?lang=en; *Geschichte*, Kloster Chorin, accessed March 21, 2023, https://www.kloster-chorin.org/geschichte/.

[156] Just two years after memorandum.

[157] Some of the drawings are displayed permanently on the exhibition in the cloister museum

See "Karl Friedrich Schinkel und Chorin," *Kloster Chorin*, accessed June 12, 2023, https://www.kloster-chorin.org/ausstellung-karl-friedrich-schinkel/

[158] Marcel Piethe, Michael Lissok, Franziska Siedler, and Stefanie Wagner, *Enthusiastischer Weltverschönerer – Karl Friedrich Schinkel: Sonderheft 2019* (Berlin: Ammian Verlag, 2019); "Enthusiastischer Weltverschönerer · Karl-Friedrich Schinkel," *Die Mark Brandenburg*, accessed June 9, 2023, https://www.die-mark-brandenburg.de/p/enthusiastischer-weltverschoenerer-karl-friedrich-schinkel.

The significance of Schinkel's intervention at Chorin Abbey extends far beyond immediate preservation. Chorin represents one of the earliest intentional efforts to conserve a ruin rather than reconstruct it or leave it to decay[159]. Through this approach, Schinkel pioneered the transition from Romantic admiration of ruins to the professionalisation of heritage conservation[160].

His practical interventions established foundational principles, minimal intervention, respect for original substance, and the recognition of historical layering and somehow foreshadowed later debates about restoration[161] that remain central to the conservation field today. Chorin Abbey[162] stands not only as a milestone in the history of German heritage practice but also as a crucial link between Romantic sensibility, and the emergence of a modern, doctrinal approach to conservation.

The Cologne Cathedral[163] (High Cathedral of Saint Peter), together with Chorin Abbey, exemplifies the evolving approach to architectural reconstruction in the early 19th century and the ideological underpinnings of the Gothic Revival in Germany. Cologne Cathedral is particularly significant in the context of conservation discourse because it challenges the boundary between reconstruction and completion. The 19th-century effort to resume construction was not seen as an imaginative revival but rather as the continuation of a medieval project, justified by the survival of original drawings and the persistence of a unified design vision. This raises fundamental questions about authenticity and reconstruction: can a structure completed after nearly 300 years of interruption still be considered original? Is its authenticity based on material continuity or on fidelity to its original conception?

Originally initiated in 1248 by Archbishop Konrad von Hochstaden, Cologne Cathedral drew direct inspiration from French Gothic masterpieces such as Beauvais[164], Chartres and Amiens[165]. Construction began with the presbytery while remnants of the earlier Romanesque cathedral remained in use. The Gothic choir was consecrated in 1322, following which the Romanesque elements were dismantled to allow the Gothic structure to expand. Progress continued until the early 16th century, when work halted due to shifting aesthetic preferences toward the Renaissance and the economic-political consequences of the Protestant Reformation. For centuries, the unfinished silhouette of the cathedral,

[159] The aspect of the southern nave of the monastery is particularly interesting, as Schinkel chose not to reconstruct it, even though the northern nave survived and provided information about its design, and It could result in enclosing of the church building.

[160] By translating Romantic fascination for the picturesque and sublime into systematic documentation and careful stabilisation, Schinkel provided a model for how heritage conservation could balance aesthetic, historical, and national values.

[161] Especially the conservative and preservative approach discussed by John Ruskin In his *Seven lamps of Architecture* published in 1849.

[162] Chorin Abbes will reaper in chapter 4 in this work as part of immersive and virtual sightseeing example of direct use in the context of the ruined monastery.

[163] Designated a UNESCO World Heritage Site in 1996, the cathedral is celebrated for its outstanding universal value, meeting criteria I (representing a masterpiece of human creative genius), II (exhibiting significant interchange of human values), and IV (an outstanding example of a type of building, architectural or technological ensemble, or landscape illustrating a significant stage in human history)

See *Cologne Cathedral*, UNESCO World Heritage List, accessed June 21, 2022, https://whc.unesco.org/en/list/292/.

[164] Beauvais Cathedral in France, when compared to Cologne Cathedral, offers valuable insights into differing trajectories of Gothic ambition. Both were monumental Gothic projects begun in the 13th century and left incomplete during the medieval period, yet their outcomes diverged significantly. Beauvais, envisioned as the tallest and most daring of Gothic cathedrals, partially collapsed in 1284 due to structural overreach and was never completed. Cologne Cathedral, though similarly unfinished for centuries, maintained its structural integrity and was ultimately completed in the 19th century, faithfully following its original Gothic design. Whereas Beauvais embodies the fragility and limits of Gothic aspiration, Cologne represents a Romantic revival of a medieval vision shaped by national sentiment and scholarly restoration. Their juxtaposition underscores contrasting interpretations of the Gothic legacy: Beauvais as a sublime ruin and Cologne as the monumental continuity of idea and form.

[165] Unlike Cologne or Beauvais, Chartres and Amiens represent fully realized Gothic cathedrals of the medieval period

with its signature medieval construction crane perched atop the south tower, became an iconic image, frequently depicted in paintings and engravings[166].

The 19th century Romantic movement fostered a new cultural and aesthetic appreciation for the Middle Ages. Already mentioned Goethe played a pivotal role in reviving interest in Gothic architecture, and in Cologne Cathedral particularly through his reflections on Strasbourg Cathedral. Friedrich Schlegel, in his Letters from Travels in the Netherlands, the Rhineland, Switzerland, and Parts of France (1805)[167], similarly expressed admiration for the grandeur and unrealized potential of Cologne Cathedral[168]. In his critique of the dismantled Gothic altar, replaced by an Italianate Baroque one, Schlegel lamented the loss of stylistic unity[169], a sentiment foreshadowing the stylistic restoration doctrine that would dominate mid-19th-century conservation efforts[170].

While Schlegel conveyed his ideas through literary reflection, Sulpiz Boisserée transformed them into concrete scholarly and curatorial efforts. In his 1823 publication Architecture of Cologne's Cathedral[171], Boisserée carefully documented the unfinished building and most notably recovered the original medieval plans, which survived in two separate parts[172]. As an antiquarian, he used these sources to

---

[166] David Watkin, *Historia architektury zachodniej* (Warszawa: Arkady, 2001), 158–59; *Domgrabung*, *Kloster Dom (Kölner Dom)*, accessed March 21, 2023, https://www.koelner-dom.de/erleben/domgrabung.

[167] Friedrich Schlegel, "Letters from Travels in the Netherlands, the Rhineland, Switzerland and Parts of France" (1806), in *Wokół problemów konserwacji i ochrony zabytków w XIX wieku*, ed. Piotr Kosiewski and Jarosław Krawczyk (Warszawa: Muzeum Pałac w Wilanowie, 2011), 251–62.

[168] Ibid. 251: *"Of all the monuments, the Cathedral is the most noteworthy. If it had been completed, it too would have boasted a gigantic piece of Gothic architecture, comparable to the grandest buildings of new or ancient Rome."*

[169] Ibid. 256: "mo*reover, in order to make room for the Italian altar, which may be beautiful in its own right but is not at all suited to a Gothic church, some forty years ago the old altar, made with the greatest refinement and craftsmanship exactly in the style of the church itself and made up of only turrets and buds, was unfortunately demolished: it showed the viewer the whole great edifice as if on a reduced scale and was the quintessence of an art which, in the whole of the building itself, is too diffuse to be grasped at a single glance.'*

[170] Schlegel's writings also advanced an early periodisation of medieval art, distinguishing Gothic from earlier "Constantine-Byzantine" traditions. For him, Gothic was both a spiritual and national style, an authentic expression of Germanic cultural identity rooted in nature and imagination.

[171] Sulpiz Boisserée, "Architecture of Cologne's Cathedral" (1823), in *Wokół problemów konserwacji i ochrony zabytków w XIX wieku*, ed. Piotr Kosiewski and Jarosław Krawczyk (Warszawa: Muzeum Pałac w Wilanowie, 2011), 269–86.

[172] Sulpiz Boisserée, *Geschichte und Beschreibung des Doms von Köln nebst Untersuchungen über die alte Kirchenbaukunst* (Stuttgart: J. G. Cotta'sche Buchhandlung, 1823), 10:
"Doch auch über diese hat ein trauriges Schicksal gewaltet: keines derselben ist zu der beabsichtigten Vollendung gediehen; die meisten sind sogar nach früheren und späteren Plänen, aus verschiedenartigen Teilen zusammengesetzt. Der Dom von Köln, eines der größten und vollkommensten Gebäude dieser Art, obwohl auch unvollendet, wurde indessen durch eine besondere Fügung begünstigt. Dieser Wunderbau, in allen wesentlichen Teilen nach einem und demselben Plan im reinsten Stil angelegt, ist durch keine fremdartigen Zufüge entstellt, und man besitzt selbst noch den ursprünglichen Entwurf desselben; so dass aus dem Bestehenden und Beabsichtigten ein Ganzes von der höchsten Einheit und Vollständigkeit zusammengesetzt werden kann, und so wie es aus dem Geiste des Baumeisters hervorging.

Darum wählte ich dieses Gebäude zum Musterbilde der alten Kirchenbaukunst. Es schien mir ein, dem Ruhme der Vorfahren gebührendes, allen wahren Kunstfreunden willkommenes Unternehmen, wenn ich wenigstens im Bilde auszuführen suchte, was das Missgeschick der Zeiten in der Wirklichkeit nicht hat zustande kommen lassen."

Eng. trans.: "But even over these [buildings], a sorrowful fate has ruled: none of them reached its intended completion; most were assembled from parts of earlier and later designs, composed of heterogeneous elements. The Cathedral of Cologne, one of the largest and most perfect buildings of its kind, although also unfinished, was nonetheless favored by a special providence. This miraculous work, conceived in all its essential parts according to one and the same plan and in the purest style, has not been disfigured by any foreign additions, and the original design is still preserved. From what exists and what was intended, a whole can be assembled with the highest degree of unity and completeness, just as it emerged from the spirit of its builder.

For this reason, I chose this building as the ideal model of ancient ecclesiastical architecture. It seemed to me a project worthy of the fame of our ancestors and welcome to all true lovers of art, if I could at least attempt in images what the misfortunes of time have not allowed to be realized in reality."

advocate for a reconstruction that faithfully adhered to the cathedral's original homogeneous Gothic design. His work had a lasting impact on the study of Gothic architecture[173], establishing Cologne Cathedral as a rare case of stylistic integrity and continuity of design vision.

In 1842, the "Zentral-Dombauverein zu Köln" (Central Cathedral Building Society) initiated the resumption of construction. Financed two-thirds by public subscription and one-third by the Prussian state, the effort reflected a collective civic desire to revive and complete the monumental structure[174]. The project culminated in 1880[175], 632 years after the original foundation of Gothic design, with the completion of the cathedral's iconic twin spires, were the tallest in the world at that time.

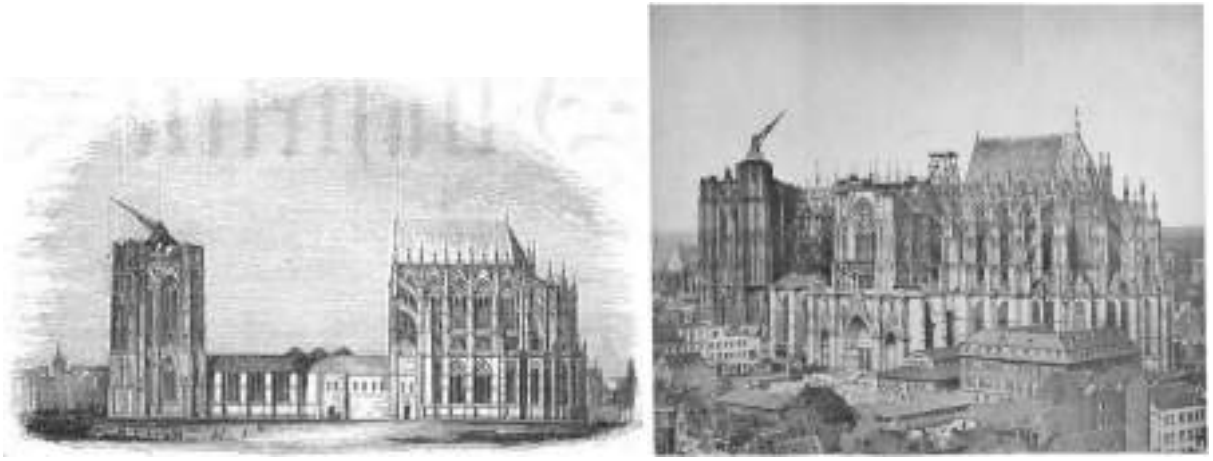


Fig. 20. The unfinished cathedral in 1855. The medieval crane was still in place, while constructions for the nave had been resumed earlier in 1814 (source: Wikimedia commons[176]).

What makes Cologne Cathedral unique is its construction history, marked by a remarkable continuity of design from the late medieval period through to its completion in the 19th century, preserving the integrity of the original vision. Unlike many European cathedrals whose later façades were completed in 19th and reflect stylistic evolution, such as Milan Cathedral, the Cathedral of Santa Maria del Fiore in

[173] Another significant figure in the history of Cologne Cathedral was Jakob Burckhardt. In 1843, he wrote Cologne and the Rhineland in the 13th Century, initiating a discussion on the cultural history and ideological context of that period. Burckhardt also examined the historical biography of Conrad von Hochstaden, the archbishop who initiated the Gothic construction of the cathedral.

See: Jakob Burckhardt, "Cologne and the Rhineland in the 13th Century" (1843), in *Wokół problemów konserwacji i ochrony zabytków w XIX wieku*, ed. Piotr Kosiewski and Jarosław Krawczyk (Warszawa: Muzeum Pałac w Wilanowie, 2011), 287–94; Felix Gilbert, "Jacob Burckhardt's Student Years: The Road to Cultural History," *Journal of the History of Ideas* 47, no. 2 (1986): 249–74, https://doi.org/10.2307/2709813, at 262.

[174] Stephanie A. Glaser, "'Deutsche Baukunst', 'Architecture Française': The Use of the Gothic Cathedral in the Creation of National Memory in Nineteenth-Century Germany and France," in *Orientations*, ed. Claus Clüver, Véronique Plesch, and Leo H. Hoek (Leiden: Brill, 2005), 77–91.

[175] Its completion sparked a widespread re-evaluation of Gothic art and architecture, contributing directly to the rise of Historicism and the Neo-Gothic movement in 19th-century Europe. It became both a symbol of national pride and a precedent for stylistic restoration in conservation.

[176] Johannes Franciscus Michiels, *Bau des Doms, Köln, 1855* (salt paper photograph), Wikimedia Commons, accessed June 13, 2025, https://commons.wikimedia.org/wiki/File:Johannesfranciscus-Michiels_bau-des-doms-koeln-1855.jpg.

Florence[177], Santa Croce in Florence[178], or St. Vitus Cathedral in Prague[179], Cologne stands out for adhering closely to its original medieval blueprint. These other examples illustrate alternative creative approaches to completing medieval structures, often shaped by later aesthetic or ideological influences. In contrast, the cathedrals of Utrecht[180] and Beauvais represent cases where theirs integrity is not complete, and their partially ruined states have been preserved as historical witnesses to collapse or disaster.

The 19th-century completion of many medieval churches and cathedrals was driven by a convergence of Romanticism, nationalism, and historicism. Gothic architecture, once neglected, was reinterpreted as a symbol of cultural identity and spiritual depth. Influenced by Romantic ideals and the rise of stylistic restoration, architects and scholars sought to complete unfinished monuments in accordance with their original designs or perceived intent. These efforts were often tied to emerging national movements, as seen in Cologne, Prague, and Florence, where architecture became a tool for expressing historical continuity and civic pride. Advances in technology and funding also made such large-scale completions feasible for the first time.

Cologne Cathedral thus holds extraordinary value as a case study in conservation ethics, authenticity theory, and the cultural construction of architectural identity. Its unique trajectory illustrates how authenticity can be mediated not only through material substance but also through ideological and scholarly continuity, making it a foundational case for any modern reflection on architectural reconstruction.

Neoclassicism - Romantism

The late eighteenth and early nineteenth centuries saw the emergence of two distinct but closely connected, and often overlapping, attitudes towards the architectural past. Neoclassicism sought to revive the ideals of antiquity by constructing new buildings inspired by ancient Greek and Roman forms, aiming to reconstruct the past in its most perfected and harmonious image. In contrast, Romanticism fostered an appreciation for ruins and artefacts, valuing them for their evocative connection to history, their fragmentary nature, and the visible traces of time and decay. These perspectives frequently overlapped in artistic and architectural practice, reflecting a shared fascination with the legacy of the past.

This interplay between reconstruction and the celebration of ruin is central to the evolution of heritage values and conservation philosophy explored in this thesis. By examining how these contrasting yet intertwined approaches have shaped attitudes towards authenticity, preservation, and interpretation,

[177] The facade of Florence Cathedral remained incomplete for centuries. While the cathedral was finished in the 15th century, the grand facade designed by Arnolfo di Cambio in the 13th century was left unfinished. It was completed in 1887 by Emilio De Fabris.

See Edmund Małachowicz, *Konserwacja i rewaloryzacja architektury w środowisku kulturowym* (Wrocław: Oficyna Wydawnicza Politechniki Wrocławskiej, 2007), 31–35; Jukka Jokilehto, *A History of Architectural Conservation*, 2nd ed. (New York: Routledge, 2017), 165–67.

[178] Façade of Santa Croce in Florence was completed between 1857 and 1863 by Niccolò Matas, centuries after the church's foundation in 1294.

[179] St. Vitus Cathedral in Prague, begun in 1344 in the Gothic style, remained unfinished for centuries. Its completion was only achieved in 1929, marking nearly 600 years of interrupted construction. The 19th- and early 20th-century efforts, led by Josef Kranner, Josef Mocker, and Kamil Hilbert, followed medieval plans where available, blending historicist Neo-Gothic elements with original Gothic work.

[180] The Dom Church in Utrecht remains unfinished after a storm in 1674 caused the central nave to collapse, which was never rebuilt. The Dom Tower survived and stands as a free-standing landmark. The church's incomplete structure, with its ruins, is a lasting reminder of the disaster.

this research situates both physical and digital heritage practices within a broader historical continuum of responding to the architectural past.

With the emergence of neostyles, the replication of historical buildings became an intriguing aspect of architectural reconstruction. Structures such as La Madeleine in Paris[181] and the German projects inspired by Friedrich Gilly's design for the Frederick the Great Monument, which helped ignite this movement, along with later realisations such as the National Gallery in Berlin, are faithful copies of Greek originals[182]. Further notable examples, especially the works of Leo von Klenze, include the Walhalla near Regensburg[183] and a series of buildings in Munich: the Propylaea[184], based on the Athenian gateway; the Feldherrnhalle[185], modelled after the Loggia dei Lanzi in Florence; and the Königsbau[186], based on the Palazzo Pitti. These architectural replicas reveal the complex interplay between originality and imitation in heritage practice, underscoring the dynamic processes through which societies reinterpret, reconstruct, and transmit their architectural legacy[187].

Fig. 21. Architectural copies. Left - Galeria Dei Lanzi, Florence, Italy. Right - Feldherrenhalle, Munich, Germany. Source: author, 2024.

Stylistic restauration

The 19th century marked a pivotal moment in the redefinition of historical architecture across Europe. Shaped by the cultural forces of Romanticism, nationalism, and a revived fascination with the medieval past, this era witnessed the emergence of two opposing yet foundational philosophies that would dominate architectural conservation: stylistic restoration and conservationist theory. The tension between these doctrines underpins the modern understanding of authenticity, historical integrity, and architectural reconstruction.

In France, the transition into the 19th century was accompanied by widespread destruction of architectural heritage, particularly during and after the French Revolution, when numerous churches, monasteries, and historical monuments were vandalised, repurposed, or demolished. In response to this cultural crisis, one of the earliest and most influential voices was Victor Hugo. In his 1832 essay

[181] La Madeleine in Paris, designed by Pierre-Alexandre Vignon and completed by Jean-Jacques-Marie Huvé in 1842

[182] The Parthenon in Nashville, constructed in the 1930s, stands as a American direct copy of Greek Temple.

[183] Completed in 1842 and designed by Leo von Klenze.

[184] Completed in 1862 and designed by Leo von Klenze

[185] Completed in 1835 and designed by Leo von Klenze. The Feldherrnhalle in Munich, constructed between 1841 and 1844, was designed by Friedrich von Gärtner on the Odeonsplatz, to honour Bavarian military leaders. During the Nazi era, the Feldherrnhalle was appropriated as a site of propaganda and commemoration, marking the location of the failed 1923 Beer Hall Putsch and serving as a symbol of Nazi martyrdom and state rituals.

[186] Completed in 1835 and designed by Leo von Klenze.

[187] David Watkin, *Historia architektury zachodniej* (Warszawa: Arkady, 2001), 332–35, 354–57.

Guerre aux démolisseurs (War on the Demolishers)[188], Hugo issued a passionate call to protect France's historic architecture, especially Gothic monuments, by denouncing ongoing demolition practices. He illustrated his plea with vivid examples of churches[189] and castles[190] in decay or threatened with destruction, positioning such losses as attacks on the shared heritage of the nation[191].

That same year, Charles de Montalambert issued a direct response to Hugo's letter Vandalism and Catholicism in Art[192]. Acknowledging Hugo as a leading voice in the emerging heritage discourse, Montalambert expanded the conversation by framing the destruction of sacred buildings as part of a broader ideological conflict between Catholicism and modern secularism. He defended the Church's central role in shaping France's artistic and architectural legacy, while condemning the Revolutionary desecration of religious monuments. His reflections offered an early theoretical foundation for future conservation efforts and highlighted the need to reconcile historical value with evolving societal functions[193].

These literary and ideological appeals soon translated into institutional action. Under the reign of King Louis-Philippe, France adopted its first state-sponsored conservation policies. At the initiative of François Guizot, then Minister of the Interior, the position of Inspector of Historical Monuments was created. The post was first held by Ludovic Vitet, who was later succeeded by Prosper Mérimée, initially appointed as deputy and eventually becoming the most influential figure in early French heritage administration. Mérimée's contributions, particularly his work Études sur les arts du Moyen Âge (Studies of Art in the Middle Ages)[194], combined literary sensibility with emerging scientific rigour. His systematic surveys, classifications, and preservation initiatives brought scholarly[195] and administrative attention to Gothic architecture and other medieval monuments[196].

Mérimée was assisted in several of his projects by the architect Eugène Viollet-le-Duc, whose influence on 19th-century conservation theory remains both foundational and controversial. With the Romantic period with appreciation for the medieval past came a parallel temptation to idealise historical architecture. This inclination gave rise to a new model of intervention often termed Romantic

---

[188] Victor Hugo, "War on the Demolishers!" (1832), in *Wokół problemów konserwacji i ochrony zabytków w XIX wieku*, ed. Jarosław Krawczyk and Piotr Kosiewski (Warszawa: Muzeum Pałac w Wilanowie, 2011), 85–98.

[189] Hugo also highlighted the decay of Notre-Dame, which was central to the narrative of his earlier work The Hunchback of Notre-Dame (1831), ultimately contributing to its later restoration by Viollet-le-Duc.

[190] Hugo references key sites in cities like Soissons, Autun, and Orléans, linking them to major historical events such as Joan of Arc's defence of Orléans, reflecting his early recognition of their cultural and historical significance.

[191] Victor Hugo, *Guerre aux démolisseurs*, *Revue des Deux Mondes*, 1st ser., 8, no. 4 (September 1, 1832): 751–58, https://fr.wikisource.org/wiki/Guerre_aux_d%C3%A9molisseurs:
"Miserable men, and such imbeciles that they do not understand that they are barbarians! There are two things in an edifice: its use and its beauty. Its use belongs to the owner, its beauty belongs to everyone, to you, to me, to us all; the owner, therefore, would exceed his rights to destroy it."

[192] Charles de Montalembert, "Vandalism and Catholicism in Art" (1832), in *Wokół problemów konserwacji i ochrony zabytków w XIX wieku*, ed. Jarosław Krawczyk and Piotr Kosiewski (Warszawa: Muzeum Pałac w Wilanowie, 2011), 99–112.

[193] Montalambert notably highlights how secularisation in 19th-century Europe led to the repurposing of churches, often as prisons.

[194] Prosper Mérimée, "Studies in Art in the Middle Ages" (1832), in *Wokół problemów konserwacji i ochrony zabytków w XIX wieku*, ed. Jarosław Krawczyk and Piotr Kosiewski (Warszawa: Muzeum Pałac w Wilanowie, 2011), 113–22.

[195] Similar to the other characters such as Winckelman, Goethe, Schinkel, Boissiere.

[196] Jukka Jokilehto, *A History of Architectural Conservation*, 2nd ed. (New York: Routledge, 2017), 129–33; Janusz Krawczyk, *Nazwać, Żeby Ocalić. Klasycy Myśli Konserwatorskiej Wobec Reliktów Przeszłości* [*To Name to Preserve. Classicists of Conservation Thought towards Relics of the Past*] (Toruń: Wydawnictwo Naukowe Uniwersytetu Mikołaja Kopernika, 2020), 53–56.

Restoration[197], a vision-driven approach wherein the architect reconstructed not what had survived, but what should have existed according to an imagined stylistic ideal.

Viollet-le-Duc embodied this paradigm through his extensive and ambitious interventions, most famously in the fortified town of Carcassonne[198]. His methodology rested on the belief that the architect could complete an unfinished or deteriorated historical work in the spirit of its original creators, thus restoring its conceptual unity. However, this often entailed the removal or disregard of historical stratifications and the imposition of a homogenized stylistic narrative, commonly referred to as "stylistic purism." Rather than preserving the material record of change and use over time, this approach sought to recover an abstract, idealized form of the monument.

His practical work on monuments provided him with the opportunity to study architectural structures in depth. Combined with his fascination for the medieval past and exceptional drawing skills, this led to the publication of the ten-volume encyclopaedic dictionary: *Dictionnaire raisonné de l'architecture française du XIe au XVIe siècle.* The work aimed to systematically document and analyse the principles of medieval French architecture. It featured detailed illustrations, architectural descriptions, and theoretical reflections, largely based on Viollet-le-Duc's own surveys, restoration projects, and imaginative reconstructions. Unlike earlier antiquarian studies, mentioned previously in this text, which focused primarily on stylistic classification or decorative detail, Viollet-le-Duc approached Gothic architecture as a rational and coherent system grounded in structural logic and material function. His emphasis on the initial, framed medieval architecture not as a primitive art form but as a sophisticated engineering achievement with an internal logic that could be rediscovered, completed, or even perfected by the modern architect[199].

However, this same conceptual framework supported and justified his controversial practices, in which theoretical analysis often blurred with historically inspired creative design. In the *Dictionnaire*, he presented his influential definition of "restoration,"[200] which reflected his personal approach to heritage and guided his interventions, and corrections of authentic substance. Viollet-le-Duc did not merely describe what had existed, but proposed what should have existed based on his interpretation

[197] The terms *Romantic, Stylistic, and Puristic Restoration* are often used interchangeably, yet they represent distinct approaches that emerged in 19th-century conservation, particularly in France and Germany. All were later criticized for compromising historical stratification and authenticity, contributing to the development of modern principles favouring minimal intervention and respect for historical layering. Based on Jokilehto's synthesis: *Romantic restoration*, influenced by nationalism and medieval revival, involved imaginative and symbolic reconstructions, as seen in the early works of Viollet-le-Duc. *Stylistic restoration*, codified in Viollet-le-Duc's *Dictionnaire raisonné*, aimed to unify a monument under a dominant historical style, allowing selective removal of later elements. *Puristic restoration* pushed this further, advocating for the complete elimination of all features not belonging to the selected stylistic phase, often motivated by nationalistic ideals and particularly prominent in German-speaking regions.

See Jukka Jokilehto, *A History of Architectural Conservation*, 2nd ed. (New York: Routledge, 2017), 137–148.

[198] Among the most significant restorations conducted by Eugène Viollet-le-Duc are: Notre-Dame de Paris (1844–1864), including the reconstruction of the spire and decorative sculpture; Sainte-Marie-Madeleine in Vézelay, one of his earliest large-scale interventions; the Cité de Carcassonne (from 1853), restored into an idealized medieval fortress; Château de Pierrefonds (1857–1885), transformed from ruin into a romantic castle; Mont-Saint-Michel, involving structural and stylistic interventions; the Cathedral of Amiens, and the Palais des Papes in Avignon.

[199] Jukka Jokilehto, *A History of Architectural Conservation*, 2nd ed. (New York: Routledge, 2017), 137–148.

[200] *Eugène-Emmanuel Viollet-le-Duc, "Restauration," in Dictionnaire raisonné de l'architecture française du XIe au XVIe siècle, vol. 8 (Paris: B. Bance, 1858), 14–34, https://archive.org/details/dictionnairerai08viol/page/14/mode/2up?q=Restaurer+un+%C3%A9difice (accessed June 19, 2025).*

"RESTORATION, s. The word and the thing are modern. To restore a building is not to maintain it, repair it or redo it, it is to re-establish it in a complete state that may never have existed at a given moment."

of stylistic purity and structural intention[201]. The work became both a manual and a manifesto, it educated about the architectural history of middle ages, but also propagated the principle that restoration could involve an act of creative completion.

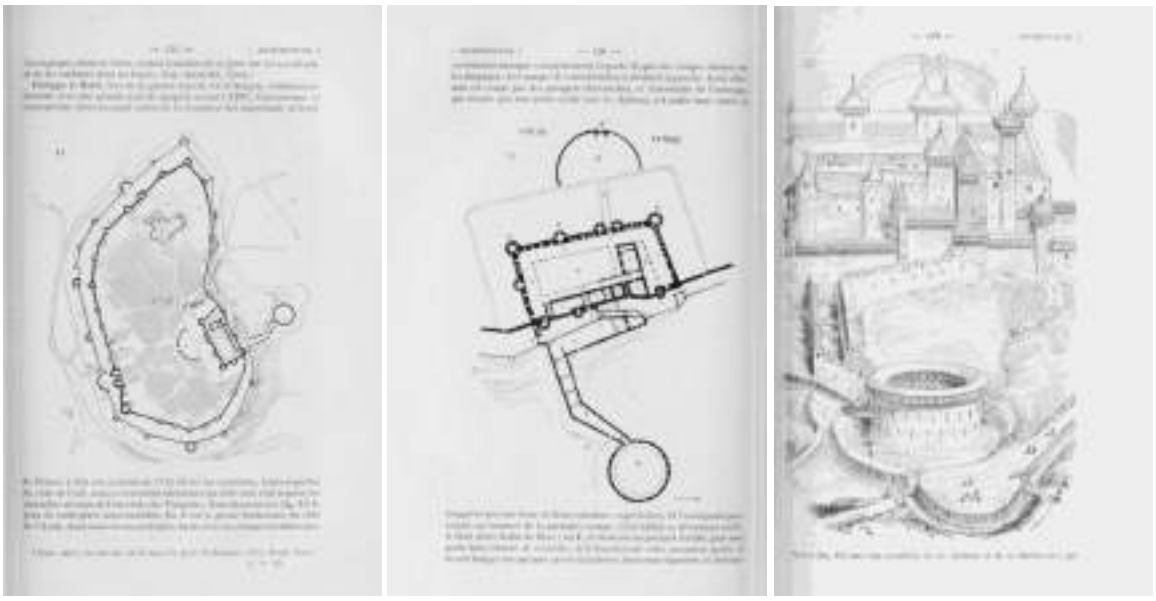


Fig. 22. Analysis of Carcassonne[202] by Villet-le-Duc in Dictionnaire raisonné de l'architecture française du XIe au XVIe siècle. [203]

The case the author would like to discuss is also one of the most debated examples of 19th-century restoration: the reconstruction of the fortified city of Carcassonne[204] in the Languedoc region of southern France[205], led by Eugène Viollet-le-Duc from 1853 until his death in 1879[206]. Instead of preserving the layered palimpsest of Carcassonne's architectural history[207], Viollet-le-Duc undertook a radical reinterpretation of its medieval character, guided by his ideals of stylistic unity and his extensive studies of defensive structures[208]. In Carcassonne, he reimagined the city as a model of 13th-century

[201] *Dictionnaire* illustrates a central paradox in his legacy: while it provided a foundational resource for the academic study of medieval architecture, it also promoted restoration practices that sometimes obscured or erased the very historical complexity it aimed to document.

[202] Carcassonne is discussed both in Viollet-le-Duc's Dictionnaire and in a dedicated monograph, both of which are referenced later in this work.

[203] Eugène-Emmanuel Viollet-le-Duc, *Dictionnaire raisonné de l'architecture française du XIe au XVIe siècle*, vol. 1 (Paris: A. Morel, 1875), page 358, Internet Archive, accessed June 19, 2025, https://archive.org/details/raisonnedelarchi01viol/page/358/mode/2up?view=theater.

[204] Today, Carcassonne is a UNESCO World Heritage Site, inscribed in 1997, recognized for both its architectural significance and its influential role in the history of architectural restoration.

See UNESCO World Heritage Centre, *Historic Fortified City of Carcassonne*, UNESCO World Heritage List, no. 345, accessed June 21, 2025, via https://whc.unesco.org/en/list/345/

[205] Prosper Mérimée, as Inspector-General, was the first to advocate for Carcassonne's protection, leading to its designation as a historic monument by the French state.

[206] Later completed by his pupil Paul Boeswillwald.

[207] Over the centuries, the fortified city accumulated traces of its Roman founders, who established the original fortifications later incorporated into the medieval castle, as well as Visigothic, medieval, and subsequent additions, each contributing to its unique historical identity.

[208] Eugène Viollet-le-Duc, *La cité de Carcassonne* (Paris: A. Morel, 1888).

military architecture, removing later additions and reconstructing towers, crenellations, and curtain walls to match his vision of a "pure" medieval fortress[209].

While Viollet-le-Duc's interventions undoubtedly prevented the complete loss of Carcassonne and played a significant role in both the broader and national revival of Gothic architecture in the 19th century, they also highlight the risks inherent in reconstructive idealism. Rather than preserving a ruin, the result was a didactic creation, a simulacrum of medieval Carcassonne shaped more by the romantic and nationalist sensibilities of the 19th century than by strict architectural or archaeological evidence. Nevertheless, Carcassonne remains a paradigmatic example in the ongoing debate over authenticity: whether to preserve buildings with all their historical layers and imperfections or to recreate an idealized vision of the past. In this way, Carcassonne stands as both a remarkable monument and a cautionary tale in the history of architectural conservation.

Fig. 23. Carcassonne. Source: author, 20217.

Parallel restorative developments occurred in other parts of Europe, especially in Prussia, where Conrad Steinbrecht led the restoration of the Teutonic Castle in Malbork (Marienburg)[210], the former capital of the Teutonic Order[211]. Malbork is widely recognized as a monument that exemplifies the transformation of conservation theory and practice from the 19th to the 20th century, while also standing as a vivid example of how monuments and restoration processes can be subordinated to ideological purposes

The restoration of Malbork Castle is notably complex due to its lengthy process and interruption during the Second World War. Major restoration phases include the period from 1882 to 1922 under Conrad Steinbrecht, continued work until 1945, and renewed efforts by Polish conservators beginning after 1947 and continuing to the present day. Steinbrecht's interventions, conducted in a stylistic reconstruction spirit akin to that of Viollet-le-Duc, aimed to create an idealized symbolic seat of the Teutonic Knights. Malbork Castle offers a compelling example of the ongoing evolution of conservation principles in Europe, illustrating how national aspirations and changing doctrines have shaped approaches to heritage.

After the secularization of the Teutonic Order in 1525, Malbork came under Polish, then Swedish, and later Prussian rule. The castle was adapted for new functions, including use as a royal residence,

[209] Viollet-le-Duc's decision to use northern slate roofs in Carcassonne, although alien to the Languedoc tradition of clay tiles, reflected his commitment to stylistic coherence rather than historical or regional accuracy.

[210] Malbork Castle was inscribed as a UNESCO World Heritage Site in 1997, recognized for its outstanding example of medieval brick architecture and its historical significance in the development of conservation philosophy.

See UNESCO World Heritage Centre, *Castle of the Teutonic Order in Malbork*, UNESCO World Heritage List no. 847 (inscribed 1997), accessed June 21, 2025, via UNESCO website.

[211] Malbork and Carcassonne are frequently cited as complementary examples of large-scale stylistic restoration in Europe, illustrating both the achievements and controversies of 19th-century approaches to medieval fortifications

military barracks, warehouse, and even as a prison. Portions of the castle fell into disrepair, with some buildings partially ruined or collapsed. By the early 19th century, significant parts of the structure were in poor condition. Utilitarian adaptations and neglect during this period led to the loss of many original stylistic features, and by the early 1800s, the High Castle was transformed into a large military warehouse, with Gothic vaults removed, new floors inserted, and original defensive walls demolished. The outer walls were plastered, and new window openings appeared, fundamentally altering the medieval character

Fig. 24. Malbork castle. Source: author, 2024.

The legacy of Steinbrecht's interventions extended well beyond his tenure, as subsequent restorers continued to apply similar principles up to the outbreak of the Second World War. This initial phase of restoration exemplifies the widespread appeal of stylistic reconstruction across Europe in the late 19th and early 20th centuries. Similar to Viollet-le-Duc's methodology, the castle complex was extensively surveyed, and form of architectural investigations were carried out, resulting in numerous drawings and interpretations of findings[212]. At Malbork, restoration decisions were frequently shaped by the nationalist and romantic ideals of the era, favoring a unified medieval image over the preservation of later historical layers. The castle was systematically purified of later additions and reconstructed to reflect an idealized vision of Teutonic Gothic architecture, serving not only as a monument to the Middle Ages but also as an ideological symbol, especially of Prussian and later German military aspirations toward the East (ger. *Drang nach Osten*)[213]. This process could define and sometimes redefine the historical narrative embodied in architectural heritage, ultimately creating a simulacrum comparable to that of Carcassonne

The Second World War marked a significant point in Malbork's history, with the castle sustaining extensive damage during military operations. In the postwar period, restoration was taken up by Polish conservators, especially Maciej Kilarski, who adopted emerging conservation principles that emphasised thorough documentation, respect for material authenticity, and the preservation of the castle's historical layers, including visible traces of wartime destruction, as presented in his book summarising the postwar efforts[214]. Another author who presented the complex architectural history

[212] Mariusz Mierzwiński, *Katalog rysunków architektonicznych dawnego Zarządu Odbudowy Zamku w Malborku: (1817–1945)* (Malbork: Muzeum Zamkowe w Malborku, 2019).

[213] Malbork Castle was politically instrumentalized as a symbol of German nationalist heritage and the Christianization of Eastern Europe, first by Prussian authorities as a monument to Teutonic "civilizing" power, and later by the Nazis, who used it for propaganda events, youth gatherings, and as a stage for narratives of Aryan supremacy and territorial expansion.

[214] Maciej Kilarski, *Odbudowa i konserwacja zespołu zamkowego w Malborku w latach 1945–2000* (Malbork: Muzeum Zamkowe w Malborku, 2007).

of the castle was Kazimierz Pośpieszny[215]. These postwar activities were pragmatic and reflected the process of Polonization and re-Polonization of the monument, as Malbork became part of the Polish state after 1945. The technical reintegration and conservation of surviving medieval and nineteenth-century elements, as well as a critical approach to previous restoration errors, became central to the Polish conservation strategy. This shift reflected broader changes in conservation philosophy, moving away from puristic and stylistic restoration practices toward approaches that prioritise historical stratification and critical, evidence-based conservation[216].

Carcassonne and Malbork represent two of the most significant and debated cases of large-scale architectural reconstructions in European heritage. Both sites underwent extensive interventions aimed at recreating an idealised vision of the medieval past, often at the expense of historical layering and material authenticity, blurring the line between authentic preservation and creative invention. Their histories highlight how reconstruction can serve both nationalistic and ideological purposes, while also provoking ongoing debates about authenticity, interpretation, and the ethical limits of restoration.

Conservation

The late 19th century witnessed a shift in conservation philosophy, marked by a growing opposition to stylistic restoration and extensive interference with the original substance of historic monuments. This movement was led by John Ruskin, whose writings and activism fundamentally challenged prevailing restoration practices and William Morris. Ruskin, though not an architect or restorer himself, profoundly influenced conservation thought through works such as The Seven Lamps of Architecture (1849)[217] and The Stones of Venice (1851)[218]. In The Seven Lamps of Architecture (1849), Ruskin sets out seven guiding "lamps," or moral principles, for architecture: Sacrifice, Truth, Power, Beauty, Life, Memory, and Obedience. Of these, the Lamp of Memory is most significant for heritage preservation. He passionately argued that restoration was "the greatest damage a building can suffer,"[219] warning that any attempt to recreate a building's original state inevitably results in the irreversible loss of its accumulated history and authenticity[220], which his thoughts, were ahead of their time[221]. This perspective was also aligned with Ruskin's background as an art historian and critic, and with the

[215] Kazimierz Pospieszny, *Domus Malbork. Zamek krzyżacki w typie regularnym* (Toruń: Wydawnictwo Uniwersytetu Mikołaja Kopernika, 2014).

[216] Grzegorz Bukal, "Konserwacja Zamku w Malborku jako przykład kształtowania się doktryny konserwatorskiej," *Ochrona Zabytków*, no. 3 (2008): 91–102.

[217] John Ruskin, *The Seven Lamps of Architecture* (London: Smith, Elder & Co., 1849).

[218] John Ruskin, The Stones of Venice (London: Smith, Elder & Co., 1851).

[219] John Ruskin, *The Seven Lamps of Architecture* (London: Smith, Elder & Co., 1849), 161.

Neither by the public, nor by those who have the care of public monuments, is the true meaning of the word restoration understood. It means the most total destruction which a building can suffer: a destruction out of which no remnants can be gathered; a destruction accompanied by a false description of the thing destroyed. Do not let us deceive ourselves in this important matter; it is impossible, as impossible as to raise the dead, to restore anything that has ever been great or beautiful in architecture.

[220] Interestingly, Ruskin's ideas were developed independently and did not directly respond to Viollet-le-Duc, as the first edition of The Seven Lamps of Architecture was published in 1849, nearly six years before Viollet-le-Duc's Dictionnaire. Nevertheless, Ruskin's work reflected and opposed the restoration movement that was emerging in 19th-century Europe.

[221] Jukka Jokilehto, *A History of Architectural Conservation*, 2nd ed. (New York: Routledge, 2017), 174-180.

broader nostalgic movement in painting that celebrated romantic landscapes and the archetype of the picturesque ruin[222].

The Stones of Venice is are seminal three-volume study of Venetian architecture. Blending art history, architectural analysis, and social critique, Ruskin explores the city's buildings from the Byzantine through the Gothic and Renaissance periods. He also attaches drawings of the details, elements or whole buildings. Comparing Ruskin's work with that of Viollet-le-Duc highlights their common interest in the systematic study of architecture through typology and documentation. For Ruskin, these efforts primarily illustrated and supported his theoretical arguments. For Viollet-le-Duc, however, they became the basis for developing practical templates used directly in restoration projects.

Building on Ruskin's ideas, William Morris founded the Society for the Protection of Ancient Buildings (SPAB) in 1877, advocating for minimal intervention and the utmost respect for the patina of age, historical layering, and material integrity. The doctrine promoted by Morris and Ruskin explicitly rejected the creative reconstructions exemplified by Viollet-le-Duc, insisting instead on the careful preservation of all historical stages as essential evidence of a building's life[223].

From ruin to reconstruction

A notable 19th-century example of large-scale, precise reconstruction[224] is the rebuilding of San Paolo fuori le Mura in Rome. After a devastating fire in 1823 destroyed most of the original Paleochristian basilica[225], the question arose whether to restore, rebuild anew, or reconstruct the church in its historical form. Ultimately, given the basilica's immense religious and cultural significance as one of the four major Constantinian basilicas, the decision was made to reconstruct San Paolo as faithfully as possible to its pre-fire appearance. Under the direction of Luigi Poletti, the project carefully incorporated surviving fragments[226], while the majority of the structure was newly created with both traditional techniques and modern materials[227]. This reconstruction became a landmark precedent in European conservation history, demonstrating the powerful symbolic impetus for reconstruction in the face of destruction, as well as the complex questions of authenticity and historical continuity that such projects entail[228].

---

[222] Example such as: J.M.W. Turner: "Tintern Abbey: The Crossing and Chancel, Looking towards the East Window" (1794) or "The Fighting Temeraire" (1839). Caspar David Friedrich: "Abbey in the Oakwood" (1810), "Ruins of Eldena Abbey" (1825), John Constable: "Hadleigh Castle" (1829), Samuel Palmer: "The Lonely Tower" (1879)

See William Vaughan, *Romantic Art* (Cary, NC: Oxford University Press, 1978).

[223] Jukka Jokilehto, *A History of Architectural Conservation*, 2nd ed. (New York: Routledge, 2017), 184-186; Janusz Krawczyk, *Nazwać, Żeby Ocalić. Klasycy Myśli Konserwatorskiej Wobec Reliktów Przeszłości* (Toruń: Wydawnictwo Naukowe Uniwersytetu Mikołaja Kopernika, 2020), 73–90.

[224] This case differs from the examples previously described due to the nature of its destruction. While Cologne Cathedral remained unfinished and Carcassonne had suffered gradual deterioration, San Paolo fuori le Mura was almost entirely lost to a sudden catastrophe.

[225] San Paolo fuori le Mura was originally founded by Emperor Constantine in the 4th century (circa 324 AD) and subsequently expanded in later centuries.

[226] The reconstruction of San Paolo fuori le Mura, which integrated original fragments into the rebuilt basilica, can be regarded as an early form or a predecessor of the anastylosis method, foreshadowing the systematic use of original architectural elements in later conservation practice.

[227] Richard Wittman, "Luigi Poletti and the Challenge of Rebuilding San Paolo," in *Rebuilding St. Paul's Outside the Walls*, ed. Richard Wittman (Cambridge: Cambridge University Press, 2024), 207–45.

[228] Jukka Jokilehto, *A History of Architectural Conservation*, 2nd ed. (New York: Routledge, 2017), 165

Fig. 25. Architectural reconstructions. Left: San Paolo outside the walls. Right: The Campanile of San Marco in Venice. Source: author, 2023.

A similar case of post-disaster reconstruction was the collapse of the Campanile of San Marco in Venice on July 14, 1902, which was the result of long-term structural weaknesses, worsened by ongoing repair work. In the aftermath, Venetian authorities quickly decided to rebuild the tower "where it was and how it was" ("dov'era e com'era"), highlighting its deep symbolic and cultural significance[229]. Led by architect Luca Beltrami[230], reconstruction began in 1903 with the construction of a fortified foundation, using new piles and stone slabs to ensure lasting stability. The project replicated the campanile's original appearance, blending traditional craftsmanship with modern engineering techniques and materials, such as reinforced concrete and steel ties. Completed in 1912, the new Campanile became a landmark in the history of conservation. Its reconstruction showed how the powerful symbolism and cultural value of a monument could justify its faithful restoration after complete loss, with a new term introduced, "restauro storico"[231]. The "dov'era e com'era" principle set an influential precedent for prioritising visual and historical continuity over original material, shaping later restoration practices across Europe and sparking ongoing debates about authenticity, cultural identity, and the purpose of reconstruction in preserving collective memory in the historical landscape[232].

2.4 Development Of Current Doctrine

Prima Carta del Restauro

The contrast between the far-reaching interventions characteristic of stylistic restoration and the restrained, minimal approach of conservation philosophy shaped the evolution of conservation thinking in the twentieth century. As the century brought unprecedented challenges, these previously opposing approaches began to converge in the search for a unified doctrine that could balance respect for authentic historical substance with the practical demands of reconstruction and preservation. Camillo Boito played a pivotal role in bridging this divide, synthesising and balancing the two

[229] There was indeed a lively discussion about whether and how to rebuild the campanile, with the final decision representing a compromise between tradition, authenticity, safety, and public sentiment. The case became a foundational example in the ongoing debates about restoration, authenticity, and the symbolic value of monuments.

[230] The pupil of Camilo Boito.

[231] Restauro storico: restoration that aims to recover a monument's historically significant state, based on research, while respecting authentic materials and distinguishing new work.

[232] Jukka Jokilehto, *A History of Architectural Conservation*, 2nd ed. (New York: Routledge, 2017), 205 -207.

perspectives in his influential chapter “Restaurare o conservare”[233] in *Questioni pratiche di belle arti,*[234] published in 1893[235]. In this work, Boito strongly argues that conservation, or "conservare," should always be prioritised over restoration, or "restaurare."

In the same chapter, he reiterates the synthesis of ideas that he had previously presented at the Third Congress of Architects and Civil Engineers in Rome in 1883, in a document that would later become known as the "Prima Carta del Restauro," or the Charter of Restoration[236]. Particularly important is the first principle, which follows Boito’s doctrine of respecting the original fabric, limiting interventions, and maintaining the authenticity of historic buildings[237].

Boito developed the concept of filological reconstruction[238], which is based on a careful study of a building’s historical layers and a clear distinction between them. His method prioritises preserving the material authenticity of a monument, aiming to balance the needs of both conservation and restoration. Importantly, Boito’s approach requires that original elements be retained whenever possible and that any new additions be clearly identified, so they cannot be mistaken for historical parts of the structure[239].

A direct successor to Boito, Gustavo Giovannoni advanced the concept of philological restoration by developing the idea of scientific restoration. His book Questioni di Architettura nella Storia e nella Vita (Questions of Architecture in History and in Life), published in 1929, is considered his major theoretical work and a foundational text for modern conservation theory in Italy. Giovannoni was critical of

---

[233] In “Restaurare o conservare,” Camillo Boito positions himself between Viollet-le-Duc’s creative, often imaginative restoration and Ruskin’s strict, minimal conservation. Boito advocates for a balanced approach: conservation should be prioritized, but careful restoration is sometimes justified

[234] Camilo Boito, *Questioni pratiche di belle arti: Restauri, concorsi, legislazione, professione, insegnamento* (Milano: Ulrico Hoepli, 1893).

[235] He uses the analogy of a monument as a book: just as a scholar wants to read a text without modern additions or falsifications, so too should we want to encounter monuments in their genuine, unaltered state.

[236] Simplified version by Szymon Kowalski, based on *Questioni Pratiche Di Belle Arti* of Camilo Boito:

1. Consolidate, Repair, Restore: Intervene only when absolutely necessary; prefer consolidation (strengthening), then repair, and only restore as a last resort. Avoid additions or innovations as much as possible.

2. Distinguish New Additions: If additions or renewals are unavoidable and concern parts that are missing or unknown, ensure new work is clearly different in style from the original, while not clashing with the monument’s appearance.

3. Mark and Materially Distinguish New Work: If rebuilding parts that are destroyed but whose form is known, use visibly different materials or mark them with a sign or date, so future observers are not deceived. For monuments of high archaeological value, replacements should be plain and geometric.

4. Preserve Artistic Qualities: Consolidation should be strictly limited to essentials and must not diminish the beauty, uniqueness, patina, or even the picturesque ruinous state of the monument.

5. Value Later Additions: Treat later historical additions as monuments themselves, unless they are of clearly inferior value and obscure important original parts—in which case, removal may be considered, but the removed elements should be preserved if possible.

6. Documentation: Take photographs before, during, and after work. Submit these, along with drawings and reports, to authorities, and ensure documentation is kept with the monument for future reference.

7. Inscription: Place an inscription on the building to record the date and nature of the restoration works.

Source: Boito, Camilo. 1893. Questioni Pratiche Di Belle Arti: Restauri, Concorsi, Legislazione, Professione, Insegnamento. Milano: Ulrico Hoepli. Pp.28

[237] Camilo Boito, *Questioni pratiche di belle arti: Restauri, concorsi, legislazione, professione, insegnamento* (Milano: Ulrico Hoepli, 1893), 28.

“When it has been shown without a shadow of doubt that there is a need to intervene, architectural monuments should be consolidated rather than repaired, repaired rather than restored, taking great pains to avoid any additions or renovations.”

[238] Boito's works, such as the restoration of the Gussoni-Franchetti Palace in Venice, exemplify these principles by combining conservation practices with thoughtful modern additions.

[239] Jukka Jokilehto, *A History of Architectural Conservation*, 2nd ed. (New York: Routledge, 2017), 198-205.

frivolous stylistic reconstruction, advocating instead for a more rigorous approach[240], and developed four distinct reconstructions[241]. While Boito's methodology was rooted primarily in architectural and historical analysis, Giovannoni broadened the approach by incorporating scientific and technical disciplines, creating a more systematic and interdisciplinary framework. Boito established the ethical foundations of conservation theory, whereas Giovannoni formalised and expanded these principles, adapting them for broader, even international, application. Furthermore, while Boito focused mainly on individual monuments or buildings, Giovannoni extended the scope to the urban scale, emphasising the importance of preserving historic environments as integrated wholes[242].

Valorisation Riegl-Dehio-Frodl

While Boito and Giovannoni helped shape the ethical and methodological basis of conservation, Alois Riegl, an art historian, introduced a new and influential perspective that broadened the theoretical framework. In his seminal work from 1903, *Der moderne Denkmalkultus. Sein Wesen und seine Entstehung* (The Modern Cult of Monuments)[243], Riegl emphasised that the significance of monuments lies not only in their material authenticity but also in the multiple values society attributes to them[244]. He distinguished two main groups of values: commemorative values—including age value (Alterswert), historical value, and intentional monument value—and contemporary values—such as use value, artistic value, novelty value, and relative artistic value. Riegl's pluralistic approach recognised that the meaning and importance of monuments evolve over time, shaped by changing societal attitudes. His ideas justify considering not only physical preservation, but also how communities engage with and interpret historic places today[245].

He developed the idea of Kunstwollen, which shifted art history research toward understanding art and architecture as expressions of a culture's collective will and worldview. In this context, Kunstwollen allows us to distinguish the "spirit" or cultural intent that shapes a building from its physical

---

[240] Gustavo Giovannoni, *Questioni di architettura nella storia e nella vita* (Rome: Biblioteca d'Arte Editrice, 1929), 25.

"The theme of reconstruction can present itself as extraordinarily broad if made academic through philosophical and aesthetic discussions on the various questions, whether general or specific, and the theories put forward to resolve them (…) It becomes, instead, quite simple and brief if, rather than erecting a grand theoretical framework, one thinks in terms of the gradual development of the building, and initially proposes to create the necessary structures and means, rationally studying the workshops and construction sites from which new production will emerge. The program that should be taken up by the few who are concerned with preventing the decline of one of the nation's greatest vital forces must have a twofold formula: on the one hand, ensuring that architecture—now that the disastrous era of amateurism and official incompetence is over—has a place in all assemblies, in all technical and artistic offices."

[241] Giovannoni identified four types of restoration:

1. restoration by consolidation;

2. restoration by recomposition (anastylosis);

3. restoration by liberation;

4. restoration by completion or renovation.

[242] Jukka Jokilehto, *A History of Architectural Conservation*, 2nd ed. (New York: Routledge, 2017), 219–23; Janusz Krawczyk, *Nazwać, żeby ocalić. Klasycy myśli konserwatorskiej wobec reliktów przeszłości* (Toruń: Wydawnictwo Naukowe Uniwersytetu Mikołaja Kopernika, 2020), 130–46; Narmin Babazadeh Asbagh, "Theories of Conservation and Scientific Restoration from Gustavo Giovannoni's Point of View," in *5th International Conference of Contemporary Affairs in Architecture and Urbanism* (Famagusta: Eastern Mediterranean University, Faculty of Architecture, Alanya Hamdullah Emin Paşa University, 2022).

[243] Alois Riegl, "Nowoczesny kult zabytków. Jego istota i powstanie," in *Alois Riegl, Georg Dehio i kult zabytków*, ed. Ryszard Kasperowicz (Warsaw: Muzeum Pałacu w Wilanowie, 2012), 31–90.

[244] This was set as a form basis of valorisation of heritage that later was developed by following Art historians and monuments conservators.

[245] Denkmalkultus is not limited to "outstanding works of art," but encompasses any object that is recognized today as a monument, regardless of its original function or artistic value.

"substance" or material form. This distinction is foundational in art history and conservation theory for explaining why similar building types can appear so different across cultures and periods, even when the same materials or structural techniques are used. Riegl's idea encouraged scholars to look beyond technique and individual artists, focusing instead on the broader cultural and social forces that shape artistic styles[246]. This concept helped establish contextual approaches in art history and has influenced subsequent generations of scholars[247].

Building on the evolving framework of conservation, Georg Dehio further advanced the field by promoting the principle of minimal intervention. He argued that restoration should be limited to only what is strictly necessary for a monument's survival, firmly opposing creative reconstructions or stylistic completions. His well-known maxim, "Conserve, don't restore,"[248] reflected his conviction that the value of historic monuments lies in their accumulated layers, authenticity, and visible signs of age, as well as respect for the integrity and patina of historic structures. Beyond his theoretical contributions, Dehio left a lasting legacy through his monumental "Dehio Handbook,"[249] an ambitious and systematic catalogue of German art and architectural monuments that set a standard for documentation of heritage throughout Europe[250]. In both his scholarship and practice, Dehio underscored the importance of careful study, comprehensive documentation, and a deep respect for the authentic substance and history of cultural monuments.

Based on both Riegl's values and Dehio's approach to the systematisation of heritage, Walter Frodl developed and popularised the use of utilitarian valorisation criteria in conservation practice, grounding this approach in his own concept of heritage value assessment[251]. In his view, valorisation involves the systematic identification and analysis of an object's features, including authenticity, integrity, historical, artistic, and scientific value, as well as social significance and cultural context. Frodl distinguished several key categories of value: historical value, which encompasses both scientific value and emotional factors such as age value and symbolic significance; artistic value, which includes historical-artistic value, the concept of the original state, intrinsic artistic quality, and the overall artistic impact, whether inherent or based on external qualities such as tradition or picturesque character; and utilitarian value, relating to the monument's continued use, practical utility, or appeal as a tourist attraction. Frodl emphasised that a thorough evaluation of these criteria should form the basis for all

[246] In architecture, Kunstwollen refers to the distinctive creative impulse or cultural intent that shapes the forms and styles of buildings within a particular era or society. According to Riegl, architectural styles are not simply the result of available materials or technical skill, but reflect the underlying values, aspirations, and worldview of a culture. This concept helps explain why architectural forms vary so widely across time and place, such as gothic in France or Germany etc. and their local forms, emphasizing the importance of understanding the cultural context when interpreting or conserving historic architecture.

[247] Janusz Krawczyk, "Kompromis i metoda: Wybrane aspekty teorii konserwatorskich Aloisa Riegla i Cesare Brandiego," *Ochrona Zabytków*, no. 2 (2010): 64–74; Jukka Jokilehto, *A History of Architectural Conservation*, 2nd ed. (New York: Routledge, 2017), 213–15; Janusz Krawczyk, *Nazwać, żeby ocalić. Klasycy myśli konserwatorskiej wobec reliktów przeszłości* (Toruń: Wydawnictwo Naukowe Uniwersytetu Mikołaja Kopernika, 2020), 109–29.

[248] "*Konservieren, nicht restaurieren"*

[249] Georg Dehio, *Handbuch der deutschen Kunstdenkmäler* (Berlin: Ernst Wasmuth, 1905).

[250] The Dehio Handbook served as a model and inspiration for similar inventories in Poland (Atlasy zabytków) and other European countries. Both series share the goal of providing systematic, scholarly documentation to support the protection, study, and appreciation of architectural heritage.

[251] Walter Frodl, *Pojęcia i kryteria wartościowania zabytków* (Warsaw: Biblioteka Muzealnictwa i Ochrony Zabytków, 1966); Walter Frodl, "Wartościowanie zabytków: Pojęcia i kryteria," in *Konserwacja i rewaloryzacja architektury w środowisku kulturowym*, ed. Edmund Małachowicz (Wrocław: Oficyna Wydawnicza Politechniki Wrocławskiej, 2007), 553–60.

decisions regarding the protection and conservation of architectural heritage. His ideas were later further developed, modified, and adapted to address specific circumstances and contexts[252].

Charters – Codification of actions

All of the previously mentioned figures and their influence led to the adoption of numerous international charters, each designed to address evolving challenges in heritage conservation. The primary aim of these charters is to establish clear, internationally recognised principles and guidelines for the conservation, restoration, and management of cultural heritage. By promoting best practices, ethical standards, and interdisciplinary collaboration, these documents seek to protect the authenticity, integrity, and historical value of monuments, sites, and landscapes. They are dedicated to various topics within heritage, including architecture, archaeology, historic gardens and landscapes, cultural routes, underwater cultural heritage, vernacular architecture, historic towns and urban areas, the protection of intangible (non-material) culture, cultural tourism, and the preservation of wooden, earthen, and stone structures[253]. Additionally, charters encourage documentation, public awareness and involvement, and foster international cooperation among professionals and communities, providing a framework to safeguard cultural heritage for present and future generations.

The first of these was the Athens Charter of 1931[254], developed during the International Congress of Architects and Technicians of Historic Monuments. It served as a newly developed form adopted with new threads of Prima Carta Del Restauro, and focused on the conservation of historic towns, highlighting the need to balance modernisation with the preservation of urban fabric and historic continuity.

In 1933, another Athens Charter was published, focusing on a modernist approach to urban planning. While most of the charter was dedicated to issues of city design and organisation, it also included points concerning historic architecture. Notably, point 70 specifically addressed the approach to the reconstruction of historic structures[255].

Following the devastation of the Second World War, the Hague Convention for the Protection of Cultural Property in the Event of Armed Conflict was adopted in 1954[256]. This treaty was the first dedicated exclusively to the safeguarding of cultural heritage in times of war. It established rules for protecting historic buildings, museums, and works of art both in peace and conflict, introduced the

[252] Edmund Małachowicz, *Konserwacja i rewaloryzacja architektury w środowisku kulturowym* [*Conservation and restoration of architecture in the cultural environment*] (Wrocław: Oficyna Wydawnicza Politechniki Wrocławskiej, 2007), 19–21; Michał Witwicki, "Kryteria oceny wartości zabytkowej obiektów architektury jako podstawa wpisu do rejestru zabytków," *Ochrona Zabytków*, no. 1 (2007): 77–98.

[253] ICOMOS, "Charters and doctrinal texts," *ICOMOS*, accessed June 26, 2025.

[254] Not to confuse with Athens Charter of 1933, dedicated to urban planning.

See *The Athens Charter for the Restoration of Historic Monuments*, adopted at the First International Congress of Architects and Technicians of Historic Monuments, Athens, 1931, accessed June 28, 2025, https://civvih.icomos.org/wp-content/uploads/2022/03/The-Athens-Charter_1931.pdf

[255] *Charter of Athens, 1933, art. 70, accessed June 28, 2025, https://portal.uur.cz/pdf/charty-deklarace/charter-of-athens-1933.pdf.*

"The re-use of past styles of building for new structures in historic areas under the pretext of aesthetics has disastrous consequences. The continuance or the introduction of such habits in any form should not be tolerated."

[256] *Hague Convention for the Protection of Cultural Property in the Event of Armed Conflict*, adopted at The Hague, 14 May 1954; entered into force 7 August 1956, accessed 28 June 2025, https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU19570460212

blue shield emblem for protected sites[257], and called for special registries and protective measures by member states[258].

In 1964, the Venice Charter, formally known as the International Charter for the Conservation and Restoration of Monuments and Sites[259], was adopted during the Second International Congress of Architects and Technicians of Historic Monuments, organised under the auspices of UNESCO and ICOMOS. As an expanded follow-up to the Athens Charter of 1931, the Venice Charter refined, clarified, and broadened the basic principles of its predecessor, moving from early international recommendations to a systematic and universally recognised doctrine for the conservation and restoration of monuments and sites.

Widely regarded as the most important document ever published for the protection of cultural heritage, the Venice Charter established a comprehensive set of internationally accepted principles that remain central to conservation practice today. Like earlier charters, it emphasised the preservation of authenticity and integrity, advocating respect for all historical periods and layers rather than favouring a single era or style. Unlike the more general Athens Charter, the Venice Charter is highly detailed and rigorous, setting out specific definitions, methodologies, and ethical standards for conservation and restoration. It expanded the concept of heritage to include not only individual buildings but also groups of buildings, urban ensembles, rural settings, and even modest works that have acquired cultural value (Article 1). The Charter established that restoration is a highly specialised operation, which must reveal the aesthetic and historical value of a monument, be based on authentic documentation, and avoid any conjecture. Additions or integrations must be distinguishable and, wherever possible, reversible, in order to safeguard historical truth. It also made interdisciplinary collaboration a requirement, involving scientific, technical, and historical expertise throughout the conservation process. Furthermore, the Charter underscored the necessity for thorough documentation of all interventions and the publication of this information for transparency and future reference. The Venice Charter had a profound impact on both national and international policy, shaping modern conservation ethics and influencing the development of subsequent heritage charters. Its principles continue to provide the foundation for the protection, management, and understanding of cultural heritage sites worldwide.

The Amsterdam Declaration of 1975[260], adopted at the European Congress on the Rehabilitation of Historic Towns, marked an important development in European heritage conservation. It broadened the focus from individual monuments to the preservation of entire historic urban ensembles[261], advocating for conservation as an integral part of urban policy, community life, and education, and

[257] Designed by Jan Zachwatowicz

[258] "Review of the Convention for the Protection of Cultural Property in the Event of Armed Conflict" (UNESCO, 1993), accessed June 28, 2025, https://unesdoc.unesco.org/ark:/48223/pf0000100159.locale=en

[259] *International Charter for the Conservation and Restoration of Monuments and Sites* (The Venice Charter, 1964), IInd International Congress of Architects and Technicians of Historic Monuments, Venice, adopted by ICOMOS in 1965, accessed June 28, 2025, https://admin.icomos.org/wp-content/uploads/2025/03/Venice_Charter_EN.pdf

[260] *Declaration of Amsterdam* (1975), adopted at the Congress on the European Architectural Heritage, Amsterdam, October 1975, accessed June 28, 2025, https://civvih.icomos.org/wp-content/uploads/2022/03/Declaration-of-Amsterdam_25_10_1975.pdf

[261] Other ICOMOS publications that address the historical urban context include the *Washington Charter* (1987) and the *Valletta Principles for the Safeguarding and Management of Historic Cities, Towns and Urban Areas* (2011). For the industrial context, the *Joint ICOMOS–TICCIH Principles for the Conservation of Industrial Heritage Sites, Structures, Areas and Landscapes* (2011), also known as the *Dublin Principles*, were adopted. Most recently, for the military context, ICOMOS issued the *Guidelines on Fortifications and Military Heritage* (2021).

stressing public participation. The Declaration emphasised maintaining not only the architectural fabric but also the social functions and landscape context of historic towns.

Most recently, the Nara Document on Authenticity (1994)[262], adopted at an international conference in Japan, represented a major milestone by responding to the growing recognition of cultural diversity in heritage. It broadened the concept of authenticity, emphasising that heritage values and forms must be understood within their specific cultural contexts. The Nara Document established that authenticity is not fixed or universal, but depends on unique traditions, materials, and meanings, thereby reinforcing the importance of inclusivity and context-sensitive approaches to heritage management worldwide.

One more publication is crucial for this study, as a significant part of this work focuses on heritage documentation[263]. The Principles for the Recording of Monuments, Groups of Buildings and Sites (1996)[264] emphasise that recording is essential for understanding, managing, and preserving cultural heritage. The principles also highlight the importance of interdisciplinary collaboration in the recording process and recommend that documentation efforts be carefully planned, taking into account available resources and the significance of the heritage.

2.5 Reconstruction In The Post-War Approach

In the aftermath of wartime destruction, reconstruction became a means of preserving history and both national and community identity, prompted by the circumstances of destruction or damage rather than neglect[265]. Post-war efforts often focused on restoring cultural landmarks as symbols of resilience and continuity, aiming to recover collective memory and social cohesion by returning sites to their pre-destruction state rather than simply renovating or conserving them. While these actions raised debates over authenticity and historical accuracy, they also marked a significant shift in heritage practice, demonstrating approaches that were not always aligned with established conservation principles.

Early post-war approaches to the reconstruction,

With the outbreak of the Great War (1914–1918), the Western Front solidified into a stagnant line stretching from Switzerland, through northern France and Flanders, to the North Sea coast. This period saw the extensive use of artillery and explosives, as the nature of warfare shifted from manoeuvre-based tactics to a war of attrition. As a result, enormous destruction was concentrated along the

[262] *Nara Document on Authenticity* (1994), accessed June 28, 2025, https://whc.unesco.org/document/116018

[263] In this study, digital documentation is approached as an essential tool for the accurate, comprehensive, and accessible recording of cultural heritage. Employing technologies such as photogrammetry, laser scanning, and digital archiving, this method enables the preservation and analysis of heritage sites in a manner consistent with the ICOMOS Principles for the Recording of Monuments, Groups of Buildings and Sites (1996), supporting both conservation practice and future research.

[264] *Principles for the Recording of Monuments, Groups of Buildings and Sites* (1996), ratified by the 11th ICOMOS General Assembly, Sofia, October 1996, accessed June 28, 2025, https://admin.icomos.org/wp-content/uploads/2025/03/archives-eng.pdf

[265] An early documented example is Theodoric the Great, who, after establishing the Ostrogothic Kingdom in Italy in 493, recognised the cultural and historical significance of ancient Rome and aimed to restore its former glory following devastation by the Visigoths and Vandals. His policies prioritised the repair of public buildings, restoration of infrastructure, and revival of iconic monuments such as the Colosseum and aqueducts, along with the renewal of Rome's cultural and administrative life. Theodoric's efforts demonstrate how a post-war approach to reconstruction has long served as a means of reasserting identity and continuity in the aftermath of destruction.

See Edmund Małachowicz, *Konserwacja i rewaloryzacja architektury w środowisku kulturowym* [*Conservation and restoration of architecture in the cultural environment*] (Wrocław: Oficyna Wydawnicza Politechniki Wrocławskiej, 2007), 27.

relatively narrow strip of France and Belgium where the front remained static. The series of battles around Ypres, in the Flanders region of Belgium, led to the near-total destruction of the medieval town's urban fabric, including its churches and the important Ypres Cloth Hall[266].

The Ypres Cloth Hall, originally built in the 13th century in the Northern European Gothic style, featured a Belfry Tower[267] and was one of the largest commercial buildings of the Middle Ages. It symbolised the prosperity of Ypres as a centre of the cloth industry. The Cloth Hall sustained especially heavy damage during the Second Battle of Ypres in 1915. By the end of the Great War, both the town and the Cloth Hall were almost entirely destroyed. The building was left gutted, with only sections of the perimeter walls and a portion of the Belfry Tower still standing.

The Belgian government decided to reconstruct both the Cloth Hall and the nearby Church of Saint Martin, recognising the action as a powerful symbol of resilience and the nation's commitment to recovering from wartime destruction. This decision was motivated not only by a desire to honour those who suffered during the war, but also by the need to restore a vital part of Belgium's cultural heritage, even against the thinking and discourse that preceded the Athens Charter of 1931. In Ypres, reinstating the Cloth Hall as the focal point of the Grote Markt was crucial in reestablishing the town's traditional layout. The landmark's silhouette, once again dominating the skyline, became a vital point of orientation and a renewed source of civic pride. By reviving not only the building but also its relationship to the urban landscape, the reconstruction fostered a sense of continuity and supported both the physical and psychological recovery of the entire urban complex[268].

Reconstruction work began in 1928 and spanned nearly 30 years, culminating in completion in 1967. The project prioritised historical accuracy, relying on original plans, photographs, and drawings to guide the restoration and return the buildings to their pre-war appearance[269]. As a result, the present Cloth Hall is largely a faithful replica of the medieval structure as it existed before the war. Some original elements survive, particularly in the western section and at the base of the Belfry Tower. The completed building, therefore, combines authentic medieval remnants with supplemented reconstruction. Today,

[266] I had the opportunity to visit the site in 2014 and observe the restoration challenges firsthand. Unfortunately, during my trip I was robbed and lost all the photographs I had taken there.

[267] The Belfries of Belgium and France, a group of 56 historic belfry towers, including Ypres, are listed as UNESCO World Heritage sites due to their significance in medieval civic and religious life. These towers symbolise the communal independence of towns and are celebrated for their architectural and cultural heritage. Interestingly, the typical gothic four-corner belfry tower design, popular in Flanders, inspired the shape of the tower of Main Town Hall in Gdańsk.

[268] The reconstruction of prominent landmarks also profoundly transforms the surrounding landscape and urban environment. In historic cities devastated by war, the restoration of key landmarks helps to reestablish the spatial organization of the urban fabric, restoring lost visual corridors, sightlines, and traditional relationships between buildings and public spaces.

Later, international conservation doctrine, including the Venice Charter (1964) and subsequent ICOMOS documents, recognized the importance of context, emphasizing that the relationship between a monument and its setting is an essential aspect of heritage value.

[269] The reconstruction of the Ypres Cloth Hall was overseen by Belgian architect Jules Coomans. He was responsible for designing and managing the restoration project in accordance with historical documentation, aiming to return the Cloth Hall to its pre-war appearance. After Coomans's death in 1937, the work was continued by his assistant, Pierre Pauwels, who saw the project through to completion in 1967.

See Marie Nevejan and Gisèle Gantois, "Restoring Broken Journeys in the Framework of Urban Reconstruction after a Disaster: The Ypres Case," *Architecture_MPS* 29, no. 1 (2024): Article 3, DOI: 10.14324/111.444.amps.2024v29i1.003

the Cloth Hall houses the In Flanders Fields Museum[270], which is dedicated to the history of World War I and stands as a major cultural and historical landmark in Belgium[271], recognised on the UNESCO list[272].

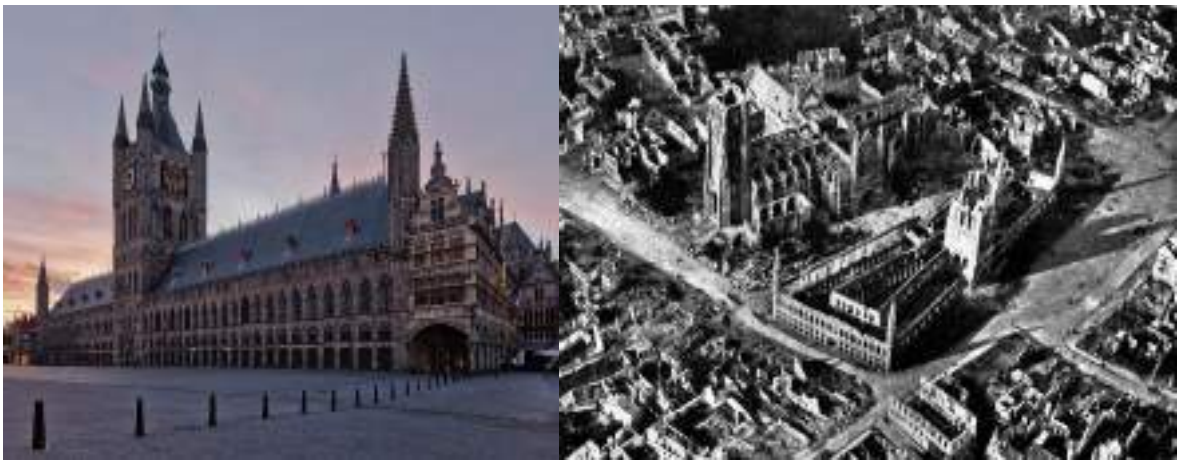


Fig. 26. Ypres Cloth Hall. Left- today's view after reconstruction (source: Wikimedia Commons[273]), right- aerial view after the Great War (source: Wikimedia Commons[274]).

Other notable examples of early post-war reconstructions include Leuven, where both St. Peter's Church and the University Library were rebuilt after suffering significant damage[275] . The Cathedral of

[270] In Flanders Fields Museum, "In Flanders Fields Museum," accessed December 1, 2024, https://www.inflandersfields.be/en/in-flanders-fields-museum-1

[271] Hugh Clout, "The Great Reconstruction of Towns and Cities in France 1918–35," *Planning Perspectives* 20, no. 1 (2005): 1–33; Jukka Jokilehto, *A History of Architectural Conservation*, 2nd ed. (New York: Routledge, 2017), 282–83; Kristof Van Assche and Monica Gruezmacher, "Remembering Ypres: Post-War Reconstruction, Land and the Legacies of Shock and Conflict," *Land* 12, no. 1 (2023): 21. https://doi.org/10.3390/land12010021; Marie Nevejan and Gisèle Gantois, "Restoring Broken Journeys in the Framework of Urban Reconstruction after a Disaster: The Ypres Case," *Architecture_MPS* 29, no. 1 (2024). https://doi.org/10.14324/111.444.amps.2024v29i1.003

[272] Ypres is represented on the UNESCO World Heritage List in two distinct ways. First, while the city itself is not individually listed, the Belfry Tower of the Ypres Cloth Hall is included as part of the serial inscription "Belfries of Belgium and France." This listing recognizes 56 belfries across Belgium and northern France for their historical and architectural significance as symbols of civic independence.

See *Belfries of Belgium and France, UNESCO World Heritage List, no. 943 (inscribed 1999; extended 2005), accessed June 29, 2025, https://whc.unesco.org/en/list/943*

Second, UNESCO has more recently acknowledged World War I heritage. In 2023, the "Funerary and Memorial Sites of the First World War (Western Front)" was added to the World Heritage List. This transnational site includes numerous memorials and cemeteries, among them the Menin Gate Memorial in Ypres, reflecting the global significance of remembrance and commemoration associated with the city.

See *Funerary and Memory Sites of the First World War (Western Front)*, UNESCO World Heritage List, no. 1567 (inscribed 2023), accessed June 29, 2025, https://whc.unesco.org/en/list/1567/

[273] *Ypres Cloth Hall* (photograph), Wikimedia Commons, accessed December 1, 2024, https://upload.wikimedia.org/wikipedia/commons/thumb/5/54/Ypres_Cloth_Hall_%28DSCF9459-DSCF9469%29.jpg/1020px-Ypres_Cloth_Hall_%28DSCF9459-DSCF9469%29.jpg.

[274] National Geographic Society, *View of Ypres: Photograph taken from a flying machine (Ypres Belgium NGM-v31-p337-B)*, photograph, Wikimedia Commons, accessed December 1, 2024, https://upload.wikimedia.org/wikipedia/commons/thumb/2/2b/Ypres_Belgium_NGM-v31-p337-B.jpg/1020px-Ypres_Belgium_NGM-v31-p337-B.jpg.

[275] In August 1914, at the start of World War I, German forces set fire to Leuven in retaliation for alleged civilian resistance, resulting in the near-total destruction of the city's key landmarks, especially St. Peter's Church and the University Library. The loss of the University Library was particularly severe, with over 300,000 books and rare medieval manuscripts destroyed, an event that shocked the international community and represented a major loss for European scholarship. These landmarks were central to Leuven's spiritual and intellectual identity. Their destruction provoked widespread condemnation and inspired a global effort to rebuild. The reconstructed University Library, funded by donations from

Reims, which was heavily damaged during World War I, with its roof and upper sections destroyed by German shelling, also underwent extensive restoration[276]. Another important example is the Alcázar of Toledo, which was severely damaged during the Spanish Civil War from 1936 to 1939. Efforts to rebuild the fortress began in the late 1940s and were guided by historical research and a commitment to its original design[277].

The reconstruction of Kalisz after 1914 is a key example in Polish conservation history, notable for its hybrid approach that balanced the preservation of the historic urban layout with modern planning needs. Despite the city's devastation, architects and conservators aimed to restore the prewar street grid and architectural character, often blending historical styles with contemporary techniques. Figures like Sylwester Pajzderski and Marian Lalewicz promoted the integration of surviving fragments and respect for historical continuity[278]. As a result, Kalisz's rebuilt centre became an important reference in debates on authenticity and reconstruction in Poland[279].

Today, those examples serve as a symbol of resilience and a significant cultural and historical landmark and highlight how architecture can serve as both a physical and symbolic restoration of identity that was lost during the war, contributing to the broader dialogue on reconstruction issues[280].

While the Great War's destruction was largely confined to a narrow strip along the Western Front, the Second World War brought unprecedented devastation to architectural heritage across much of

around the world, stands today as a symbol of resilience, international solidarity, and the importance of preserving cultural heritage even in times of crisis.

See Richard Plunz, "Reflections on Leuven as Martyred City and the Realignment of Propinquity," in *Revival after the Great War*, 55–64 (Leuven: Leuven University Press, 2020).

[276] Reims Cathedral was severely damaged by German artillery during World War I, with its roof, sculptures, and stained glass destroyed. After the war, an extensive restoration led by architect Henri Deneux and funded in part by international donors, including the Rockefeller Foundation, restored the cathedral by the 1930s. The rebuilt cathedral stands as extraordinary example of French gothic and a symbol of resilience and the importance of preserving cultural heritage after conflict, inscribed on UNESCO list.

See Lorraine Boissoneault, "The Debate Over Rebuilding That Ensued When a Beloved French Cathedral Was Shelled During WWI," *Smithsonian Magazine*, April 19, 2019, accessed June 29, 2025, https://www.smithsonianmag.com/history/debate-over-rebuilding-ensued-when-beloved-french-cathedral-was-shelled-during-wwi-180971999/; *Cathedral of Notre-Dame, Former Abbey of Saint-Rémi and Palace of Tau, Reims*, UNESCO World Heritage List, no. 601 (inscribed 1991), accessed June 29, 2025, https://whc.unesco.org/en/list/601

[277] The reconstruction of the Alcázar of Toledo under Franco's regime was a highly political act. After the Spanish Civil War, the ruined Alcázar became a powerful symbol of Nationalist victory and resilience. Franco's government deliberately restored the fortress to promote its ideology and legitimize its rule, presenting the siege and defense of the Alcázar as the ultimate example of patriotic sacrifice and loyalty to Spain. The site was frequently used in official ceremonies and state propaganda to reinforce narratives of national unity and the triumph of Franco's forces. As a result, the reconstructed Alcázar functioned not only as a historical monument but also as a key instrument for shaping collective memory and asserting political control, transforming architecture into a tool of myth-making and state narrative.

See Lynn Cartwright-Punnett, *How Spain Sees Its Past: The Monumentalization of the Spanish Civil War*, thesis, Wesleyan University (Middletown, CT), May 1, 2007, pp. 17–61; Juan Miguel Ochotorena, "The Hidden Scars of the Spanish Civil War in Madrid," *SAH Blog* (Society of Architectural Historians), April 5, 2022, accessed June 29, 2025, https://www.sah.org/publications/sah-blog/blog-detail/sah-blog/2022/04/05/the-hidden-scars-of-the-spanish-civil-war-in-madrid

[278] Małgorzata Omilanowska, "Odbudowa Kalisza po zniszczeniach 1914 roku," *Biuletyn Historii Sztuki: Kwartalnik Instytutu Sztuki Polskiej Akademii Nauk* 78, no. 4 (2016): 663–86; Mateusz Rabiega, "Problem odbudowy centrum Kalisza po 1914 roku z punktu widzenia niemieckiego konserwatora zabytków Juliusa Kohtego," *Zeszyty Kaliskiego Towarzystwa Przyjaciół Nauk* 21 (2021): 105–21, https://doi.org/10.4467/26578646ZKNT.21.005.17589.

[279] The reconstruction of Kalisz played a significant role as a precedent for the postwar rebuilding of Gdańsk and Warsaw, serving as an early experimental model for large-scale urban restoration in Poland.

[280] The approach to destroyed heritage after the Second World War requires separate discussion due to the scale of the problem, which encompassed many cities and significant landmarks, the influence of the Athens Charter, and the shift in attitudes during the final quarter of the 20th century. This will be covered in the following paragraphs.

Europe, especially in Central and Eastern regions. In countries such as Poland and Germany, entire cities were reduced to rubble, erasing centuries of built heritage and cultural memory in the span of a few years. This sweeping loss shattered the continuity of urban landscapes and national identities, leaving societies and conservators to grapple with profound questions: Should the ruined past be rebuilt, and if so, how? What would reconstruction mean for the authenticity of heritage and the cultural identity of affected communities? The scale of destruction after 1945 forced a re-examination of the very principles of conservation, raising debates that would shape the future of heritage policy and memory across Europe.

Monte Cassino

The destruction and subsequent reconstruction of Monte Cassino Abbey[281], stand as a powerful example of the challenges and dilemmas faced in restoring cultural monuments devastated by war. As one of the most prominent religious sites in Europe, the abbey's completely destroyed during the Italian Campaign of World War II, between 17 January and 18 May 1944[282].

After the war, the question of whether and how to reconstruct Monte Cassino Abbey became the subject of considerable debate. Given the abbey's exceptional religious and cultural significance as the birthplace of Western monasticism, the Italian government and the Vatican ultimately chose to rebuild it as an exact replica of its pre-war appearance. The reconstruction relied on historical photographs, detailed inventories, and architectural research, following the principle of "Com'era, dov'era" ("as it was, where it was"). The aim was to faithfully restore the abbey's original appearance, similar to the earlier reconstruction of the Campanile of San Marco. Surviving architectural elements were incorporated into the new structure wherever possible, further enhancing its historical value. Led by architect Giuseppe Breccia Fratadocchi, the rebuilding began in 1949 and was completed in 1956, restoring the abbey to its former form[283].

The question of authenticity is central to the reconstruction of Monte Cassino Abbey, since the current building is a replica rather than the original structure with its historic fabric. As Alois Riegl's concept of "age value" (Alterswert) suggests, this quality is lost in the reconstruction, as the entire complex now appears artificially new, lacking the patina of time. The process of rebuilding has resulted in a mechanised repetition of historical forms, leading some critics to view the outcome as inauthentic or

[281] The monastery was founded in 529 AD by Saint Benedict of Nursia and is perched atop a 500-meter-high mountain near the ancient city of Cassino (Latin: Casinum), overlooking the Liri River valley. Widely regarded as the birthplace of Western monasticism, it was at Montecassino that Saint Benedict established his vision for monastic life, later codified in the Rule of Saint Benedict. The Abbey was originally centered around an early Christian basilica, which underwent significant transformations and expansions throughout its long history. Notably, the original garden cloister, characteristic of early Christian monasticism, was later incorporated into an axial layout featuring prominent stairways and a cloister designed by Donato Bramante. The entire hilltop complex came to resemble a fortified castle.

See David Watkin, *Historia architektury zachodniej* (Warsaw: Arkady, 2001), 88; Michela Cigola, *L'abbazia benedettina di Montecassino: La storia attraverso le testimonianze grafiche di rilievo e di progetto* (Cassino: Ciolfi Editore, 2005)

[282] Strategically located atop a mountain, Montecassino and its surroundings became part of the German Gustav Line, a major defensive position during World War II. Although German forces asserted that the abbey itself was not used for military purposes, Allied commanders believed it served as an artillery observation post and stronghold. Acting on these suspicions, the Allies launched a massive bombardment, employing heavy artillery and airstrikes that completely destroyed the historic monastery. Later investigations confirmed that no German troops had occupied the abbey prior to the attack; their positions were instead in the areas surrounding the site. Ironically, the destruction of the abbey created ideal defensive ruins, which German troops subsequently fortified and used to their advantage. In May 1944, after intense and prolonged fighting, the Polish II Corps succeeded in capturing Montecassino, breaking through the Gustav Line and enabling the Allied advance into Italy.

[283] Tommaso Breccia Fratadocchi, *La ricostruzione dell'abbazia di Montecassino* (Rome: Gangemi Editore, 2014); Kriston R. Rennie, *The Destruction and Recovery of Monte Cassino, 529–1964* (Amsterdam: Amsterdam University Press, 2021).

even “fake”, showing that no destruction happened. Although the monastic landscape and the Benedictine tradition at Cassino were restored, the architecture itself remains a replica. This situation has generated ongoing debate about the true value and significance of such reconstructions. Nevertheless, Monte Cassino represents an approach that emphasises the symbolic and historical importance of a major religious site, privileging its spiritual and cultural legacy over the preservation of original materials. In addition to its religious and cultural functions, the abbey also serves as a war memorial.

Fig. 27. Monte Cassino. Left: Monastery after destruction (source: National Geographic[284]). Right: Reconstructed monastery (source: Cassino Appartamenti website[285])

Warsaw[286]

The reconstruction of Warsaw should be viewed from multiple perspectives, with particular attention given to the historic medieval city centre, the Royal Castle, and the broader urban fabric, each reflecting different approaches towards reconstruction and rebuilding within a single city. Approximately 80% of Warsaw, the capital city, was destroyed during the Second World War[287], with the most severe devastation occurring in 1944 as a result of the Warsaw Uprising[288]. The uprising resulted in prolonged urban combat, widespread bombing, arson, and the extensive demolition of buildings during 63 days of resistance organised by the Polish underground. Following the suppression of the uprising, Warsaw was subjected to systematic destruction. On Adolf Hitler’s orders[289] for the complete obliteration of the city, designated German units proceeded to methodically demolish the city centre, targeting historic

[284] *Mar* (photo), Historia – National Geographic España, accessed June 16, 2024, https://historia.nationalgeographic.com.es/medio/2014/02/17/mar-w269049_2000x1168.jpg.

[285] *Abbazia di Montecassino* (photograph), Cassino Appartamenti, accessed June 16, 2024, http://www.cassinoappartamenti.com/wp-content/uploads/2015/10/abbazia_montecassino.jpg.

[286] The topic of Warsaw’s reconstruction is highly complex, and a comprehensive analysis would require a separate doctoral dissertation. However, the author aims to emphasize the global significance of Warsaw’s reconstruction within this work, though only in a limited scope due to volume constraints of this work.

[287] Including the outbreak of World War II and the September 1939 campaign, which brought intense Luftwaffe bombings and artillery shelling during the city’s defense; the German policy of repression against the Polish capital, involving the systematic destruction of infrastructure, cultural sites, and monuments as part of a broader strategy to annihilate the Polish nation; and the Warsaw Ghetto Uprising of 1943, which resulted in widespread devastation during the suppression of the Jewish resistance and the subsequent demolition of the entire Jewish district by German forces.

Nazis also devised the so-called Pabst Plan, a project aimed at transforming Warsaw into a small German provincial town by demolishing most of its residential buildings and drastically reducing its population; however, the plan was never fully realized.

See Stanisław Jankowski, “Warsaw: Destruction, Secret Town Planning, 1939–44, and Postwar Reconstruction,” in *Rebuilding Europe’s Bombed Cities*, ed. Jeffry M. Diefendorf (London: Palgrave Macmillan UK, 1990), 77–93.

[288] Władysław Bartoszewski, *Powstanie Warszawskie* (Warszawa: Świat Książki, 2009); Norman Davies, *Rising ’44: The Battle for Warsaw* (London: Pan Books, 2018).

[289] “Order for the Destruction of Warsaw” (Befehl zur Zerstörung von Warschau), issued on October 17, 1944.

monuments, churches, palaces, and residential buildings[290]. The destruction of the city following the fighting is well documented in numerous photographs[291]. This destruction was implemented as a punitive measure for Warsaw's resistance and was accompanied by reprisals against the civilian population[292]. The Red Army, together with Polish forces, finally liberated Warsaw in January 1945, following the fall of the Warsaw Uprising in October 1944[293].

Fig. 28. Destroyed historic city centre of Warsaw (source: Wikimedia Commons[294]).

On February 14, 1945[295], by decision of the Praesidium of the Provisional Government of the Republic of Poland, the Warsaw Reconstruction Office (Biuro Odbudowy Stolicy, BOS) was established. This institution was created specifically to plan and coordinate the reconstruction of Warsaw after the destruction caused by the Second World War. BOS was responsible for inventorying the damage, documenting the city's condition, and developing urban and architectural concepts for the city's reconstruction, including designs for the restoration of historical monuments[296].

The devastation of Poland's capital and its heritage sparked intense debate over the most suitable approach to urban reconstruction[297]. Ultimately, a hybrid strategy was adopted, restoring the historic

[290] Jerzy Elżanowski and Carmen M. Enss, "Cartographies of Catastrophe: Mapping World War II Destruction in Germany and Poland," *Urban History* 49, no. 3 (2022): 589–611, https://doi.org/10.1017/s0963926820000772.

[291] Leonard Sempoliński and Emilia Borecka, *Warszawa 1945* (Warszawa: Państwowe Wydawnictwo Naukowe, 1985); Zofia Chomętowska and Maria Chrząszczowa, *Kronikarki. Fotografie Warszawy 1945–1946*, ed. Karolina Lewandowska (Warszawa: Archeologia Fotografii, 2011); "Warszawa 1945," *Google Arts & Culture*, accessed July 11, 2025, https://artsandculture.google.com/story/yQWhS5Gh6u2hLw?hl=pl; "Warszawa 1945: Przewodnik po mieście ruin," *Culture.pl*, accessed July 11, 2025, https://culture.pl/pl/superartykul/warszawa-1945-przewodnik-po-miescie-ruin; "Maciej Czapliński. Album: Powojenna Warszawa," *Fototeka 1944.pl*, accessed July 11, 2025, https://www.1944.pl/fototeka/kolekcja/maciej-czaplinski-album-powojenna-warszawa-pa,163,strona,4.html.

[292] During the systematic destruction of Warsaw by German forces after the fall of the uprising, the Soviet Army, positioned on the eastern bank of the Vistula River, did not intervene or advance to aid the city. This period of deliberate inaction, often described as "Soviet passivity" or "Russian stagnation," allowed German units to carry out the demolition largely unimpeded, significantly contributing to the scale of the city's devastation

[293] Bolesław Dolata and Tadeusz Jurga, *Walki zbrojne na ziemiach polskich 1939–1945: wybrane miejsca bitew, walk i akcji bojowych*, ed. Jan Brodała (Warszawa: Rada Ochrony Pomników Walki i Męczeństwa, 1970), 466–76.

[294] Old Town, Warsaw, 1945 (photograph), Wikimedia Commons, accessed July 9, 2025, https://upload.wikimedia.org/wikipedia/commons/0/0f/Warsaw_Old_Town_1945.jpg; Old Town, Warsaw, 1945 (photograph), Wikimedia Commons, https://upload.wikimedia.org/wikipedia/commons/f/fd/Old_Town_Warsaw_waf-2012-1501-31%281945%29.jpg.

[295] Still during the war in Europe, 4 weeks after the liberation of Warsaw in 17th January of 1945.

[296] Aleksandra Zadrożniak, "Biuro Odbudowy Stolicy – od początków działalności do programu 'Pamięć Świata' UNESCO," *Kronika Warszawy*, no. 2 (2011): 85–91; Małgorzata Omilanowska, "Architectural Reconstructions in Post-War Poland," *Architectura* 46, no. 1 (2016): 28–48.

[297] Some argued for preserving the ruins as a "city of memory," maintaining them as an authentic reminder of the consequences of war and a lasting warning to future generations. This concept will be covered deeply, with realized examples in following paragraph.

city centre and key landmarks while implementing more pragmatic and modern solutions in other parts of the city. The entire post-war rebuilding process was highly politicized, guided by party and state authorities, and closely aligned with communist ideology. Under the leadership of Bolesław Bierut[298], president and first secretary of the communist party, architecture and urban planning were deliberately used to serve political objectives and to forge a new socialist identity for the capital[299].

Jan Zachwatowicz, a key figure in this process, was a strong advocate for the reconstruction of Warsaw's historic urban fabric, particularly the Old Town and the Royal Route, both of which had been almost entirely destroyed during the war. He argued that the symbolic and cultural value of the city justified the exceptional measure of large-scale reconstruction, an approach that diverged from the prevailing conservation philosophies and practices of the time, such as those set out in the Athens Charter of 1933. For Zachwatowicz, the reconstruction of historic Warsaw was not merely an architectural or technical challenge, but a moral obligation to restore the heart of the nation and national identity, the destruction of which had been intended as an act of cultural annihilation[300]. The importance of Jan Zachwatowicz also lies in his extensive inventory work, which he carried out together with his students at the Warsaw University of Technology, where he was a professor of the history of Polish architecture. These inventory drawings proved invaluable after the war, as they documented the condition of buildings prior to their destruction[301].

Another author, Ksawery Piwocki, well-versed in conservation discourse, identifies three main arguments in favor of reconstruction of Warsaw in his article: emotional (the symbolic need to restore important buildings, such as the Royal Castle, as an act of justice for wartime losses), social (providing historic monuments with practical functions and integrating them into social life), and artistic (the urbanistic role of monuments as city landmarks and compositional anchors)[302].

---

[298] Bolesław Bierut, *Sześcioletni plan odbudowy Warszawy* (Warszawa: Książka i Wiedza, 1950).

[299] Andrzej Skalimowski, "Budowniczy Stolicy. Warszawski mecenat Bolesława Bieruta w latach 1945–1955," *Pamięć i Sprawiedliwość* 2, no. 24 (2014): 75–94.

[300] Jan Zachwatowicz, "Program i zasady konserwacji architektury," *Biuletyn Historii Sztuki i Kultury* 8, no. 1–2 (1946): 48–52.

"The importance of the monuments of the past for the nation has been powerfully underscored by the experience of recent years, when the Germans, seeking to destroy us as a nation, demolished the monuments of our past. For the nation and the monuments of its culture are one. Since we cannot consent to being deprived of these monuments, we shall reconstruct them — we shall rebuild them from the ground up in order to pass them on to future generations, if not in their authentic substance, then at least in the precise form preserved in our memory and in surviving materials. At all costs, the remnants of cultural heritage had to be saved from final annihilation, so that they might still carry meaning and, to some degree, fulfill the role we ascribe to monuments in the life of the nation and in the shaping of its culture. They had to be given a form resembling their proper form. Of course, in the exalted science of conservation this represents a regression of many decades, but in our situation it was the only course of action. The cataclysm of the last war made this necessity even more urgent. Entire pages of our history, inscribed in the stone letters of architecture, were deliberately torn out. A sense of responsibility toward future generations requires the reconstruction of what has been destroyed — a complete reconstruction, fully conscious of the tragedy of the historical falsification it entails."

[301] Another important aspect was his pre-war involvement in architectural investigations and research into the historic city centre, particularly the fortification system, with the aim of making these features more identifiable.

Jan Zachwatowicz, "Mury obronne Warszawy i prace nad ich odsłoną," *Biuletyn Historii Sztuki i Kultury* 2 (1937): 279–87.

[302] Piwocki, Ksawery. 1946. "Uwagi o Odbudowie Zabytków." *Biuletyn Historii Sztuki i Kultury* 1-2 (8): 53–59.

Fig. 29. Left: Inventory of damage to Warsaw of the Bureau of Capital Reconstruction 1945-1946 (source: state archive in Warsaw[303]). Right: Elevation of Piwna Street in Warsaw based on surveys, and reconstruction realisation in 1956 (source: Szanajca-Kossakowska 1956[304]).

One of the most important publications on the reconstruction of Warsaw is Stare Miasto w Warszawie. Odbudowa, published in 1956[305]. This volume provides a comprehensive summary of the reconstruction process, as well as the architectural and archaeological research carried out in the historic city centre to inform the reconstruction projects. It also presents numerous drawings resulting from interdisciplinary research and serves as an excellent album for comparing various aspects of the reconstruction. Another significant work, authored by Jan Zachwatowicz[306], compares the reconstruction of Warsaw with that of other Polish cities after the war. Additional insight into the complexities of the reconstruction is offered by Jan Górski[307], whose source publication focuses on the early stages of Warsaw's rebuilding. One of the more recent publications by Tomasz Fudala, produced as an outcome of an exhibition on the reconstruction of Warsaw[308], offers a much broader perspective on the subject. It examines not only the reconstruction of the historic city centre, but also the rebuilding of Warsaw as a whole and its impact on contemporary times.

The reconstruction of Warsaw's Old Town relied on a wide range of sources, including photographs, archival documents, and detailed architectural inventories. Among the most important were the eighteenth-century vedute by Bernardo Bellotto (Canaletto), whose highly accurate paintings provided essential visual documentation of the city's appearance before the war. The reconstruction of Warsaw was not only a technical undertaking but above all an expression of collective strength, optimism, and a response to the assault on Polish identity. Postwar decisions represented a compromise between the need to restore the city's historical appearance and the introduction of modern urban solutions. Although mistakes were made, the overall outcome of the reconstruction is clearly positive both materially and symbolically[309].

303 "Plan inwentaryzacji zniszczeń Warszawy Biura Odbudowy Stolicy z lat 1945–1946," detail of plates 31 and 32, original scale 1:2,500, Archiwum Państwowe w Warszawie (APW), BOS 1040.

304 *Stare Miasto w Warszawie. Odbudowa*, ed. Zofia Szanajca-Kossakowska (Warsaw: Budownictwo i Architektura, 1956), drawing 105.

305 *Stare Miasto w Warszawie. Odbudowa*, ed. Zofia Szanajca-Kossakowska (Warsaw: Budownictwo i Architektura, 1956).

306 Jan Zachwatowicz, *Ochrona zabytków w Polsce* (Warsaw: Polonia, 1965), 51–57.

307 *Odbudowa Warszawy w latach 1944–1949: Wybór dokumentów i materiałów*, ed. Jan Górski (Warsaw: Państwowe Wydawnictwo Naukowe, 1977).

308 Tomasz Fudala, *Spór o odbudowę Warszawy: od gruzów do reprywatyzacji* (Warsaw: Muzeum Sztuki Nowoczesnej, 2016).

309 Stanisław Jankowski, "Warsaw: Destruction, Secret Town Planning, 1939–44, and Postwar Reconstruction," in *Rebuilding Europe's Bombed Cities*, ed. Jeffry M. Diefendorf (London: Palgrave Macmillan UK, 1990), 77–93.

While the historic centre was reconstructed with an emphasis on authenticity, modern construction methods and materials were employed where appropriate, to create the post-war residential district[310]. Wherever possible, original building materials, sculptural fragments, and architectural details salvaged from the ruins were incorporated into the new structures, enhancing their authenticity. When complete documentation was unavailable, architects relied on comparisons with similar buildings or typical architectural elements from the same period to create historically plausible reconstructions. The reconstruction of Warsaw's historic city centre was officially completed in 1953[311].

Fig. 30. Reconstructed historical city centre and Barbican, Warsaw. Source: author, 2025.

Beyond the historic core, the post-war development of Warsaw was characterised by a more modernist and pragmatic approach, guided largely by the needs of the socialist state and rapid urbanisation. New districts such as Muranów and the Marszałkowska Residential District (MDM) were constructed according to contemporary urban planning principles, reflecting both socialist ideology and the urgent need for rapid housing development. This process marked a conscious departure from the traditional, pre-war urban fabric, as planners sought to implement new spatial solutions, frequently introducing wide green belts and separating functional zones.

New landmark projects were also constructed, most notably the socialist realist Palace of Culture and Science, a deliberately monumental insertion into the city's centre. Its scale and architectural style not only broke with the historic skyline but also served as a powerful political statement, signifying Soviet influence and the dawn of a new social order.

Later, with the rise of socialist modernism and the introduction of large-panel prefabricated building techniques, districts such as Ursynów, Służew, and parts of Mokotów were developed, offering much-needed housing for Warsaw's rapidly growing population and increasing development density. However, as Krystyna Guranowska-Gruszecka notes, the lack of a comprehensive and consistent urban planning framework led to a fragmented and polycentric city structure. Individual projects and new nodes of urban activity often emerged in isolation, without sufficient integration into the broader urban context. As a result, Warsaw's post-war growth reflected both the ambitions and the limitations of centrally planned development, resulting in a complex urban landscape that continues to evolve

[310] Piotr Biegański, "Odbudowa Starego Miasta w Warszawie jako dzielnicy mieszkaniowej," in *Stare Miasto w Warszawie. Odbudowa*, ed. Zofia Szanajca-Kossakowska (Warsaw: Architektura i Budownictwo, 1956), 7–18; Jan Zachwatowicz, *Ochrona zabytków w Polsce* (Warsaw: Polonia, 1965), 51–57.

[311] Jan Zachwatowicz, "Stare Miasto Warszawa wraca do życia," *Ochrona Zabytków* 6, nos. 2–3 (1953): 73–77.

today[312]. Consequently, the city has come to be defined by a diverse blend of reconstruction and redevelopment approaches[313].

Royal Castle in Warsaw

Although the reconstruction of Warsaw's historic city centre was completed in 1953, the fate of the Royal Castle remained unresolved. Once a symbol of the royal court and national identity, the Castle was almost completely destroyed by German forces during the war, with only fragments of its lower storey and a few architectural elements surviving. The Royal Castle first suffered severe damage in September 1939, when it was targeted by German air raids and artillery fire. During the subsequent German occupation, the building was systematically plundered and its valuables were looted. The most devastating destruction occurred after the Warsaw Uprising of 1944. In retaliation, and as part of a broader policy to obliterate the city, German demolition squads methodically blew up what remained of the Castle. By early 1945, only remnants of the walls and foundations survived, leaving the Castle in ruins and serving as a powerful symbol of both cultural loss and the brutality of the occupation.

While the reconstruction of the Old Town was considered essential for restoring national identity and historical continuity, the Royal Castle, which had served as a royal and state residence, was initially regarded by the communist authorities as less urgent and ideologically problematic because of its ties to prewar elites and the monarchy. However, in 1971, in response to widespread public support and changing political circumstances, the authorities[314] decided to allow for the reconstruction of the Castle in its original form. This decision was made possible by a nationwide grassroots movement, extensive fundraising efforts, and a shift in political attitudes[315].

Fig. 31. Royal Castle in Warsaw. Source: author, 2025.

Similar to the approach taken with the historic city centre, the restoration of the Royal Castle was based on a comprehensive range of historical sources, including architectural plans, archival photographs, paintings, and detailed inventory drawings. A special committee was established, with a dedicated subsection responsible for developing the reconstruction guidelines for the castle. Surviving elements

[312] Krystyna Guranowska-Gruszecka, "Shaping of the Centre of Warsaw – History of Activities and Views, Visions of Future," *Space & Form / Przestrzeń i Forma* 30 (2017): 9–46.

[313] This section is intentionally limited, as the author's aim is to focus solely on issues of reconstruction, rather than on the subsequent contemporary development of cities following their destruction.

[314] Closely linked to Edward Gierek's leadership (1970–1980), when increased openness to national heritage and symbols of statehood reflected a shift in political attitudes.

[315] Tomasz Torbus, *Rekonstrukcje, dekonstrukcje, (nad)interpretacje: studia o losach architektury środkowoeuropejskich miast i rezydencji w aspekcie politycznym (XIX–XXI wiek)* (Gdańsk: Słowo/obraz terytoria, 2019), 163.

from the original building were incorporated into the new structure[316]. Completed in 1984, the Royal Castle was fully reconstructed and was not only a museum and a cultural landmark, but also a symbol of Polish resilience and the collective will to restore the nation's historic legacy.

While the reconstruction of Warsaw's historic city centre is associated with the era of socialist realism, when traditional building practices were still prevalent, the case of the Royal Castle aligns more closely with the period of soc-modernism, which favoured new architectural approaches over established traditions. The reconstruction of the Royal Castle is also particularly interesting in light of the Venice Charter of 1964, which rejects comprehensive reconstructions in favour of clearly distinguishable, contemporary interventions. While the historic city centre was rebuilt soon after the war, work on the Royal Castle did not begin until about 25 years later. Drawing on his experiences, Zachwatowicz uses the term "restitution" to distinguish the Warsaw project from the types of actions described in the Venice Charter[317]. As Zachwatowicz points out, the Polish approach to reconstruction did not constitute a fixed doctrinal "school" of conservation, but rather a pragmatic response to the exceptional historical circumstances of postwar Poland. The immense scale of wartime destruction and the urgent need to restore national identity justified the use of methods that, while diverging from international theory, were seen as necessary under the circumstances[318]. Nevertheless, the reconstruction of the historic centre could not be considered complete without the Royal Castle. This contrast, and the deviation from prevailing conservation doctrines, make the Royal Castle's and the historical city centre reconstruction an especially intriguing example[319].

The Old Town and Royal Castle were reconstructed to their pre-war appearance, so that the project was regarded not only as a technical achievement, but also as an act of national and cultural revival. Serving as a powerful symbol of Poland's resilience and determination to recover from immense loss, against the conservation doctrine[320], the reconstructed Old Town was inscribed on the UNESCO World Heritage List in 1980 as an outstanding example of comprehensive reconstruction[321].

Gdańsk[322]

While the reconstruction of Warsaw was widely regarded as a national effort to restore the country's devastated heritage, the case of Gdańsk was far more complex due to its unique historical

---

316 Jan Zachwatowicz, "Odbudowa Zamku Królewskiego w Warszawie: Prace Komisji Architektoniczno-Konserwatorskiej Obywatelskiego Komitetu Odbudowy Zamku Królewskiego w Warszawie," *Ochrona Zabytków* 26, no. 1 (1973): 13–20.

317 *Jan Zachwatowicz, "Problemy restytucji Zamku Królewskiego w Warszawie," Ochrona Zabytków 32, no. 1 (1979): 3–18.*

"The Venice Charter does not provide for the possibility of 'reconstruction,' that is, recreating a monument, except in cases where it is assembled from surviving authentic fragments. (...) Despite the considerable number of preserved fragments that have returned or are returning to their former locations, it would be difficult to describe this process of recreation as 'anastylosis,' yet the term 'reconstruction' is not appropriate here either. One could ultimately use the word 'rebuilding,' but in my view, the most appropriate term is 'restitution.'"

318 Jan Zachwatowicz, "O polskiej szkole odbudowy i konserwacji zabytków," *Ochrona Zabytków* 34, nos. 1–2 (1981): 4–10.

319 Łukasz Bugalski and Piotr Lorens, "Post-Second World War Reconstruction of Polish Cities: The Interplay between Politics and Paradigms," *Urban Planning* 8, no. 1 (2023). https://doi.org/10.17645/up.v8i1.6116.

320 The case of Warsaw illustrates how urban reconstruction can integrate heritage preservation with contemporary approaches, a model of particular relevance for the post-war rebuilding of Ukrainian cities.

See Galyna Fesenko, "Rebuilding the Architectural Heritage: Reflections on the Case of Post-War Warsaw," in *Theory and Practice of Modern Science*, 186–89 (2023).

321 *Historic Centre of Warsaw*, UNESCO World Heritage List, site no. 30 (inscribed 1980; minor boundary modification 2014), accessed June 29, 2025, https://whc.unesco.org/en/list/30/

322 As with the discussion of Warsaw, the scope here will be strictly limited to the topic of reconstruction and will be presented in a highly condensed form. This is a conscious decision, especially since Gdańsk is the author's hometown and holds personal significance. The author therefore chooses to address the issue briefly, treating Gdańsk's reconstruction as a phenomenon similar to that of Warsaw, but also recognizing its unique character.

background[323]. The city suffered extensive destruction in March 1945, when Soviet and Polish forces encircled and eventually captured the heavily fortified city, which was defended by the Wehrmacht. Following intense bombardment and fierce street fighting, Gdańsk fell on March 30, 1945[324]. Much of the historic city was subsequently looted and destroyed by shellfire and numerous fires that broke out after the collapse of fire prevention measures[325]. An interesting perspective on the Polish view of prewar Gdańsk is provided by Jan Kilarski in his 1937 publication[326], in contrast to the ruin in 1945. The ruined city centre, filled with burned-out buildings and lacking stabilisation of surviving structures, suffered even further damage during a severe storm in February 1946, causing additional collapses[327].

The devastated state of the city was thoroughly documented by Kazimierz Lelewicz[328], who took numerous photographs capturing the extent of the destruction[329], as well as Zbigniew Kosycarz, and people later involved in the rebuilding process.

The reconstruction of Gdańsk has been the subject of research and description by numerous authors, mostly in polish language. Among the earliest were Jerzy Stankiewicz and Bohdan Szermer, whose summary of the reconstruction was published in 1958[330]. The similar article was published in monography dedicated to city of Gdańsk in 1969[331]. Jan Zachwatowicz in 1965 presented his summary on case of Gdańsk, presenting the limitations of carried out reconstruction[332]. Bohdan Szermer presented his publication on the reconstruction and rebuilding of Gdańsk in 1971[333], where he presents many design photographs, including design models, and a synthesis on city destruction in the form of a chart. In 1978 for the first time the memories of the reconstruction were published[334], in the form of primary source. Another notable work is Lech Krzyżanowski's 1986 publication, which focuses on the reconstruction within the urban context[335]. Dedicated to the commemoration of 1000 years of the city

[323] The reconstruction of Gdańsk was considered the third most important, following Warsaw and Poznań and preceding Wrocław and Szczecin. This sequence reflects a broader approach to the complex heritage of cities affected by shifting borders.

See Marcin Gawlicki, *Zabytkowa architektura Gdańska w latach 1945–1951: kształtowanie koncepcji, konserwacji i odbudowy* (Gdańsk: Słowo/obraz terytoria, 2012), 171.

[324] Bolesław Dolata and Tadeusz Jurga, *Walki zbrojne na ziemiach polskich 1939–1945: Wybrane miejsca bitew, walk i akcji bojowych*, ed. Jan Brodala (Warsaw: Rada Ochrony Pomników Walki i Męczeństwa, 1970), 99–102.

[325] An interesting perspective is offered by Maciej Zakiewicz in his book "Gdańsk 1945. Kronika wojennej burzy", in which he draws on numerous personal accounts to depict the horrors experienced during the liberation of Gdańsk.

See Maciej Żakiewicz, *Gdańsk 1945: Kronika wojennej burzy* (Gdańsk: Oskar, 2011).

[326] Jan Kilarski, *Gdańsk* (Poznań: Wydawnictwo Polskie R. Wagner, 1937).

[327] Jacek Friedrich, *Odbudowa Głównego Miasta w Gdańsku w latach 1945–1960* (Gdańsk: Słowo/obraz terytoria, 2015), 50–51.

[328] "Lelewicz Kazimierz, fotografik," *Encyklopedia Gdańska*, Gedanopedia (Fundacja Gdańska / Muzeum Gdańska), accessed July 13, 2025, https://gdansk.gedanopedia.pl/gdansk/?title=LELEWICZ_KAZIMIERZ,_fotografik

[329] "Między zniszczeniem a odbudową – Gdańsk na fotografii Kazimierza Lelewicza," *Google Arts & Culture*, Muzeum Gdańska, accessed July 13, 2025, https://artsandculture.google.com/story/mi%C4%99dzy-zniszczeniem-a-odbudow%C4%85-%E2%80%93-gda%C5%84sk-na-fotografii-kazimierza-lelewicza/9QUBrz3ybHcAzg?hl=pl

[330] Jerzy Stankiewicz and Bohdan Szermer, *Gdańsk: rozwój urbanistyczny i architektoniczny oraz powstanie zespołu Gdańsk–Sopot–Gdynia* (Warsaw: Arkady, 1959), 264–309.

[331] Janusz Kowalski, Ryszard Massalski, and Jerzy Stankiewicz, "Rozwój urbanistyczny i architektoniczny Gdańska," in *Gdańsk: jego dzieje i kultura*, ed. Franciszek Mamuszka (Warsaw: Arkady, 1969), 215–47.

[332] Jan Zachwatowicz, *Ochrona zabytków w Polsce* (Warsaw: Polonia, 1965), 57–61.

[333] Bohdan Szermer, *Gdańsk – przeszłość i współczesność* (Warsaw: Interpress, 1971), 83–118.

[334] Izabella Trojanowska, *Wspomnienia z odbudowy Głównego Miasta* (Gdańsk: Marpress, 1997).

[335] Lech Krzyżanowski, "Gdańsk," in *Zabytki urbanistyki i architektury w Polsce: Odbudowa i konserwacja*, ed. Wiktor Zin (Warszawa: Arkady, 1986).

of Gdańsk, Robert Hirsch, Krzysztof Krzempek, and Piotr Popiński published an album[336] with comparative photographs, showing the changes of the city on given examples, providing deeper insight into the city's evolution and reconstruction efforts. Maciej Gawlicki presented in 2012 the publication presenting the multiple conservation efforts, from the perspective of a conservator and an architect[337], while Jacek Friedrich[338] presented from the perspective of an art historian. These efforts were even deepen by Andrzej Macur who publishes two publications focusing of his father[339], and his own[340] efforts in reconstruction and stabilization of heritage objects in Gdańsk. Recently in 2023 Lukasz Bugalski presented study[341] that focused mostly on western part of the historical city, but included numerous archival sources on reconstruction and rebuilding.

Fig. 32. Photographs of destroyed city of Gdańsk by Kazimierz Lelewicz (source: Google Arts & Culture[342]).

As in Warsaw, one of the original concepts for post-war Gdańsk was to preserve the ruins as a memorial to the city's destruction. However, this idea was quickly abandoned, largely due to the urgent need to provide housing for workers and to create new residential estates[343]. The reconstruction process, both in Warsaw and Gdańsk, proved to be far more complex than initially anticipated, with different areas of the city approached according to distinct philosophies and priorities.

Before its destruction, Gdańsk consisted of several historically distinct districts, most notably the so-called "Main Town" (Główne Miasto), "Old Town" (Stare Miasto), and adjoining quarters, covering a

[336] Robert Hirsch, Krzysztof Krzempek, and Piotr Popiński, *Gdańsk: Dwa oblicza miasta* (Gdańsk: Holm, 1997).

[337] Marcin Gawlicki, *Zabytkowa architektura Gdańska w latach 1945–1951: Kształtowanie koncepcji, konserwacji i odbudowy* (Gdańsk: Słowo/obraz terytoria, 2012).

[338] Jacek Friedrich, *Odbudowa Głównego Miasta w Gdańsku w latach 1945–1960* (Gdańsk: Słowo/obraz terytoria, 2015).

[339] Andrzej Macur, *Gdańsk Kazimierza Macura* (Gdańsk: Słowo/obraz terytoria, 2016).

[340] Andrzej Macur, *Pół wieku z zabytkami* (Gdańsk: Słowo/obraz terytoria, 2018).

[341] Łukasz Bugalski, *Zachodni front śródmieścia Gdańska: Studium urbanistyczno-konserwatorskie* (Gdańsk: Słowo/obraz terytoria, 2023).

[342] "Między zniszczeniem a odbudową — Gdańsk na fotografii Kazimierza Lelewicz," Google Arts & Culture, accessed July 13, 2025, https://artsandculture.google.com/story/mi%C4%99dzy-zniszczeniem-a-odbudow%C4%85-%E2%80%93-gda%C5%84sk-na-fotografii-kazimierza-lelewicza/9QUBrz3ybHcAzg?hl=pl.

[343] Janusz Kowalski, Ryszard Massalski, and Jerzy Stankiewicz, "Rozwój urbanistyczny i architektoniczny Gdańska," in *Gdańsk: Jego dzieje i kultura*, ed. Franciszek Mamuszka (Warszawa: Arkady, 1969), 224.

total area of around 4.5 square kilometres. A large proportion of the building stock in these areas was severely damaged or destroyed during the war.

In the immediate aftermath of the war, the Gdańsk Planning Bureau (Biuro Planu "GD") was established as the main institution responsible for drawing up urban plans and reconstruction strategies for the devastated city. Its work laid the foundations for the post-war rebuilding of Gdańsk's Main Town, striving to strike a balance between the preservation of historical structures and the requirements of a modern city. In 1947, the Bureau compiled a comprehensive study of war damage, which served both as an inventory and as an assessment of destruction, providing a crucial basis for the future development of the historic city centre[344]. At the same time, new visions for the city's reconstruction were developed, most notably by Władysław Czerny, whose 1948 project. "Szkic projektu odbudowy" (eng. Draft of rebuilding project), proposed the extension of the Royal Route with new developments inspired by socialist realism[345]. In the years that followed, successive plans for the Main Town were created, constantly adapting to evolving possibilities and changing priorities.

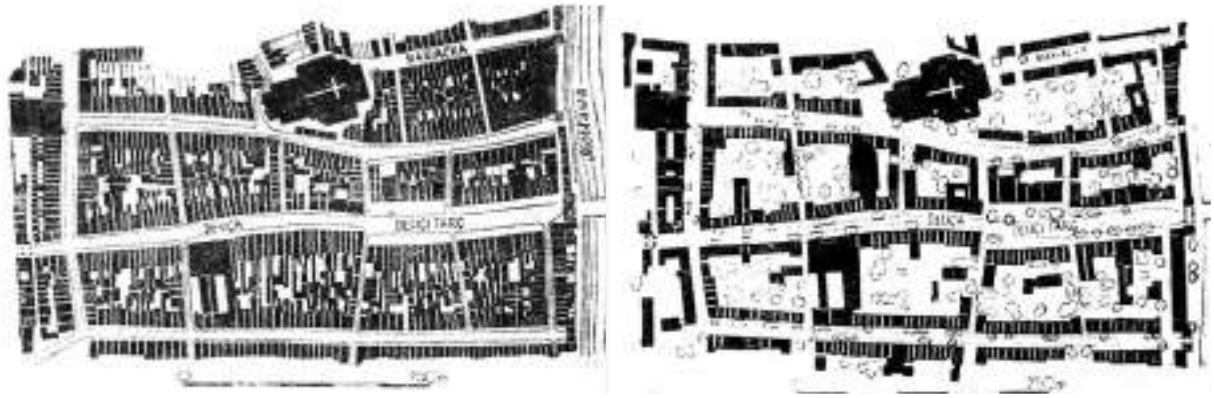


Fig. 33. Change in building density. Left: prewar Gdańsk. Right: Gdańsk after reconstruction (source: Stankiewicz and Szermer 1959[346]).

Given the available documentation, such as pre-war photographs, the decision was taken to concentrate reconstruction efforts primarily on the most prestigious district, the Main Town[347] . This area contains the city's most important landmarks, including the Town Hall, St Mary's Church, the Great Crane, the Green Gate, and Artus Court. The reconstruction of the Main Town entailed many key decisions aimed at recreating the city in a modernised form. Although many prominent buildings and churches were damaged, most were not entirely destroyed. In many cases, the main structural walls of significant monuments such as the Great Armoury, the Town Hall, and Artus Court survived, while much of the reconstruction effort focused on rebuilding vaults, roofs, and architectural details, particularly in the case of the city's churches. Another crucial aspect of the post-war period was the fate of the city's population. A significant proportion of Gdańsk's pre-war population was displaced or deported, and the city was subsequently repopulated by newcomers and repatriates from Poland's eastern

344 Jacek Friedrich, *Odbudowa Głównego Miasta w Gdańsku w latach 1945–1960* (Gdańsk: Słowo/obraz terytoria, 2015), 23–37.

345 Jacek Friedrich, *Odbudowa Głównego Miasta w Gdańsku w latach 1945–1960* (Gdańsk: Słowo/obraz terytoria, 2015), 90–96.

346 Jerzy Stankiewicz and Bohdan Szermer, *Gdańsk: Rozwój urbanistyczny i architektoniczny oraz powstanie zespołu Gdańsk–Sopot–Gdynia* (Warsaw: Arkady, 1959), 274.

347 Not to be confused with the Old Town. The Old Town, so named because the first settlements were established around the Church of Saint Catherine. However, because the postwar reconstruction did not involve rebuilding the historic residential structures, the district has largely lost its "old" character.

borderlands[348]. This resulted in a marked break with pre-war traditions and a loss of the city's former local identity, visible in the reconstruction processes[349].

Residential buildings faced a different set of challenges. Most of the original dwellings were destroyed and, for various reasons, were rebuilt using new approaches. According to Stankiewicz and Szermer, the reconstruction plan called for reducing the depth of residential blocks by about one-third to create inner courtyards for community use[350]. This concept reflected new ideas in urban development, partly inspired by discussions at the 1933 Athens Charter. This approach marked a departure from the prewar layout, in which densely built plots and numerous annexes characterized the city blocks to accommodate a growing population. Because the government prioritized building as many new dwellings as possible, many simplifications were introduced. Ogarna Street, the first to be fully reconstructed with this new urban layout, serves as a clear example of these changes. Most of the new buildings were combined into larger blocks of flats, which reduced the number of staircases and allowed for the creation of more spacious apartments within each block[351]. Restoration efforts focused on recreating the appearance of the original buildings, using archival documentation, photographs, and reincorporation of surviving fragments into new structures, blending contemporary blocks of flats with authentic historical decoration.

Fig. 34. Project of reconstruction of Ogarna street (source: Stankiewicz and Szermer 1959[352]).

Not every structure was rebuilt; the case of Świętego Ducha (St Spirit) Street offers an instructive example of this selective approach. Here, one of the street's façades was intentionally left unreconstructed, instead serving as a spatial reserve and creating a pocket park within the historic city centre, complete with partially reconstructed forecourts. On the same street, the former Sailors' Guild at Świętego Ducha 107 provides further insight into the reconstruction process, where salvaged bricks and stone elements were reused, and the mannerist façade was reconfigured to accommodate an additional storey, making the building more suitable for contemporary use[353].

[348] After World War II, Poland underwent large-scale resettlements that dramatically changed its demographic landscape. Millions were displaced, including Germans expelled from newly annexed western territories and Poles forced to leave areas incorporated into the Soviet Union. Minority groups such as Ukrainians and Lemkos were also resettled as part of government campaigns.

[349] Similar case of socialist realism reconstruction of historical city centre can be observed in Olsztyn.

[350] Jerzy Stankiewicz and Bohdan Szermer, *Gdańsk: Rozwój urbanistyczny i architektoniczny oraz powstanie zespołu Gdańsk–Sopot–Gdynia* (Warszawa: Arkady, 1959), 274.

[351] Although the façades often imitated the vertical divisions of historic tenement houses to preserve the prewar appearance, these divisions were mostly decorative. In reality, a single apartment could span across what appeared to be two separate "tenement houses."

[352] Jerzy Stankiewicz and Bohdan Szermer, *Gdańsk: Rozwój urbanistyczny i architektoniczny oraz powstanie zespołu Gdańsk–Sopot–Gdynia* (Warsaw: Arkady, 1959), 276.

[353] Due to the complexity of the reconstruction issues involved, an in-depth analysis of this case will be presented in a separate scientific publication. In the present thesis, the author originally intended to use St Spirit Street as an example of

Fig. 35. Inventory of The Holy Spirit street in Gdańsk, post reconstruction state. Source: author in cooperation with students, 2022.

During the post-war reconstruction of Gdańsk, the city's complex history played a significant role in shaping decisions about which buildings were restored. Many structures from the nineteenth century were deliberately not rebuilt, in favour of recreating earlier, predominantly Polish, architectural forms. This approach reflected the broader policy of "Polonisation" pursued in the late 1940s, which aimed to reinforce Gdańsk's image as a historic Polish city. This policy was evident in the intentional dismantling of partially surviving nineteenth-century buildings that could otherwise have been adapted or repurposed. Notable examples include the Senate of the Free City of Gdańsk, the theatre on the Coal Market, the Danziger Hof Hotel, the Municipal Savings Bank on Granary Island, the post office on Długa Street, and numerous department stores from the late nineteenth and early twentieth centuries. Many of these buildings, although only partially damaged rather than completely destroyed, were either demolished or left unrestored, as they were considered undesirable elements of the city's heritage. This selective approach to reconstruction contributed to a break with the city's recent past and the deliberate shaping of a new, ideologically-driven urban identity[354].

From a reconstruction perspective, the case of the historic tenement at 14 Chlebnicka Street is particularly compelling. Originally constructed in the early sixteenth century in the late Gothic style, the building was renowned for its remarkable sandstone façade. In 1823, this façade was carefully dismantled and transported to Berlin, where it was incorporated into the *Kavalierhaus on Pfaueninsel* by Karl Friedrich Schinkel. During Gdańsk's post-war reconstruction, a faithful replica of the original façade was created on the site, using detailed measurements of the relocated original and archival records[355]. This has produced a unique situation, with two nearly identical façades now existing, one in Gdańsk and one in Berlin[356].

---

the direct application of virtual reconstruction. However, given that the case is more architectural in scope than urban, it was decided to postpone a detailed study for a future publication.

[354] Jacek Friedrich, *Odbudowa Głównego Miasta w Gdańsku w latach 1945–1960* (Gdańsk: Słowo/obraz terytoria, 2015), 57–61.

[355] Małgorzata Omilanowska and Edmund Kizik, "Wędrująca kamienica: Kilka uwag o translokacji i zreplikowaniu kamienicy gotyckiej przy ulicy Chlebnickiej w Gdańsku w świetle dokumentów," in *Budowanie nad Bałtykiem: Studia z architektury i sztuki Gdańska, Pomorza i Żmudzi*, ed. Małgorzata Omilanowska (Gdańsk: Słowo/obraz terytoria, 2017), 52–63.

[356] The story of the Chlebnicka 14 façade strongly echoes postmodern philosophical concepts of simulation and authenticity. The physical doubling of the façade, with an original in Berlin and a reconstruction in Gdańsk, illustrates Baudrillard's notion

Unlike the Main Town, the reconstruction of the Old Town and Old Suburb was not regarded as a top priority by post-war authorities and planners, resulting in these areas being addressed at a later stage. The interventions and planning phases extended beyond the era of Stalinism and socialist realism in Poland, ushering in a second wave of modernism, often referred to as "soc-modernism", with its first project developed in 1958[357], that based on the same inventory study as Main Town. While the Main Town underwent a comprehensive restoration of its historic street patterns and urban blocks, albeit with reduced density, the approach in the Old Town and Old Suburb was markedly different. In these districts, planners frequently made a conscious decision not to recreate the former parcel divisions or the densely built pre-war fabric. Instead, a policy of selective reconstruction was adopted, concentrating on the restoration of the most valuable historic monuments, such as churches, town halls, and a limited number of townhouses. The majority of residential buildings were replaced by new constructions in simplified forms, or the districts were provided with entirely new urban layouts. In much of the Old Town and Old Suburb, post-war planning introduced modern solutions, favouring open spaces, greenery, and blocks of flats over the traditional dense development.

Fig. 36. Reconstructed Main Town of Gdańsk. Source: author, 2023.

The widespread belief that post-war Gdańsk, particularly the Main Town, was faithfully reconstructed as a replica of its pre-war appearance is, as Friedrich points out, largely a myth. In reality, the process of rebuilding was profoundly influenced by political agendas, both during the communist period and after 1989, leading to significant departures from strict historical accuracy. The present-day Main Town thus only resembles its historical form and stands as a clear example of post-war selective reconstruction, guided by available historical sources rather than a desire for exact replication. The reconstruction also created the framework for a new, largely incoming population, which played a decisive role in shaping a new urban identity for Gdańsk. In the following decades, the city's urban fabric underwent further transformation as a result of incomplete reconstruction, the layering of contemporary architectural interventions, and the intensification of development. In recent years, the effects of Disneyfication and increasing tourism have posed additional challenges, continually reshaping both the image and the everyday reality of historic Gdańsk.

of the "simulacrum," where the copy acquires its own life, meaning, and even authority, sometimes surpassing that of the original.

[357] Jacek Friedrich, *Odbudowa Głównego Miasta w Gdańsku w latach 1945–1960* (Gdańsk: Słowo/obraz terytoria, 2015), 306–15.

2.6 Modern Rebuilding

Kaiser Wilhelm Memorial Church in Berlin

While post-war reconstruction efforts in many European cities focused on restoring buildings to their pre-war condition, certain sites were intentionally left with visible traces of destruction. These locations reflect a conscious choice to preserve war damage as a historical record, rather than conceal it through full reconstruction.

A notable example is the Kaiser-Wilhelm-Gedächtniskirche in West Berlin. Designed by Franz Schwechten and constructed between 1891 and 1895 in the neo-Romanesque style, the church was commissioned by Kaiser Wilhelm II to commemorate his grandfather, Kaiser Wilhelm I. The building suffered extensive damage during an Allied air raid in November 1943, with only the western façade and its damaged tower surviving. After the war, discussions considered both demolition and preservation of the remaining structure. The final decision was to retain the ruined tower and façade as a memorial. Architect Egon Eiermann was commissioned to design a new church complex, completed in 1963, that incorporated the historic remnants into a new architectural ensemble. This ensemble comprises the preserved tower, an octagonal chapel, and a separate bell tower. The modern additions, characterized by geometric forms and stained-glass walls, were deliberately designed not to replicate the original structure but to contrast with the historic remains. The resulting complex is an example of integrating preserved ruins within a new architectural context. The original damaged elements serve as a record of wartime destruction, while the new buildings fulfil liturgical functions and introduce contemporary architectural language. This approach illustrates how authentic material can be preserved alongside new construction, providing both historical continuity and functional adaptation[358].

Fig. 37. Kaiser Wilhelm Memorial Church in Berlin. Source: author, 2023.

At around the same time, a similar approach was adopted at Coventry Cathedral in the United Kingdom. The cathedral was destroyed during German air raids in the Blitz of 1940–1941. Instead of fully reconstructing the original building, the decision was made to preserve its ruins as a lasting record of wartime destruction. A new cathedral was subsequently built adjacent to the remains, allowing the preserved ruins to function as a monument and historical witness to the impact of the Second World

[358] Rüdiger Zill, "'A True Witness of Transience': Berlin's Kaiser-Wilhelm-Gedächtniskirche and the Symbolic Use of Architectural Fragments in Modernity," *European Review of History / Revue européenne d'histoire* 18, no. 5–6 (2011): 811–27, https://doi.org/10.1080/13507486.2011.618332.

War[359]. Despite being located in different countries, the treatment of Coventry Cathedral and the Kaiser-Wilhelm-Gedächtniskirche in Berlin demonstrates a comparable approach, highlighting a significant development in post-war conservation doctrine[360].

Rotterdam, Le Havre

In contrast to Berlin and Coventry, post-war Rotterdam was redeveloped through a decisive commitment to modernism and comprehensive urban renewal. On May 14, 1940, the city centre was devastated by the German Luftwaffe, resulting in significant loss of life and destruction of infrastructure. The psychological impact of the bombing led to the Dutch capitulation the following day[361].

Fig. 38. Rotterdam, White house with redeveloped city centre. Source: Anna Kolasa, 2024.

Prior to the war, Rotterdam's city centre was characterized by a dense network of medieval and early modern buildings, canals, and a distinctive urban heritage that reflected centuries of architectural development. The bombing almost entirely erased this historic fabric, marking a profound loss not only of buildings but also of the city's traditional urban identity. One notable exception was the "Witte Huis" ("White House"), an iconic early skyscraper built in 1898, which survived the air raid and remains a rare vestige of pre-war Rotterdam. Rather than restoring the pre-war urban fabric or preserving ruins, Rotterdam's planners viewed the destruction as an opportunity to apply modernist planning principles. Influenced by the ideas of the Athens charter of 1933 (CIAM), the post-war reconstruction prioritized functionality, efficiency, and open public spaces. The initial plan by Willem Gerrit Witteveen, later adapted by Cornelis van Traa, envisioned a new city layout with wider streets, separated pedestrian and vehicle traffic, integrated green areas, and a strong emphasis on commercial development. Historic continuity was largely set aside in favour of progress and innovation, making Rotterdam an example of post-war modern urbanism and architectural transformation[362]. The resulting cityscape, shaped by modernist ideals, stands today as a testament to both the scale of wartime destruction and the

[359] Richard Thomas Howard, *Ruined and Rebuilt: The Story of Coventry Cathedral 1939–1962* (Coventry: The Council of Coventry Cathedral, 1962).

[360] Interestingly also the bell tower survived during the destruction, making those two examples even more similar.

[361] At the outset of World War II, the Netherlands declared neutrality, as it had during World War I. Nevertheless, on May 10, 1940, German forces invaded the country as part of their plan to circumvent the French Maginot Line. This strategy was reminiscent of the Schlieffen Plan used in World War I, which sought to bypass French defences by advancing through the Netherlands and Belgium toward Paris. However, unlike in the First World War, the German offensive in the spring of 1940 was successful, leading to the rapid capture of Paris.

[362] Jukka Jokilehto, *A History of Architectural Conservation*, 2nd ed. (New York: Routledge, 2017), 286.

ambition of mid-20th-century urban planning, which later evolved into a dense landscape of glass skyscrapers, further distancing the city from its lost historical context.[363].

Le Havre was another area heavily impacted during the Second World War. Located in North Normandy, this port city on the northern bank of the Seine River featured a vast industrial wharf capable of handling large quantities of war equipment. Declared a Festung (fortress) by Hitler[364] in 1944, and part of Atlantic Wall, was ordered to be defended to the last man. Le Havre became the target of "Operation Astonia" in September 1944, a strategic effort to secure another deep-water port[365] and facilitate the Allied breakout from Normandy. The Allies launched an intensive bombardment phase to weaken and destroy German troop concentrations in Le Havre. This included large-calibre naval bombardments and multiple air raids. The assault inflicted catastrophic damage, with most of the of the city centre destroyed. Historic landmarks, including 16th-century buildings, Gothic-style churches, houses, schools, and other significant sites, were obliterated[366]. The port and industrial zones, crucial to Allied objectives, were also almost completely demolished, leaving a impact on Le Havre's historical and cultural heritage[367], and resulted in high civil loses[368].

As in Rotterdam, the decision was taken not to reconstruct the historical urban fabric of Le Havre, but to reimagine it entirely. The responsibility for this ambitious undertaking was entrusted to Auguste Perret. His vision sought to merge functionality with modernist aesthetics, resulting in an urban layout based on an orthogonal modular grid, a clear departure from the city's former organic structure. Perret's design emphasised geometric order, broad boulevards, and the interplay of light and space, all in alignment with the principles set out in CIAM's Athens Charter. A staunch proponent of béton brut, he made extensive use of exposed concrete, which was regarded both as a symbol of modern progress and a practical material for rapid post-war reconstruction. Nevertheless, many critics argued that this approach disregarded the city's historical identity[369]. Completed in 1964, the minimalist architecture of the rebuilt centre stood in stark and conscious contrast to the pre-war cityscape, raising concerns over cultural loss[370]. Despite ongoing debate, Le Havre's city centre was inscribed on the UNESCO World

[363] John McCarthy, "Reconstruction, Regeneration and Re-Imaging: Case of Rotterdam," *Cities* 15, no. 5 (1998): 337–44, https://doi.org/10.1016/S0264-2751(98)00029-8.

[364] The term Festung (fortress) was used by Hitler to designate cities and areas as heavily fortified strongholds, meant to be defended to the last man. This strategy aimed to delay or prevent Allied advances by treating these locations as last-ditch defensive positions, with extensive fortifications and garrisons. Cities like Brest, Cherbourg, Le Havre, Calais, Gdańsk, Poznań, Wrocław, Konigsberg, Kostrzyn, Antwerp, others and ultimately Berlin, were designated Festungen. While these defences delayed the Allies, they often resulted in heavy casualties and destruction, and the cities were eventually captured despite the fortifications.

[365] This operation aimed to supplement the port of Cherbourg, which had been captured earlier in June 1944 but remained inoperative for an extended period due to German sabotage.

[366] With approximation around 80%, similarly to Gdańsk and Warsaw.

[367] Andrew Knapp, "The Destruction and Liberation of Le Havre in Modern Memory," *War in History* 14, no. 4 (2007): 476–98, https://doi.org/10.1177/0968344507081551; Karel Margry, "The Capture of Le Havre," *After the Battle*, no. 139 (2008): 2–31.

[368] Critics argue that the scale of destruction in Le Havre was disproportionate to the military objectives, as only a small part of the city remained under German control. The bombing resulted in over 5,000 civilian deaths and thousands more injuries, sparking debates over the ethics of targeting civilian areas for military gains.

[369] Interestingly, the city of Rouen, located approximately 60 kilometres from Le Havre, also sustained significant damage during the Allied northern advance, yet its post-war reconstruction followed a markedly different approach. Rather than opting for radical redesign, Rouen pursued a historically sensitive strategy that carefully integrated surviving structures with new construction. Notably, the city's iconic Gothic cathedral, whose spire had been destroyed, was restored, along with the historic half-timbered houses in the old town. This approach aimed to preserve Rouen's architectural identity and reinforce continuity with its pre-war urban character.

[370] Hugh Clout, "The Reconstruction of Upper Normandy: A Tale of Two Cities," *Planning Perspectives* 14, no. 2 (1999): 183–207, https://doi.org/10.1080/026654399364292; Paweł Piotr Szumigała and Karolina Olenia Szumigała, "Forgotten

Heritage List in 2005, recognised as an "exceptional example of post-war architecture and urban planning"[371].

Modernistic rebuilding of polish towns[372]

The shift in dominant artistic style from socialist realism to social modernism that occurred in Poland after 1956 also influenced approaches to destroyed heritage, as modernism typically rejected historical tradition. Consequently, the majority of rebuilt mid-sized towns and provincial settlements were rebuilt according to modernist principles, leading to the discontinuity of traditional urban landscapes. Towns such as Szczecin, Malbork (excluding the castle), Koszalin, Kołobrzeg, Lidzbark Warmiński, Braniewo, Kętrzyn and others represent a group of prewar German towns that were extensively damaged during the Second World War due to the trajectory of the Soviet offensive towards Berlin. These towns were later incorporated into Poland's postwar territory and officially designated as Ziemie Odzyskane (Recovered Territories)[373]. The struggle between new polish inhabitants on recovered territories with German heritage has been partially described by Tomasz Torbus, he presents two approaches one – intentional "deconstruction"[374] and familiarization through reconstruction[375]. In most cases, the rebuilding process prioritised the implementation of modernistic blocks of flats into the historical urban fabric of the destroyed settlements, resulting in a rupture with the preexisting architectural traditions[376]. This approach aligns with the case studies of Rotterdam and Le Havre, where the intentional discontinuation of historical structures formed a central part of the post-war urban vision.

2.7. Ruins As Witnesses

While the post-Second World War period was marked by two dominant approaches towards destroyed heritage, reconstruction and modern rebuilding, a third, often overlooked, option also emerged: the preservation of ruins in alignment with John Ruskin's idea of authentic ruin conservation. Ruins occupy a unique position within the field of architectural heritage conservation. The conservation of ruins represents a conscious decision to preserve traces of destruction, rather than to restore or reconstruct them into an idealised or complete state. This approach, rooted in the recognition of authenticity and memory, elevates ruins from mere relics of the past to active bearers of historical narrative and collective identity. Their fragmentary condition allows for the legibility of historical stratification, testifying to cycles of creation, transformation, decline, and sometimes violent destruction. As

Academic Modernism in the Reconstruction of Downtown Le Havre by Auguste Perret," *Teka Komisji Architektury, Urbanistyki i Studiów Krajobrazowych* 17, no. 1 (2021), https://doi.org/10.35784/teka.2651

[371] UNESCO World Heritage Centre, *Le Havre, the City Rebuilt by Auguste Perret*, inscribed 2005, accessed December 10, 2024, https://whc.unesco.org/en/list/1181

[372] The author does not aim to fully explore the rebuilding of Polish towns due to the scope and length of this work, but rather to highlight the shift in the general approach to reconstruction during the modernist period.

[373] The Recovered Territories (Ziemie Odzyskane) refer to former German regions such as Silesia, Pomerania and southern East Prussia that were transferred to Poland after the Second World War, as determined by the Potsdam Conference in 1945. These areas were incorporated into postwar Poland and underwent extensive population resettlement and nationalisation policies.

[374] Tomasz Torbus, *Rekonstrukcje, dekonstrukcje, (nad)interpretacje: Studia o losach architektury środkowoeuropejskich miast i rezydencji w aspekcie politycznym (XIX–XXI wiek)* (2019), 49–72.

[375] He presents case studies on Gdańsk, Wroclaw and Szczecin, and focus on the case of reconstruction not rebuilding.

See Tomasz Torbus, *Rekonstrukcje, dekonstrukcje, (nad)interpretacje: Studia o losach architektury środkowoeuropejskich miast i rezydencji w aspekcie politycznym (XIX–XXI wiek)* (2019), 73-94.

[376] Łukasz Bugalski, "Kwestia odbudowy zabytkowych zespołów staromiejskich na Ziemiach Odzyskanych," Przegląd Zachodni 3 (2014): 212–34.

Szmygin[377] emphasises, the decision to maintain a structure in a state of permanent ruin is itself an act of protection, preserving the authenticity of material substance while resisting the temptations of reintegration or commercial adaptation

Oradur-sur-Glane

A striking example of this approach is found in the preserved ruins of Oradour-sur-Glane in France, maintained as a powerful memorial to the French villagers massacred by Nazi forces[378]. Similar examples could be ruins of Belchite in Spain[379] or the village of Lidice[380] in the Czech Republic.

Fig. 39. Oradur-sur-Glane. Left: Aerial view of (source: Warfare History Network webpage[381]. Right: Destroyed street (source: Wikimedia commons[382]).

In 1946, Charles de Gaulle declared that the site would be preserved in its destroyed state as a national memorial. The ruins, intentionally left untouched, serve as a tribute to the victims and a stark reminder of the horrors of war. The site features burned-out buildings, rusted vehicles, and personal items frozen in time, symbolising the lives of the villagers who were tragically cut short. A remembrance centre and

[377] Bogusław Szmygin, "Ochrona zabytkowych ruin – założenia do teorii i praktyki," in *Historyczne ruiny: Ochrona, użytkowanie, zarządzanie*, ed. Bogusław Szmygin (Warszawa: Polski Komitet Narodowy Międzynarodowej Rady Ochrony Zabytków ICOMOS, 2018), 191–200.

[378] The massacre occurred on June 10, 1944, when a unit of the Waffen-SS brutally murdered 642 residents of the village in one of the worst Nazi atrocities during World War II. Following the massacre, in which the men were executed and women and children were locked in the church and burned alive, the village was looted and set alight, leaving behind only ruins and charred remains.

The massacre at Oradour-sur-Glane is often thought to have stemmed from a misinterpretation or misidentification by the German SS troops. Historical evidence suggests that the SS may have confused Oradour-sur-Glane with the nearby village of Oradour-sur-Vayres, where resistance activity was reportedly more prevalent.

See Vincent Depaul Lupiano, *Massacre at Oradour-Sur-Glane: Nazi Gold and the Murder of an Entire French Town by SS Division Das Reich* (Lanham, MD: Lyons Press, 2024).

[379] Village in northeastern Spain, which was devastated during a battle in the Spanish Civil War (1937–1938) between Republican and Nationalist forces. The ruined old town was left untouched as a memorial to the conflict.

[380] The Lidice Monument, located in the Czech Republic, honours the village of Lidice, which was destroyed by Nazi forces in 1942 in retaliation for the assassination of Reinhard Heydrich. The entire village was obliterated, and its memory is preserved through the original layout of Lidice.

[381] "Q-Spr23: Oradour," photograph, Warfare History Network, accessed November 30, 2024, https://warfarehistorynetwork.com/wp-content/uploads/2023/02/Q-Spr23-Oradour-1-2000x1334.jpg.

[382] "Main Street of Oradour-sur-Glane" (photograph), Wikimedia Commons, accessed June 29, 2025, https://commons.wikimedia.org/wiki/File:Oradour-sur-Glane-mainstreet.jpg.

exhibit were established[383] to display items recovered from the ruins[384]. The preserved ruins at these sites serve as reminders of the war's destruction and have become important destinations for historical tourism and reflection. Their impact is often stronger than that of monuments alone because they represent direct, authentic witnesses to history[385].

Pointe du Hoc

Another example closely related to warfare, but different from the places of martyrdom are battlefields[386]. The Pointe du Hoc is a significant heritage site on the Normandy coast of northern France[387], located atop a 30-metre-high cliff peninsula overlooking the English Channel. It was a strategic German defensive position famously assaulted by U.S. Army Rangers on D-Day, June 6, 1944[388].

Today, Pointe du Hoc stands as a preserved battlefield, intentionally maintained to reflect its wartime condition. The landscape remains scarred by massive bomb craters, with bunkers and gun emplacements left in their original state. This approach creates a highly authentic memorial site, allowing visitors to connect, and partially feel, the real historical events that unfolded there. A monument, visitor centre, museum, and informational displays further enrich visitors' understanding and historical context of this remarkable chapter in history[389].

---

[383] The entry pavilion, built in 1999, is an intriguing example of commemorative museum architecture that seamlessly blends with the landscape of martyrdom.

[384] *Martyr Village & Memory Center of Oradour-sur-Glane*, Destination Limoges, accessed November 30, 2024, 'Martyr village & memory center of Oradour-sur-Glane' page, https://www.destination-limoges.com/en/la-destination/incontournables/village-martyr-centre-memoire-doradour-sur-glane; *Le récit du massacre d'Oradour-sur-Glane*, Centre de la mémoire d'Oradour-sur-Glane, accessed November 30, 2024, https://www.oradour.org/recit-du-massacre.

[385] I had the opportunity to visit Oradour-sur-Glane in 2019; however, I unfortunately lost my photographs, which had been stored on a hard drive.

[386] Interesting case of battlefield preservation, not strictly a ruin in the architectural sense but embodying a comparable notion of authenticity preservation, is the wreck of the USS *Arizona* and its memorial site at Pearl Harbor, Honolulu. A related site is the USS *Utah* Memorial, which likewise honours the crews of both battleships sunk during the Japanese attack of December 7, 1941, with their wrecks still resting in situ. The USS *Arizona* was struck by multiple bombs, the most devastating of which detonated her forward magazines, breaking the ship in two and causing her rapid sinking. The memorial, designed by Alfred Preis and dedicated in 1962, spans the sunken hull, allowing visitors to see remnants above and below the water. Nearby lies the USS *Missouri* (BB-63), now a museum ship, on whose deck Japan's formal surrender was signed on September 2, 1945, an arrangement that symbolically unites the beginning and end of the United States' involvement in the conflict.

See Andrew Hyde, *After the Battle: Then & Now – Pearl Harbour*, ed. Winston Ramsey (London: Battle of Britain Prints, 1982).

[387] The site's importance stems from the frontal assault by the Rangers, who were tasked with scaling the cliffs under heavy German fire to neutralise a strategic battery of artillery that threatened the Allied landings at Omaha and Utah beaches

Interestingly, Allied intelligence was mistaken about the gun emplacements. The battery removed large-calibre guns captured from France during the Spring Offensive of 1940. The cannons were found, and ultimately destroyed away from the emplacement. Before the landing, the Allied air force conducted numerous bombing raids intended to weaken he defensive capabilities, leaving behind many bomb craters still visible today.

[388] Steven Zaloga, *Rangers Lead the Way: Pointe-du-Hoc, D-Day 1944* (London: Osprey Publishing, 2009).

[389] Other important memory sites I have visited, but mention here only briefly due to the scope of this work, include the Waterloo Memorial Site and the Monument to the Battle of the Nations in Leipzig from the Napoleonic Wars, Beaumont-Hamel Newfoundland Memorial and Thiepval, Lochnagar Crater, and the forts surrounding Verdun such as Fort Douaumont and Fort de Vaux from the First World War, as well as Second World War battlefields including the Normandy D-Day sites (Arromanches-les-Bains, Port-en-Bessin, Ouistreham, Caen, Sainte-Mère-Église, Carentan, Pegasus Bridge) and Operation Market Garden's Arnhem Bridge, where the original structure remains preserved.

Fig. 40. Pointe Du Hoc[390]. Left: Aerial view June 1944 (source: Normandie Tourisme webpage[391]). Right: present day (source: D-Day-Overlord Media Library webpage[392]).

Hiroshima Memorial

Perhaps no other site is as globally symbolic as the ruined Hiroshima Memorial[393], the Atomic Bomb Dome (Genbaku Dome), in Hiroshima, Japan. , it was one of the few structures left standing near the bomb's hypocentre after the atomic explosion on August 6, 1945[394]. Preserved in its ruined state, the building is a powerful testament to the destructive power of nuclear weapons and the importance of peace[395]. The Dome is the centrepiece of a memorial park, which includes the Cenotaph for A-bomb Victims, the Children's Peace Monument[396], and other commemorative installations. In 1996, the site was inscribed as a UNESCO World Heritage Site[397]

A similar narrative is found in Nagasaki, where the Peace Park and the Nagasaki Atomic Bomb Museum commemorate the second atomic bombing. In Nagasaki, the surviving portion of the wall of the Urakami Cathedral was preserved in situ, while the Christian community opted to rebuild the destroyed church at a new site. This compromise addressed both the desire to remember the destruction and the spiritual need for resurrection, demonstrating the different approaches and symbolic meanings associated with authentic remains and reconstructed buildings[398].

[390] During my visit to the site in 2016, I was robbed and lost my camera, which I had been using to capture photographs. As a result, although I have visited the place, I am relying on open-source photographs.

[391] "Site de la Pointe du Hoc," Normandie Tourisme, accessed October 17, 2024, https://en.normandie-tourisme.fr/museums-and-heritage-sites/site-de-la-pointe-du-hoc/.

[392] "Photos of Pointe du Hoc on D-Day," D-Day-Overlord Media Library, accessed October 17, 2024, https://www.dday-overlord.com/en/media-library/photos/pointe-du-hoc/d-day.

[393] Formerly the Prefectural Industrial Promotion Hall

[394] which killed an estimated 70,000–140,000 people.

[395] The dome partially survived the atomic explosion due to its structural design, which was based on a reinforced steel frame and thick concrete walls. This allowed it to withstand the intense shockwave and heat from the explosion. The other buildings in the Hiroshima centre were wooden, making them susceptible to both the shockwave and the fire that spread after the explosion. It is the only structure near the centre of Hiroshima that remained standing in its original form.

[396] *Hiroshima Peace Memorial Museum*, Hiroshima Peace Memorial Museum, accessed October 19, 2024, https://hpmmuseum.jp/?lang=eng.

[397] *Hiroshima Peace Memorial (Genbaku Dome)*, inscribed 1996, UNESCO World Heritage Centre, accessed October 19, 2024, https://whc.unesco.org/en/list/775.

[398] Gwyn McClelland, "Remembering the Ruins of the Urakami Cathedral: Providence or Fifth Persecution?" *Journal of Religion in Japan* 5, no. 1 (2016): 47–69, https://doi.org/10.1163/22118349-00501007; Anna Gasha, "Fragmented Memory:

Fig. 41. Hiroshima Memorial (source: Wikimedia commons[399]).

Auschwitz-Birkenau

Another notable example where narrative value lies in the authenticity of the place is the network of Nazi concentration and death camps across Europe[400]. In many cases, the layouts of these camps remain visible, with partially preserved barracks, crematoria, gas chambers, and other facilities acting as powerful reminders of the atrocities that took place there.

While the prevailing conservation philosophy at Auschwitz-Birkenau[401] emphasizes preserving authentic remains and limiting interventions to a minimum, there have nevertheless been a few carefully planned reconstructions of prisoner barracks, particularly within Auschwitz II-Birkenau. These reconstructed barracks are intended primarily for educational and interpretive purposes, helping visitors gain a better understanding of the conditions prisoners endured. Each reconstruction is grounded in detailed archival research, analysis of historical photographs, and the study of original materials. In Birkenau, most of the original wooden barracks have either deteriorated severely or were destroyed after the war; consequently, only a small number have been partially reconstructed, showing blend between ruin preservation and limited reconstruction. The overwhelming majority of barracks at Birkenau, however, survive as ruins or in their original, often fragile, state, preserving the site's authenticity and reinforcing its power as a direct witness to history.

The Scattering of the Urakami Cathedral Ruins among Nagasaki's Memorial Landscape," in *Shadows of Nagasaki*, (New York: Fordham University Press, 2024), 215–42.

[399] "Hiroshima Peace Memorial: A-bomb Dome" (photograph), Wikimedia Commons, accessed October 19, 2024, https://en.wikipedia.org/wiki/Hiroshima_Peace_Memorial#/media/File:Hiroshima_A-bomb_dome.jpg; "Atomic Bomb Dome in Hiroshima" (photograph), Wikimedia Commons, accessed October 19, 2024, https://en.wikipedia.org/wiki/Hiroshima_Peace_Memorial#/media/File:Atomic_Bomb_Dome_in_Hiroshima.jpg.

[400] Auschwitz-Birkenau (Poland), Stutthof (Poland), Treblinka (Poland), Sobibor (Poland), Majdanek (Poland), Belzec (Poland), Dachau (Germany), Buchenwald (Germany), Ravensbrück (Germany), Mauthausen (Austria) and others.

[401] Similarly to Stuthoff Concentration Camp in Pomerania, Poland, where also some barracks were reconstructed for educational purposes.

Fig. 42. Auschwitz-Birkenau. Left: Reconstruction of the barracks. Right: remains of original barracks. Source: author.

The protection of battlefields as heritage sites serves a crucial purpose, aiming to preserve the authentic landscape, material remnants of combat, and spaces of memory as lasting witnesses to historical events. Contemporary principles of battlefield presentation, based on both Venice charter and Charter for the Interpretation and Presentation of Cultural Heritage Sites[402], emphasize minimal intervention and the safeguarding of original features such as trenches, bunkers, or shell craters, ensuring that the spatial layout and historical narrative remain legible for visitors. However, these sites increasingly face the risk of overtourism, which can lead to the commercialization and simplification of their meaning, as well as the loss of authenticity. A particular challenge is the banalization of death and suffering, especially in locations like Pointe du Hoc, where the theme of battle has been repeatedly popularized through video games and popular culture, sometimes resulting in a superficial engagement with the realities of war[403]. These concerns are highly relevant in the context of Westerplatte[404], which, as an authentic battlefield, similarly confronts the tension between preservation, historical interpretation, and its evolving role as a site of remembrance and tourism.

2.8 Postmodernism In Reconstruction

The late twentieth century saw a major shift in attitudes toward architectural reconstruction and heritage interpretation. Postmodernism, both as a theory and architectural style, challenged the core values of modern conservation such as authenticity, linear historical progress, and material purity, which had shaped professional practice from the Venice Charter (1964). Instead, postmodernism embraced pluralism, eclecticism, and playful reinterpretation of the past, introducing new ambiguities and controversies into the reconstruction of the built environment[405]. This was especially visible in the discontinuity of brutalism in Europe and paralleled the political transformations in former Soviet-influenced countries.

---

[402] *Charte ICOMOS pour l'interprétation et la présentation des sites culturels patrimoniaux*, ratifiée par la 16e Assemblée générale de l'ICOMOS, Québec, le 4 octobre 2008, ICOMOS, accessed June 29, 2025, https://admin.icomos.org/wp-content/uploads/2025/03/interpretation_FREN.pdf.

[403] Prioritizing action-oriented gameplay over historical context and nuance, this phenomenon, often described as the "gamification" or trivialization of history, risks reducing sites of suffering and sacrifice to mere backdrops for entertainment, thereby diminishing their emotional resonance and potentially eroding public understanding of the realities of war. While some argue that video games offer an engaging, theatrical means of participating in historical events, these representations are frequently exaggerated and dramatized for digital entertainment, often at the expense of historical accuracy and depth.

[404] Which will be covered in chapter V.

[405] Jukka Jokilehto, "Considerations on Authenticity and Integrity in World Heritage Context," *City & Time* 2, no. 1 (2006): 1–16.

While modernist conservation aimed to safeguard material authenticity, postmodernism encouraged a more adaptable and interpretive approach. Philosophers such as Jean-François Lyotard challenged the idea of a single, dominant historical narrative, instead promoting a diversity of perspectives and interpretations. Jean Baudrillard's concept of simulacra is also relevant to reconstruction, as it suggests that such projects can produce "hyperreal" spaces in which the boundaries between original and copy, or past and present, become increasingly blurred.

As postmodernism moved away from rigid historicism, heritage presentation practices evolved to meet the demands of tourism, public engagement, and urban regeneration. Many reconstructions began to prioritise emotional impact and visual spectacle over strict adherence to documentary evidence. Rather than restoring a single, verifiable past, reconstruction projects increasingly aimed to provide layered, interpretive experiences that blended historical references with contemporary needs

House of the Blackheads in Riga

The House of the Blackheads in Riga, Latvia, was originally constructed in the early 14th century during the medieval Gothic period as a guildhall for the Brotherhood of Blackheads[406], with later Renaissance additions and extensions. The building was heavily damaged during the Second World War, particularly in 1941 when it was bombed by German forces, and was subsequently demolished by the Soviet authorities in 1948 as part of urban redevelopment efforts, despite protests from the local population. Following the restoration of Latvian independence in the 1990s, the guildhall was rebuilt as a replica of the original structure. The project incorporated only minimal surviving remnants of the historic fabric. Completed in 1999, the reconstructed building now functions as a museum and is a prominent landmark within the historic centre of Riga.

The reconstruction of the House of the Blackheads sparked controversy due to the UNESCO listing in 1997[407]. Critics questioned the authenticity of the project, noting that the new structure is largely a replica, a fabricated monument, and some described it as a "Disneyfied" version of history that lacks the material integrity and authenticity of the original, raising concerns about the manipulation of urban history[408]. However, supporters view the rebuilding as a symbolic act of national and cultural restoration, especially in light of the Soviet-era destruction of the remains in 1948. This debate led to the creation of Riga "Riga Charter on authenticity and historical reconstruction in relationship to cultural heritage (2000) in which the Baltic states presented very similar approach toward purposely destroyed heritage as Jan Zachwatowicz[409] more than 50 years earlier[410]

---

[406] The Brotherhood of Blackheads was a guild of unmarried merchants and shipowners active in several Hanseatic cities, most notably in Riga, Tallinn, and Livonia, from the 14th century onwards.

[407] The rebuilding of the House of the Blackheads in Riga (1996–1999) sparked controversy, particularly with regard to UNESCO's criteria for authenticity, and became a point of concern during the nomination of the Old Riga Historic Centre for the World Heritage List in 1997. Critics argued that the project represented a replication rather than the conservation of authentic fabric, thereby raising questions about the site's eligibility. Some UNESCO advisers described the result as a "fabricated historic environment," suggesting that it conflicted with established principles of authenticity.

See *Historic Centre of Riga*, inscribed 1997, UNESCO World Heritage Centre, accessed August 6, 2025, https://whc.unesco.org/en/list/852.

[408] Herb Stovel, "Origins and Influence of the Nara Document on Authenticity," *APT Bulletin* 39, no. 2/3 (2008): 9–17.

[409] Jan Zachwatowicz, "Program i zasady konserwacji architektury," *Biuletyn Historii Sztuki i Kultury* 8, no. 1–2 (1946): 48–52.

[410] *Riga Charter on Authenticity and Historical Reconstruction in Relationship to Cultural Heritage* (Riga, Latvia, October 23–24, 2000), ICCROM, https://www.iccrom.org/sites/default/files/publications/2020-05/convern8_07_rigacharter_ing.pdf

"…excepting circumstances where reconstruction is necessary for the survival of the place; where a 'place' is incomplete through damage or alteration; where it recovers the cultural significance of a 'place'; or in response to tragic loss through disasters whether of natural or human origin, … 1. the value of cultural heritage is as evidence, tangible or intangible, of past human activity, and that intervention of any kind, even for safeguarding, inevitably affects that evidential quality, and so

Despite these debates, the building has become one of Riga's most recognisable landmarks and a major tourist attraction, celebrating the city's medieval heritage and its post-Soviet cultural renewal[411], highlighting the tensions between heritage reconstruction, authenticity, and the preservation of historical urban integrity.

Fig. 43. House of the Blackheads in Riga. Source: author, 2019.

Fig. 44. House of the Blackheads in Riga, detail with reconstruction date. Back façade of House of the Blackheads in Riga with visible fake transformations of the brick structure, resembling the state of pre destruction in 1940's. Source: author, 2019.

should be kept to the minimum necessary, … 5. replication of cultural heritage is in general a misrepresentation of evidence of the past, and that each architectural work should reflect the time of its own creation, in the belief that sympathetic new buildings can maintain the environmental context, but that 6. in exceptional circumstances, reconstruction of cultural heritage, lost through disaster, whether of natural or human origin, may be acceptable, when the monument concerned has outstanding artistic, symbolic or environmental (whether urban or rural) significance for regional history and cultures."

[411]Jānis Lejnieks, "Rebranding the Soviet Regime's Built Cultural Heritage and the Need for Collective Memory," in *The 6th Baltic Sea Region Cultural Heritage Forum: From Postwar to Postmodern – 20th Century Built Cultural Heritage*, edited by Maria Rossipal (Stockholm: Swedish National Heritage Board, 2017), 58–63.

Palace of the Grand Dukes of Lithuania

Similar to Latvia, Lithuania regained its independence in 1991, prompting a renewed search for national identity and symbolic cultural landmarks. This led to the reconstruction of the Palace of the Grand Dukes of Lithuania in Vilnius[412], widely regarded as one of the country's most ambitious heritage restoration projects. Much like the Latvians' decision to rebuild the House of the Blackheads in Riga, or the Poles' reconstruction of the Royal Castle in Warsaw, the Lithuanians chose to recreate their lost historical seat of power: the Ducal Castle in Vilnius, as well as the medieval island castle in Trakai[413], which had long remained in ruin.

The original structure, located between Vilnius Cathedral and Gediminas' Hill, served as the principal residence of the Grand Dukes of Lithuania and the Jagiellonian dynasty, with origins in the 15th century. Under the rule of Sigismund I the Old, the castle was transformed from a Gothic palace into a Renaissance residence, likely designed by the Italian architect Bartolomeo Berrecci[414], and later extended during the Baroque period. The building suffered extensive damage during the Russian invasion of 1655, leading to its abandonment. By 1801, it was almost completely demolished, and the site was subsequently levelled as part of fortification works on the hill[415].

The reconstruction was one of the key initiatives of the Lithuanian Millennium Programme, intended to mark a thousand years of Lithuania's recorded history[416]. Lobbied by then President Algirdas Brazauskas, the idea gained political momentum in the early 1990s. An architectural competition was held in 1993, with Rimas Grigas' design awarded first place. The project integrated results from extensive archaeological excavations[417], incorporating preserved foundations and other remnants into the new structure. Historical documentation and artistic depictions served as the primary sources for recreating the palace's appearance as it might have looked in its prime. Completed in stages, the

[412] Moreover, Warsaw, Riga, and Vilnius are all inscribed on the UNESCO World Heritage List, albeit for distinct reasons: Vilnius is celebrated for its authentic medieval and baroque architectural heritage (criteria ii, iv), Riga for its exceptional Art Nouveau ensemble and historic urban structure (criteria i, ii), and Warsaw uniquely for its meticulously accomplished post-war reconstruction of its Old Town.

[413] The reconstructions started before the war under the supervision of Jan Borowski, and was finished by the end of 90's, before the independence of Lithuania.

See Andrzej Macur, *Gdańsk Kazimierza Macura* (Gdańsk: Słowo/obraz terytoria, 2016), 170–71; Tomasz Torbus, *Rekonstrukcje, dekonstrukcje, (nad)interpretacje: studia o losach architektury środkowoeuropejskich miast i rezydencji w aspekcie politycznym (XIX–XXI wiek)* (Gdańsk: Słowo/obraz terytoria, 2019), 131–32.

[414] A similar Renaissance transformation took place on Wawel Hill in Kraków during the same period, where the earlier Gothic castle, damaged by fire, was rebuilt in a new architectural style. Similar to Kraków, it was founded by Sigismund the Elder, while the work was finished by Benedykt from Sandomierz as a master builder.

See Tomasz Torbus, *Rekonstrukcje, dekonstrukcje, (nad)interpretacje: studia o losach architektury środkowoeuropejskich miast i rezydencji w aspekcie politycznym (XIX–XXI wiek)* (Gdańsk: Słowo/obraz terytoria, 2019), 130.

[415] Tomasz Torbus, *Rekonstrukcje, dekonstrukcje, (nad)interpretacje: studia o losach architektury środkowoeuropejskich miast i rezydencji w aspekcie politycznym (XIX–XXI wiek)* (Gdańsk: Słowo/obraz terytoria, 2019), 126-134; *Istorinė raida*, Nacionalinis muziejus Lietuvos Didžiosios Kunigaikštystės valdovų rūmai, accessed August 7, 2025, https://www.valdovurumai.lt/lt/rumu-istorija/i/142/istorine-raida/.

[416] According to Tomasz Torbus the possible reconstruction was discussed even before the Second World War.

See Tomasz Torbus, *Rekonstrukcje, dekonstrukcje, (nad)interpretacje: studia o losach architektury środkowoeuropejskich miast i rezydencji w aspekcie politycznym (XIX–XXI wiek)* (Gdańsk: Słowo/obraz terytoria, 2019), 131.

[417] Archaeological excavations at the site of the Palace of the Grand Dukes of Lithuania began in 1937 under the supervision of Stanisław Lorentz and a Polish team, as Vilnius was within Poland's borders from 1918 to 1939. These efforts aimed to uncover and document the remains of the historic structure but were suspended with the outbreak of the Second World War.

See Tomasz Torbus, *Rekonstrukcje, dekonstrukcje, (nad)interpretacje: studia o losach architektury środkowoeuropejskich miast i rezydencji w aspekcie politycznym (XIX–XXI wiek)* (Gdańsk: Słowo/obraz terytoria, 2019), 131-134.

building was officially opened in 2009, coinciding with Vilnius being named European Capital of Culture[418].

As with the House of the Blackheads in Riga, the reconstruction provoked debates over authenticity and historical interpretation, particularly in light of principles set out in the Venice Charter, such as minimal intervention and the clear differentiation between old and new work. The controversy was, however, more intense in the case of Vilnius. Although archaeological research helped define the castle's outline, the overall design remains largely speculative, as the original palace was demolished in the early 19th century and few detailed records survived. Critics argued that the reconstruction prioritised visual grandeur over historical accuracy, incorporating modern elements that deviated from documented historical styles. While much of the public embraced the palace as a symbol of Lithuania's statehood, independence, and cultural heritage, particularly in the post-Soviet context, many experts and architects dismissed it as a fictionalised creation rather than a faithful restoration[419].

Fig. 45. Palace of the Grand Dukes of Lithuania in Vilnius. Source: author, 2015.

Drezden / Frankfurt Am Main / Berlin

After the fall of the Soviet Union, many European cities sought to reclaim their historic urban landscapes. While in Riga and Vilnius such projects were tied to renewed national sovereignty, Dresden's reconstruction unfolded in the context of German reunification. Central to this effort were the rebuilding of the Frauenkirche (Church of Our Lady), an iconic Baroque landmark designed by George Bähr and completed in 1743, celebrated for its distinctive stone dome, and the redevelopment of "Quarter I" around the Neumarkt. These projects aimed to restore the city's lost urban fabric, reaffirm its place in European heritage, and stand as enduring symbols of post-reunification renewal and reconciliation.

In February 1945, Allied bombing raids devastated the historic centre of Dresden and the Frauenkirche that collapsed. Its ruins were deliberately left in place by the authorities of the German Democratic

[418] Today, the reconstructed palace houses a museum dedicated to Lithuanian history and serves as a venue for cultural events and state ceremonies, symbolising the country's heritage.

[419] Tomasz Torbus, *Rekonstrukcje, dekonstrukcje, (nad)interpretacje: studia o losach architektury środkowoeuropejskich miast i rezydencji w aspekcie politycznym (XIX–XXI wiek)* (Gdańsk: Słowo/obraz terytoria, 2019), 134-151.

Republic as a war memorial, symbolising the city's destruction and the human cost of the war. For decades, the pile of blackened stones in the Neumarkt served as memory site, commemorating the lives lost during the air raids.

The idea of reconstruction gained momentum after German reunification in 1990, when political change and civic activism converged. Central to this was the "Ruf aus Dresden" ("Call from Dresden") campaign launched in 1990, which sought to raise international awareness and funding for the rebuilding. This citizen-led movement, supported by prominent political figures and benefactors from Germany and abroad. The reconstruction of the Frauenkirche took place between 1994 and 2005, employing a combination of advanced digital documentation techniques, archival research, and traditional stonemasonry skills. Over 8,000 original stones from the ruins were salvaged, catalogued, and reintegrated into the new structure, identifiable by their darker, fire-scorched surfaces. Historical plans, photographs, and drawings guided the restoration, while a 3D computer model served as the project synthesis[420]. The result was an executed reconstruction that restored the church's pre-war form with visual fidelity. Parallel to the rebuilding of the Frauenkirche, the redevelopment of Quarter I around the Neumarkt aimed to reinstate the pre-war urban fabric. Guided by historical street patterns and building plots, the project involved the reconstruction of historicist facades combined with contemporary building standards behind them[421]. The intention was to revive the aesthetic and spatial qualities of Dresden's pre-war centre, reinstating its role as a historic civic space.

While the project was viewed as a legitimate form of urban healing, reclaiming a cultural landmark destroyed by war and serving as an act of reconciliation for Dresden's cultural identity[422], it also generated significant debate. Critics questioned whether the Neumarkt's rebuilt ensemble represented a genuine historic cityscape or a stage-set reproduction, challenging the authenticity of the result in light of the Venice Charter's principles on discernibility and minimal intervention. Some scholars argued that the reconstruction risked promoting a selective and idealised memory, omitting the layers of history, including post-war socialist urbanism, that had shaped the site for decades[423].

[420] Brian Collins, Dave Williams, Robert Haak, Martin Trux, Herbert Herz, Luc Genevriez, Pascal Nicot, Pierrick Brault, Xavier Coyere, Burkhard Krause, Jens Kluckow, and Armin Paffenholz, "The Dresden Frauenkirche: Rebuilding the Past," in *Computer Applications and Quantitative Methods in Archaeology 1993*, edited by J. Wilcock and K. Lockyear, 19–24 (Oxford: Tempus Reparatum, 1994).

[421] Jürgen Paul, "The Rebirth of Historic Dresden," in *Debating German Cultural Identity since 1989*, ed. Anne Fuchs, Kathleen James-Chakraborty, and Linda Shortt, *Studies in German Literature, Linguistics, and Culture* (Rochester, NY: Camden House, 2011), 117–28.

[422] Elisabeth Wüstenhagen, "Undoing Trauma: Reconstructing the Church," *Future Anterior: Journal of Historic Preservation, History, Theory, and Criticism* 3, no. 1 (2006): 12–23.

[423] Huriye Armağan Doğan, "A Critique on Authenticity and Integrity in Reconstruction: Perception of Architectural Heritage and Cities of Postwar Era from Europe," *Art History & Criticism* 18, no. 1 (2022): 174–86, https://doi.org/10.2478/mik-2022-0010

Fig. 46. Drezden reconstruction of urban "Quarter I" with reconstruction of Frauenkirche. Source: author, 2023.

While the reconstruction of Dresden's Frauenkirche and Neumarkt was deeply rooted in the symbolism of German reunification, other German cities pursued heritage restoration in different contexts. In the Frankfurt am Main, the approach to the reconstruction of its historic market square (Römerberg) and adjacent Old Town as part of a broader effort to revive urban heritage and reconnect with its pre-war identity creating "new Old town"[424]. The medieval Old Town, including the distinctive half-timbered houses surrounding the square, was almost entirely destroyed during Allied bombing in March 1944. For decades, much of the area was replaced by modernist post-war buildings.

Some early reconstruction took place in the 1980s, most notably the rebuilding of the Ostzeile, the eastern row of half-timbered houses on the Römerberg. The most ambitious phase of restoration began with the Dom-Römer Project, which was officially approved in 2007 and carried out between 2012 and 2018, making it one of the most recent reconstruction actions with that scale. This redevelopment covered a 7,000 m² area between the Cathedral and the Römerberg and involved dismantling existing modernist buildings, including the Technical Town Hall that stood on the market square, to make space for the reconstruction. The project reinstates the pre-war street network and reconstructs 15 historically faithful buildings based on archival photographs, historic plans, and archaeological findings. These are complemented by 20 contemporary buildings whose exteriors evoke historic forms, while their interiors meet modern building standards. The result is a reconstructed urban quarter that aims to restore the visual and historical spatial continuity between the Dom and the market square, seeking to evoke the state before the wartime destruction[425].

It is widely noted that the project is popular with both the public and tourists. Similar to Dresden, there was strong support for reconstruction, with citizen groups actively lobbying for the project's approval and praising its contribution to urban revival. The reconstruction of part of Frankfurt am Main also sparked debate about authenticity and the role of reconstruction in contemporary heritage policy,

[424] Paul Biasco, "When It Comes to Building Anew, Frankfurt Looks to the Past," *Architectural Digest*, January 2, 2019, accessed August 9, 2025, https://www.architecturaldigest.com/story/when-it-comes-to-building-anew-frankfurt-looks-to-the-past

[425] Andreas Maier, "Erinnerung: Fachwerk für alle!," *Die Zeit*, May 18, 2006, accessed August 9, 2025, https://www.zeit.de/2006/21/Archi_Frankfurt_xml/komplettansicht; Astrid Hansen, "Die Frankfurter Altstadtdebatte zur Rekonstruktion eines ‚gefühlten Denkmals'," *Die Denkmalpflege* 66, no. 1 (2008): 5–17, https://doi.org/10.1515/dkp-2008-660105; Dima Stouhi, "The Story Behind Frankfurt's New Old Town and How the Community Revived Its Medieval Identity," *ArchDaily*, August 26, 2022, accessed August 9, 2025, https://www.archdaily.com/987963/the-story-behind-frankfurts-new-old-town-and-how-the-community-revived-its-medieval-identity; *Übersichtskarte* (interactive map of the Dom-Römer quarter), DomRömer GmbH, accessed August 9, 2025, https://www.domroemer.de/ubersichtskarte.

exemplifying a postmodern approach to heritage in which visual coherence and historical evocation outweigh documentary authenticity, resulting in the creation of a "stage-set" historic cityscape[426].

Fig. 47. Frankfurt am Main, Römerberg square with the Ostzeile and reconstructed half-timber houses. Source: author, 2017.

The most recent large-scale case in Berlin, a city long dominated by modern rebuilding processes, is the reconstruction of the Berlin Palace, a Baroque landmark designed largely by Andreas Schlüter. Severely damaged in 1945 and demolished in 1950 by East German authorities with Soviet support, the palace was replaced by the Palace of the Republic (1976–2008), which was also later demolished[427]. The decision to reconstruct the Berlin Palace between 2013 and 2020, housing the Humboldt Forum, marked a departure from the modernistic no-reconstruction policies[428]. It reflected efforts to restore elements of the city's pre-war identity and urban landscape, as well as to reinstate its historical political seat, with use of preserved decorative sculptures of Schluter that serve as spolia, made possible by the fall of the Soviet Union and the reunification of Germany[429].

The project sparked debates similar to those in Dresden and Frankfurt. Advocates framed it as the restoration of a lost urban identity and the reintegration of a historic focal point into Berlin's cityscape. Critics, however, highlighted its selective historical narrative, the prioritisation of monumental Baroque imagery over the memory of the Palace of the Republic, and the symbolic politics embedded in the project.

Elbląg / Retroversion

During the Postmodern era, marked by a rejection of modernism and a renewed interest in tradition, combined with significant political changes, numerous reconstruction projects emerged across Europe. A notable "middle-way" approach in Poland is the rebuilding of Elbląg's Old Town, which, like Gdańsk, was destroyed in 1945 but not reconstructed until the 1990s. This project adopted the strategy of retroversion, a concept introduced by Lubocka-Hoffmann, which combined inspiration from historical

[426] Nebojsa Camprag, "Museumification of Historical Centres: The Case of Frankfurt Altstadt Reconstruction," in *Tourism in the City*, edited by Cecilia Pasquinelli and Nicola Bellini, 165–78 (Berlin: Springer, 2017).

[427] *Baugeschichte*, *Das historische Schloss*, Berliner Schloss – Humboldt Forum, accessed August 9, 2025, https://berliner-schloss.de/das-historische-schloss/baugeschichte/.

[428] Interestingly the first attempts to present the potential reconstructions of the Berliner Schloss was made by using 3D technology in 1994. Somehow starting the promotion and assimilation campaign which later turn into the material realization.

See *Die Schloss-Simulation 1993 / 1994*, *Das historische Schloss*, Berliner Schloss – Humboldt Forum, accessed August 9, 2025, https://berliner-schloss.de/das-historische-schloss/die-schloss-simulation-1993-1994/.

[429] Harriet Alexander, "Berlin Begins Reconstruction of King Frederick the Great's Palace," *The Telegraph*, June 12, 2013, accessed August 9, 2025, https://www.telegraph.co.uk/news/worldnews/europe/germany/10117103/Berlin-begins-reconstruction-of-King-Frederick-the-Greats-palace.html

forms with a visible contemporary reinterpretation[430]. Rather than replicating the pre-war architecture, the design sought to evoke the historical parcel layout, street network, and building scale, while introducing modern stylistic elements to distinguish the new from the old. This approach, which is more the design method not the conservation action, responded to public demand for the revival of the historic townscape, while avoiding a direct pastiche.

Retroversion in Elbląg became an influential model, demonstrating how a historic urban identity could be symbolically recovered without resorting to full-scale replication. Similar strategies have been applied in other Polish cities, including Kołobrzeg, Głogów, and Braniewo, as well as in numerous quarter-scale urban developments. These projects illustrate how retroversion has become a distinctive Polish response to post-war heritage loss, balancing historical reference with contemporary architectural expression

2.9 Summary Of The Chapter

In antiquity, the value of heritage was often rooted in symbolic continuity, function, and collective memory rather than in strict material originality. Practices such as spolia in Roman, Christian, and Carolingian contexts served as deliberate political and ideological tools, linking the present with the authority of the past. Authenticity was understood as symbolic continuity and functional persistence, not as the preservation of original material. The reuse of spolia was celebrated as a demonstration of political legitimacy, rather than condemned as falsification.

The revival of classical ideals during the Renaissance established guiding principles for appreciating earlier epochs. Early conservation ethics were exemplified in Michelangelo's minimal interventions at Santa Maria degli Angeli, while systematic documentation, such as Raphael's papal commission, and the rise of scientific archaeology, notably at Pompeii, provided new tools for heritage engagement. Figures such as Piranesi and Winckelmann combined architectural documentation with interpretive vision, blurring the distinction between accurate record and imaginative reconstruction.

The French Revolution, although marked by the deliberate destruction of monarchical and religious symbols, paradoxically initiated national heritage protection through commissions, inventories, and preservation directives. In the nineteenth century, heritage shifted from being perceived as a universal ideal to serving as a marker of national identity. Thinkers like Goethe reinterpreted Gothic as a distinctly national style, while Schinkel promoted systematic, minimal-intervention conservation, as seen at Chorin Abbey. Simultaneously, monumental completions such as Cologne Cathedral treated fidelity to the original medieval plans as authentic continuation rather than invention. This was also the era of Eugène Viollet-le-Duc, whose doctrine of stylistic restoration proposed that buildings should be restored not merely to a previous state but to a state of "completion" they may never have possessed. His work at Carcassonne and Pierrefonds expressed an idealised vision of architectural unity, even when it relied on conjectural design. This contrasted sharply with the conservative, preservative philosophy of John Ruskin, revealing the profound doctrinal divisions of the period.

Post-war reconstruction, following both the First and Second World Wars, introduced new tensions between material authenticity and symbolic recovery. Early examples such as Ypres, Leuven, and Kalisz foreshadowed later, large-scale reconstruction efforts. In Warsaw, the Old Town was rebuilt using archival images and paintings, prioritising the recreation of urban identity over the retention of

[430] Maria Lubocka-Hoffmann, "Powojenna odbudowa miast w Polsce a retrowersja Starego Miasta w Elblągu," *Ochrona Zabytków* 1 (2019): 35–71.

surviving material fabric. This approach legitimised the concept of “authenticity of spirit and place” as an alternative to strict material survival. In contrast, cities such as Rotterdam and Le Havre chose contemporary redevelopment, accepting the loss of architectural heritage and embracing modernist urban visions. A third category, encompassing battlefields and sites of martyrdom, advanced the principle of strict preservation of the maximum amount of authentic substance, primarily for commemorative purposes.

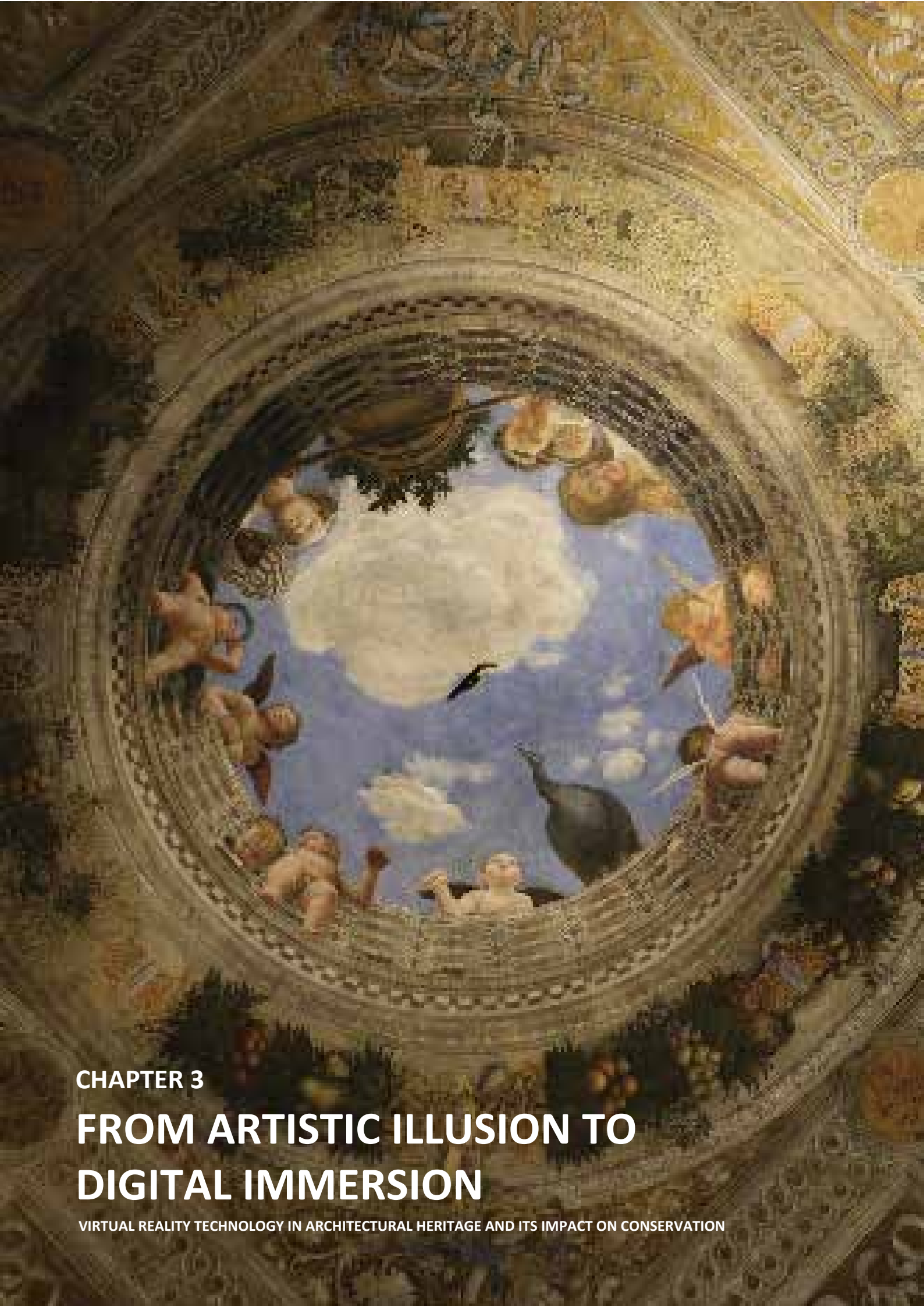
Postmodernism further questioned the notion of a universal conservation doctrine. Political change and nostalgia for the past encouraged subjective, narrative-driven reconstructions in which historical accuracy was not the sole criterion. In many cases, the recovery or reinvention of a lost national identity outweighed purist notions of authenticity.

The development of conservation doctrine and global practice in preserving authenticity and undertaking reconstruction has never been a fixed, universal standard. It is fluid, shaped by cultural values, political agendas, technological capabilities, and prevailing aesthetic philosophies. This fluidity has resulted in recurring instability in the definitions and applications of authenticity, reconstruction, and interpretation. By tracing the historical evolution of conservation thought, focusing on the shifting meanings of authenticity and the contested role of reconstruction, the chapter situates these developments within a long continuum. Virtual reality reconstructions are therefore framed as the latest stage in a centuries-old interpretive process. Each era’s approach was morally and culturally justified in its time, yet often later rejected or reinterpreted. The scope of reconstruction has continually oscillated between strict preservation and creative completion. This instability is not a flaw but a defining characteristic of heritage conservation, making VR reconstructions not a radical departure but the newest iteration in a long tradition of negotiated, context-dependent authenticity.

	Example	Date	Location	Artistic style	Method	Motivtion
1	**Eigikalamma**	6th century BC	Mesopotamia	Ancient art	Reconstruction ?	Continuity of power
2	**Temple of Jupiter Optimus Maximus**	1st century BC	Ancient Rome	Ancient Rome	Spolias reincorporation	Continuity of power
3	**The Arch of Constantine in Rome**	3rd c. AD (312–315 AD)	Ancient Rome	Ancient Rome	Spolias reincorporation	Continuity of power
4	**Basilica of Santa Maria in Trastevere**	4th c. (c. 340 AD)	Ancient Rome	Ancient Rome	Spolias reincorporation	Continuity of tradition
5	**Charlemagne's palace chapel in Aachen**	9th c. (792–805)	Holy Roman Empire	Middle Ages	Spolias reincorporation	Continuity of power
6	**Santa Maria degli Angeli e dei Martiri**	16th c. (1563–1566)	Papal States	Renaissance	Partial adapation of ruins	Respect for Rome's heritage / authentic presentation
7	**Laocoon Group**	16th c. (1506 discovery, 1532–1536 restoration)	Papal States	Renaissance	Partial conjectural reconstruction	Stylistic unity
8	**Pompeii, Herculaneum and Stabia**	18th c. (1738–1780s excavations)	Kingdome of Naples	Classicism	Preservation of ruins	Authentic presentation
9	**Works of Piranesi**	18th c. (1748–1778)	Papal States	Classicism	Documentation, survey of ruins / immaterial reconstruction	Respect for Rome's heritage / imaginative depiction
10	**Works of Winckelmann**	18th c. (1755–1768)	German confederation	Classicism	Documentation of ancient art	Respect for Rome's heritage
11	**French Revolution**	18th c. (1789–1799)	France	Classicism	Targeted destruction of symbolic monuments	Antagonism towars authentic heritage
12	**Works of Goethe**	19th c. (1770s–1832)	German confederation	Romanticism	Apreciation	Respect for Gothic heritage
13	**Karl Friedrich Schinkel's Memorandum**	19th c. (1815)	German confederation	Romanticism	Preservation advocation	Respect for Gothic heritage
14	**Chorin Monastery**	19th c. (restoration 1817–1861)	German confederation	Romanticism	Preservation and stabilisation of ruins	Respect for Gothic heritage
15	**Cologne Cathedral**	19th c. (completion 1842–1880)	German confederation	Romanticism / Gothic Revival	Completion using original medieval plans	Will to complete Gothic heritage
16	**Feldherrenhalle and other copies**	19th c. (1841–1844)	German confederation	Classicism / Romantic historicism	Copy of Original	Respect for ancient and medieval heritage
17	**Restoration works of Viollet-le-Duc (Carcassonne, Pierrefonds, Notre-Dame)**	19th c. (1844–1879)	France	Romanticism	Stylistic restoration	Restoration to an idealised "original" state
18	**Dictionnaire raisonné... (Viollet-le-Duc)**	19th c. (1854–1868)	France	Romanticism	Documentation / immaterial reconstruction	Respect for medieval heritage
19	**Works of John Ruskin**	19th c. (1849–1873)	United Kingdome	Romanticism	Preservation advocation	Respect for Gothic heritage
20	**San Paolo fuori le Mura in Rome**	19th c. (1823–1854)	Papal State	Historicism	Reconstruction	Recovery after catastrophe
21	**Campanile of San Marco in Venice**	19th c. (1902–1912)	Kingdome of Italy	Historicism	Reconstruction	Recovery after catastrophe
22	**Prima Carta del Restauro (Camillo Boito)**	Late 19th–early 20th c. (1883–1893)	Kingdome of Italy	Historicism	Codification of methods	Codification of doctrine
23	**Philological & Scientific Restoration (Boito & Giovanoni)**	Late 19th–early 20th c. (1890s–1930s)	Kingdome of Italy	Historicism	Codification of methods	Codification of doctrine
24	**Valorisation Riegl-Dehio-Frodl**	20th c. (1903–1950s)	Austria-Hungary	Historicism	Codification of methods	Codification of doctrine
25	**Ypres Cloth Hall / Church of Saint Martin**	20th c. (1919–1934)	Netherlands	Historicism	Reconstruction (post-WWI)	Recovery after catastrophe / National identity recovery

26	**Leuven, St. Peter's Church / University Library**	20th c. (1921–1928; rebuilt library 1921–1928)	Netherlands	Historicism	Reconstruction (post-WWI)	Recovery after catastrophe / National identity recovery
27	**Kalisz**	20th c. (1919–1939)	Poland	Historicism	Reconstruction (post-WWI)	Recovery after catastrophe
28	**Athens Charter of 1931**	20th c. (1931)	-	Modernism	Codification of methods	Codification of doctrine
29	**Athens Charter of 1933**	20th c. (1933)	-	Modernism	Codification of methods	Codification of doctrine
30	**Oradur-sur-Glane**	20th c. (1944)	France	-	Preservation of ruins	Authentic presentation / commemoration
31	**Pointe du Hoc**	20th c. (1944)	France	-	Preservation of ruins	Authentic presentation / commemoration
32	**Hiroshima Memorial**	20th c. (1945)	Japan	-	Preservation of ruins	Authentic presentation / commemoration
33	**Auschwitz-Birkenau**	20th c. (1945)	Poland	-	Preservation of ruins / Partial Reconstuction	Authentic presentation / commemoration
34	**Monte Cassino Abbey**	20th c. (1948–1964)	Italy	-	Reconstruction (post-WWII)	Recovery after catastrophe / national identity recovery
35	**Hitorical Town of Warsaw**	20th c. (1945–1955)	Poland	Socialist realism	Reconstruction (post-WWII)	Recovery after catastrophe / national identity recovery
36	**Gdańsk**	20th c. (1945–1960s)	Poland	Socialist realism	Reconstruction / reinterpretation / domestication (post-WWII	Recovery after catastrophe / selective national identity recovery
37	**Le Havre**	20th c. (1945–1964)	France	Modernism	Modern rebuilding	Functional postwar modernisation
38	**Rotterdam**	20th c. (1946–1980s)	Netherdlans	Modernism	Modern rebuilding	Functional postwar modernisation
39	**Hague Convention of 1954**	20th c. (1954)	-	Modernism	Protection in armed conflict	Codification of doctrine
40	**Kaiser Wilhelm Memorial Church in Berlin**	20th c. (1959–1963)	Germany	Modernism	Preservation of ruins / Modern rebuilding	Authentic presentation
41	**Venice Charter of 1964**	20th c. (1964)	-	Modernism	International conservation standards	Codification of doctrine
42	**Royal Castle in Warsaw**	20th c. (1971–1984)	Poland	Modernism	Reconstruction	National identity recovery
43	**Amsterdam Declaration of 1975**	20th c. (1975)	-	Modernism	Integrated conservation	Codification of doctrine
44	**Nara Document on Authenticity (1994)**	20th c. (1994)	-	Postmodernism	Authenticity in cultural contexts	Codification of doctrine
45	**Principles for the Recording of Monuments (ICOMOS)**	20th c. (1996)	-	Postmodernism	Documentation standards	Codification of doctrine
46	**House of the Blackheads in Riga**	20th c. (1996–1999)	Latvia	Postmodernism	Reconstruction	National identity recovery
47	**Palace of the Grand Dukes of Lithuania**	21st c. (2002–2009)	Lithuania	Postmodernism	Reconstruction	National identity recovery
48	**Drezden / Frankfurt Am Main / Berlin**	21st c. (1990s–present)	Germany	Postmodernism	Reconstruction	National identity recovery
49	**Elbląg / Retroversion**	21st c. (1990s–2006)	Poland	Postmodernism	Retroversion	Selective evocation of historic fabric

Fig. 48. Summary table of examples presented in the chapter. Source: author.



CHAPTER 3

FROM ARTISTIC ILLUSION TO DIGITAL IMMERSION

VIRTUAL REALITY TECHNOLOGY IN ARCHITECTURAL HERITAGE AND ITS IMPACT ON CONSERVATION

3. From Artistic Illusion to Digital Immersion

Introduction

To establish a broader framework for this chapter, it is necessary to address the interrelated concepts of perception, perspective, reality, and art. Interpretations of visual culture in the modern era are shaped by the cumulative achievements of earlier periods, with the inventions and cultural contributions of preceding generations influencing visual literacy from an early age.

In contemporary contexts, visual illusions are encountered routinely, often without conscious recognition. The act of watching television or cinema involves perceiving a three-dimensional illusion on a flat surface, effectively creating a sense of depth and spatial presence. Historical accounts of early film screenings, such as the projection of a train apparently approaching the viewer, record instances of genuine alarm among audiences[431]. By contrast, contemporary viewers, including children, remain unaffected by comparable imagery. Technological developments ranging from stereoscopic photography to Virtual Reality headsets have expanded the means of visual immersion. However, the novelty and sense of wonder initially associated with these innovations has diminished as audiences have become accustomed to digitally mediated experiences.

The origins of illusion and immersion extend far beyond the digital era. The construction of environments designed to evoke alternative realities has been a recurrent feature of human creativity since antiquity. A pivotal advancement in this context was the rediscovery of linear perspective during the Renaissance, which allowed for the convincing simulation of three-dimensional space on a two-dimensional surface.

Linear perspective operates on the principle of a vanishing point located along the horizon line, where parallel lines appear to converge, causing objects to diminish in size with increasing distance from the viewer. The principal types include one-point, two-point, and three-point perspective, the latter employed to depict extreme vertical or spatial depth. Curvilinear, or fisheye, perspective uses curved lines to produce panoramic spatial effects. Although the systematic application of these techniques is associated with fifteenth-century figures such as Filippo Brunelleschi and Leon Battista Alberti[432], earlier artistic traditions, particularly in the medieval period, deployed alternative approaches to suggest spatial depth[433].

The mathematical study of perspective was advanced by Kazimierz Bartel[434] in *Perspective in Painting*, regarded as the first work of its kind internationally. The first volume appeared in Lviv in 1928[435], followed by a second, posthumously published in 1958 and prepared by Bartel's former assistant,

---

[431] Stephen Bottomore, "The Panicking Audience?: Early Cinema and the 'Train Effect,'" *Historical Journal of Film, Radio and Television* 19, no. 2 (1999): 177–216, https://doi.org/10.1080/014396899100271.

[432] Tyler, Christopher W. 2000. "Perspective as a Geometric Tool That Launched the Renaissance." In SPIE Proceedings, edited by Bernice E. Rogowitz and Thrasyvoulos N. Pappas, 3959:492–97. SPIE.

[433] Edgerton, Samuel Y. 2010. "The Mirror, the Window, and the Telescope: How Renaissance Linear Perspective Changed Our Vision of the Universe: Samuel Y. Edgerton." Nexus Network Journal 12 (1): 149–152. https://doi.org/10.1007/s00004-010-0020-x

[434] Kazimierz Bartel was a Polish mathematician, full professor at the Lviv University of Technology, and politician. He served as Prime Minister of Poland five times between 1926 and 1930 and was a key figure in Polish politics during the interwar period, particularly as a supporter of Józef Piłsudski's Sanation movement. Following the German invasion of the Soviet Union in 1941, Bartel was arrested by the Gestapo and later executed in Lviv under Nazi occupation.

[435] Bartel, Kazimierz. 1928. Perspektywa Malarska : Zasady, Zarys Historyczny, Estetyka. T. 1 (Painting Perspective : Principles, Historical Outline, Aesthetics. Vol.1). Lwów-Warszawa: Książnica-Atlas.

Franciszek Otto[436]. This second volume is particularly relevant for its analysis of the restitution of perspective in multiple artworks, with a strong emphasis on Italian developments, and it remains an important reference for understanding the mathematical foundations of immersive space in art.

While theatre represents an important form of visual illusion, it is excluded from this discussion on the grounds that architectural settings most often function merely as scenic backdrops. An exception is the Teatro Olimpico in Vicenza, where the deliberate use of forced perspective directly enhances the perception of spatial depth.

This chapter examines the evolution of perspective as an immersive technique, without undertaking detailed mathematical analysis. By providing a concise historical overview from analogue artistic methods to digital technologies, it establishes the conceptual and technical foundations for understanding the emergence of fully immersive virtual environments.

3.1 Illusory Art In The History Of Architecture

3.1.1. Antics

Since the earliest beginnings of art, artists have sought to create monumental structures with ideal proportions, often employing visual illusion to correct imperfections and shape the viewer's perception. The concept of illusion has been integral to human culture from its inception. Early cave paintings, such as those at Lascaux[437], were intended to convey the presence of animals, although the technical limitations of the period restricted both the accuracy and completeness of these representations. As techniques in painting and sculpture developed over the centuries, artistic practice advanced progressively toward greater realism. At various points in history, artists and architects sought to enhance this realism through the deliberate incorporation of optical effects.

This technique, commonly employed in building design and particularly prevalent in historical architecture, involves manipulating elements to create a heightened sense of depth and distance. For example, columns on a building's façade might be proportioned to appear taller or more slender as they recede from view, thereby contributing to an overall optical effect. An early and well-documented instance of such visual correction is the ancient Greek practice of *entasis*[438], applied to classical columns within the Greek architectural orders. Architects frequently incorporated entasis into column shafts by introducing a subtle convex curvature. The purpose of this refinement was to create the visual impression of a perfectly straight column when observed from ground level. Without entasis, the interaction of light, shadow, and perspective could cause columns to appear unnaturally rigid or even slightly concave. This technique illustrates how architectural design can integrate aesthetic considerations with an understanding of optical perception to produce visually harmonious and convincing forms.

[436] Kazimierz Bartel, *Perspektywa malarska: Zasady, zarys historyczny, estetyka*, vol. 2 (Warszawa: Polskie Wydawnictwo Naukowe, 1958).

[437] Lascaux is a cave in southwestern France, renowned for its approximately 17,000-year-old Palaeolithic paintings depicting animals such as horses and bulls. Discovered in 1940, the cave was eventually closed to protect its fragile artwork, and a replica, Lascaux II, was constructed to allow visitors to experience the appearance of the original.

[438] Georgia Papadopoulou, Peter Thompson, and Eleni Vassiliou, "The Origins of Entasis: Illusion, Aesthetics or Engineering?," *Spatial Vision* 20, no. 6 (2007): 531–43, https://doi.org/10.1163/156856807782758359.

Fig. 49. Entasis effect. Parthenon, Athens, Greece. Source: author, 2023.

From antiquity to the late medieval period and beyond, many artistic traditions favoured symbolic representation over geometric perspective. The Egyptian hieratic scale[439], continued in medieval and Byzantine art, depicted important figures on a larger scale and placed them centrally, with smaller, less detailed figures surrounding them[440]. Backgrounds served narrative rather than spatial functions, prioritising symbolic meaning over realistic depth[441]. This approach reflected a fundamentally different conception of space and representation, in which hierarchy and message took precedence over optical accuracy.

The Greeks, and later the Romans who assimilated much of Greek culture, employed forced perspective in their architectural designs, particularly in theatres and temples featuring the entasis effect. Architectural elements such as tapered columns and subtly sloping floors were deliberately used to create the illusion of greater height and enhanced proportions. It is evident that the Greeks were aware of optical phenomena such as foreshortening and perspective, though they applied them primarily as visual refinements rather than as systematic principles[442]. The Romans, in contrast, expanded these ideas, employing them more overtly to create illusionistic effects in architecture and scenography[443]. In the realm of two-dimensional art in Ancient Greece, there are discernible attempts to suggest depth through overlapping forms and size variation. However, depth was not a dominant concern in Greek art, and its systematic development would not emerge until the Renaissance.

---

[439] Gay Robins, *The Art of Ancient Egypt, Revised Edition*, 2nd ed. (Cambridge, MA: Harvard University Press, 2008), 19–24.

[440] In medieval art, important figures such as Christ, saints, and kings were depicted on a larger scale and placed in central positions, while less significant individuals appeared smaller and positioned lower within the composition. In Orthodox art, this hierarchical perspective became codified within the canons of representation and icon painting.

[441] Gisela Richter, *Perspective in Greek and Roman Art* (London: Phaidon Press, 1970), 4–8; Richard H. Wilkinson, *Symbol and Magic in Egyptian Art* (London: Thames & Hudson, 1994), 36–59.

[442] In Greek vase painting, artists applied the foreshortening and overlapping to suggest depth and perspective, especially in attempts to depict architecture, although these were not developed into a formal system. The Greeks didn't develop linear perspective as we understand it today, they certainly observed and applied the principles of perspective to enhance the visual impact of their works.

Kazimierz Bartel, *Perspektywa malarska: Zasady, zarys historyczny, estetyka*, vol. 2 (Warszawa: Polskie Wydawnictwo Naukowe, 1958), 271–76.

[443] Especially in Pompeii art.

One of the most significant archaeological discoveries comes from the excavations at Pompeii, Herculaneum, and Stabiae[444]. These excavations yielded not only architectural remains and a wealth of artefacts but also, a remarkable collection of frescoes. These wall paintings provide invaluable insights into the artistic and cultural life of the inhabitants of Pompeii prior to the catastrophe[445]. Many depict scenes from daily life, mythological narratives, and vividly coloured interior decorations featuring painted columns and ceilings, executed in bright, saturated pigments[446]. The frescoes of Pompeii, traditionally classified into four stylistic phases, were often designed to create the illusion of architectural features such as columns, balconies, and gardens on flat walls. Artists employed perspective and form of *trompe-l'œil*[447] techniques to make confined interiors appear more expansive and grand. For example, some painted compositions simulate open courtyards with lush gardens beyond, even when the actual space was limited[448].

A particularly captivating example of architectural illusion can be seen in Chamber "M" of the Villa of Fannius Synistor at Boscoreale[449]. Preserved by the eruption of Vesuvius, the wall elements and paintings have since been relocated to the Metropolitan Museum of Art in New York. This room originally served as a sleeping chamber, with its rear wall depicting a rugged landscape framed by balustrades and an arbour, with a grotto containing a fountain and a small figure of Hekate. Centrally positioned between two columns, a parapet painted with a yellow-toned landscape supports a glass bowl brimming with fruit. The composition incorporates mirrored imagery on the lateral walls, while a painted window, crucial to the illusion, is depicted as the source of light, with shadows carefully rendered to enhance the overall sense of realism. The symmetrical lateral walls are divided into four sections by pilasters framing the couch area and flanked by ornate columns. These surfaces alternate between views of enclosed courtyards containing statues, rotundas, pylons, and foliage, and depictions of urban landscapes with colonnaded structures and projecting terraces.

[444] Already mentioned in previous chapter.

[445] Pedar Foss and John J. Dobbins, eds., *The World of Pompeii* (New York: Routledge, 2008).

[446] William C. Archer, "The Paintings in the Alae of the Casa Dei Vettii and a Definition of the Fourth Pompeian Style," *American Journal of Archaeology* 94, no. 1 (1990): 95–123; Rebecca Piovesan, Ruth Siddall, Claudio Mazzoli, and Luca Nodari, "The Temple of Venus (Pompeii): A Study of the Pigments and Painting Techniques," *Journal of Archaeological Science* 38, no. 10 (2011): 2633–43.

[447] Trompe-l'œil is an artistic technique that uses highly realistic imagery to create the optical illusion that depicted objects exist in three dimensions. Originating in classical antiquity and refined in later periods, it relies on perspective, shading, and detail to "deceive the eye" of the viewer.

[448] Kazimierz Bartel, *Perspektywa malarska: Zasady, zarys historyczny, estetyka*, vol. 2 (Warszawa: Polskie Wydawnictwo Naukowe, 1958), 276–79; John R. Clarke, *The Houses of Roman Italy, 100 B.C.–A.D. 250: Ritual, Space, and Decoration* (Berkeley: University of California Press, 1991), 30–77.

[449] Martin Robertson, "The Boscoreale Figure-Paintings," *The Journal of Roman Studies* 45 (1955): 58–67; John R. Clarke, *The Houses of Roman Italy, 100 B.C.–A.D. 250: Ritual, Space, and Decoration* (Berkeley: University of California Press, 1991), 37–38, 43–50; *Cubiculum (bedroom) from the Villa of P. Fannius Synistor at Boscoreale*, Roman late Republic fresco (ca. 50–40 BCE), The Metropolitan Museum of Art, accessed April 20, 2022, https://www.metmuseum.org/art/collection/search/247017

Fig. 50. Cubiculum (bedroom) with colourful decoration featuring architectural motifs and an example of linear perspective, from the *Villa of Fannius Synistor* at Boscoreale, c. 50–40 BCE, today in Metropolitan Museum of Art, New York, USA (source: Metropolitan Museum of Art [450]).

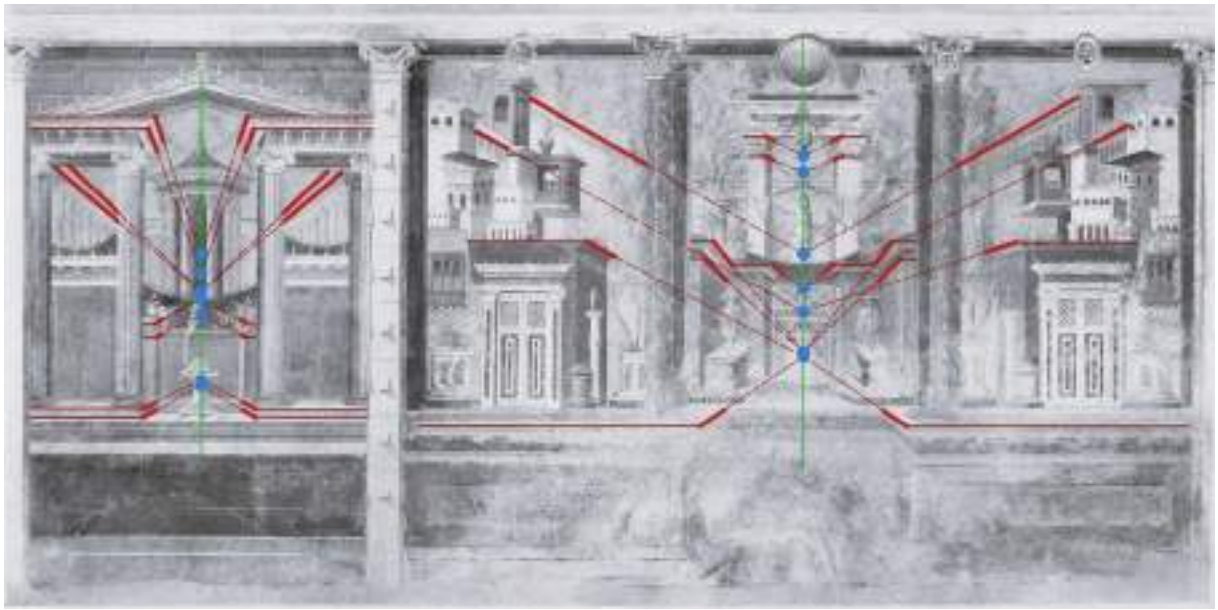


Fig. 51. Scheme of perspective analysis of *Villa of Fannius Synistor* frescoes with multiple vanishing points and converging lines that do not lead to a single point[451]. Source: author.

While the perspective analysis presented above shows that it is not fully consistent with a single vanishing point, creating the effect of so-called polyperspective, or intuitive perspective, the fresco remains an advanced, at the time, example of illusionistic wall painting from the ancient period. It offers

[450] "Cubiculum (bedroom) from the Villa of P. Fannius Synistor at Boscoreale," fresco, Roman period (ca. 50-40 BCE), The Metropolitan Museum of Art, accession no. 03.14.13a-g, accessed April 20, 2022, https://www.metmuseum.org/art/collection/search/247017.

[451] The composition lacks a unified horizon line due to the use of multiple vanishing points. Since this is not an example of typical one-point perspective, drawing a separate horizon line for each vanishing point would be inappropriate and would require covering parts of the image, thereby obscuring important elements of the scene.

a vivid testament to the artistic trends of its era, drawing viewers into immersive, imagined spaces that blur the boundary between architecture and art.

Another notable example from ancient Pompeii is the partially reconstructed *House of the Vettii*, celebrated for its elaborate frescoes in the Fourth Pompeian Style, some of which incorporate *trompel'œil* effects. Depicting scenes from mythology, nature, and daily life, these works offer valuable insight into the artistic refinement of the period[452]. While the Renaissance is often credited with the invention of linear perspective, evidence from Pompeii reveals a far earlier and more complex tradition of illusion in art. The case of Pompeii demonstrates that the ancient Romans possessed techniques for creating convincing and visually immersive effects, knowledge that was to a significant extent lost with the city's destruction in the eruption of Vesuvius in 79 CE and only rediscovered many centuries later.

The continuity of Roman approaches to illusionistic art can be partially observed in the example A particularly fascinating example is the Rotunda in Thessaloniki, Greece, presenting the example form Byzantine Empire. Constructed in the early fourth century AD, this massive cylindrical structure, likely commissioned by Emperor Galerius. The original function of the Rotunda remains debated: it may have been intended as a mausoleum for Galerius. In the late fourth or early fifth century, it was converted into a Christian church, most likely during the reign of Theodosius I, and dedicated to the Archangels[453].

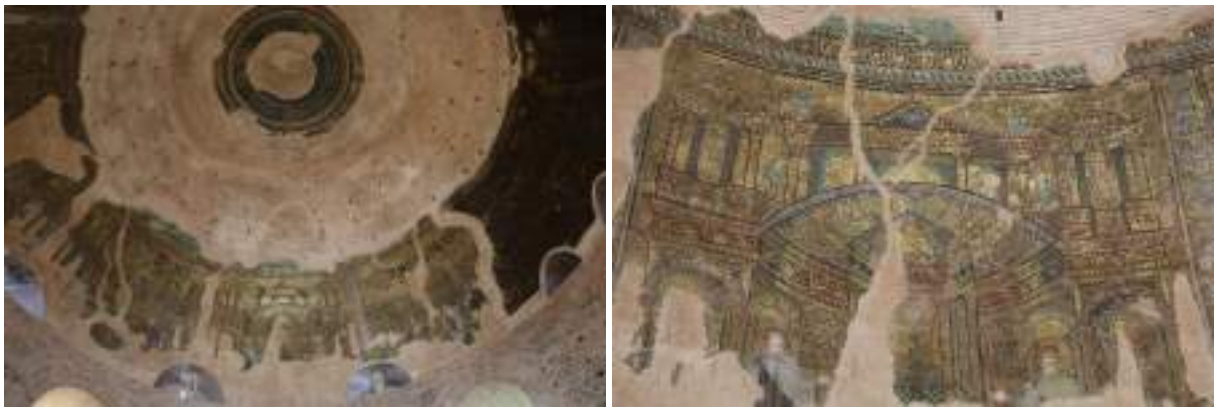


Fig. 52. Interior of the Dome of Rotunda in Thessaloniki. Source: author, 2023.

When the Rotunda was converted into a Christian church, significant mosaic decorations were added during the early Byzantine period[454]. The mosaics predominantly depict Christian themes, including scenes from the life of Christ, saints, and biblical narratives. Of particular relevance to this research are those on the masonry dome, rising to an interior height of 29.8 metres, which incorporate architectural motifs executed in a simplified and slightly distorted linear perspective. The lower register comprises

[452] William C. Archer, "The Paintings in the Alae of the Casa dei Vettii and a Definition of the Fourth Pompeian Style," *American Journal of Archaeology* 94, no. 1 (1990): 95–123, https://doi.org/10.2307/505527; John R. Clarke, *The Houses of Roman Italy, 100 B.C.–A.D. 250: Ritual, Space, and Decoration* (Berkeley: University of California Press, 1991), 65–77, https://doi.org/10.1525/9780520914445

[453] It was consecrated as the Church of the Rotunda, accompanied by significant architectural modifications. Following the Ottoman conquest of Thessaloniki in 1430, it was converted into a mosque, with further alterations including the addition of a minaret. After the city's liberation in 1912, the Rotunda was restored to Christian worship and dedicated to Saint George. Its long and varied architectural history embodies the cultural and religious transformations that have shaped Thessaloniki over the centuries. Today, it stands as a UNESCO World Heritage Site and remains open to the public.

See *Palaeochristian and Byzantine Monuments of Thessalonika*, inscribed 1988, UNESCO World Heritage Centre, accessed August 12, 2023, https://whc.unesco.org/en/list/456/.

[454] Georgios Velenis, "Some Observations on the Original Form of the Rotunda in Thessaloniki," *Balkan Studies* 15 (1974): 298–307; Laura Salah Nasrallah, "Empire and Apocalypse in Thessaloniki: Interpreting the Early Christian Rotunda," *Journal of Early Christian Studies* 13, no. 4 (2005): 465–508; "Medieval Mosaics: Rome, S Maria in Domnica, Apse and Triumphal Arch Mosaics," *Medieval Mosaics*, accessed April 2, 2024, https://medievalmosaics.com/mosaics/377

eight evenly proportioned panels, divided by vertical bands ornamented with gold, black, and silver vegetal designs. Each panel contains two praying male figures set against a backdrop of gold architectural elements, gem-studded arcades, peacock-feathered conches, and probable representations of ciboria, altars, and thrones.

3.1.2. Medieval art, and proto-renaissance

Fig. 53. Popular depictions of architecture in medieval art. Right: polyperspective technique in *Effects of Good Government in the City* by Ambrogio Lorenzetti, fresco cycle, Palazzo Pubblico, Siena, 1339 (source: Google Arts & Culture[455]). Left: Symbolic depiction of The Siege of the Castle of Mortagne, near Bordeaux, 1377, from *Recueil des croniques d'Engleterre* (source: British Library[456]).

Medieval painting evolved through distinct phases shaped by religious, social, and cultural influences, serving primarily instructional, devotional, and commemorative purposes. Architecture and landscape played only a minor role, usually as background to narrative scenes. Closely linked to religious themes, painting functioned as a visual narrative for a largely illiterate population, conveying spiritual teachings and, at times, glorifying secular authority. Mathematical perspective was largely absent; instead, spatial representation prioritised symbolism, hierarchy, and narrative clarity. Hierarchical perspective (hieratic scale) depicted important figures, such as the Virgin Mary or Christ, larger than others regardless of spatial position, similar to byzantine art. A common solution to present architecture was polyperspective, combining multiple viewpoints within a single composition, often producing deliberate distortions[457], as in Ambrogio Lorenzetti's Effects of Good Government in the City[458].

Giotto di Bondone

The fourteenth-century fresco cycles in Padua, inscribed on the UNESCO World Heritage List in 2021 as *Padua Urbs Picta*[459], represent a body of work that revolutionised spatial representation in art. The

[455] "Effects of Good Government in the City," fresco by Ambrogio Lorenzetti (1338-1339), Sala della Pace, Palazzo Pubblico, Siena. Google Arts & Culture, accessed June 21, 2023, https://artsandculture.google.com/asset/effects-of-good-government-in-the-city/WAFg-CSkcQJsMw?hl=en.

[456] "The Siege of the Castle of Mortagne, near Bordeaux, in 1377 (from *Recueil des croniques d'Engleterre*, anonymous)," watercolor manuscript illumination, British Library, Meisterdrucke, accessed June 21, 2023, https://www.meisterdrucke.us/fine-art-prints/Unbekannt/745764/The-Siege-of-the-Castle-of-Mortagne%2C-near-Bordeaux%2C-in-1377-from-Recueil-des-croniques-d%27Engleterre.html.

[457] Sarel Eimerl, *The World of Giotto: c. 1267–1337*, Time-Life Library of Art (New York: Time, Inc., 1967), 172–73.

[458] Interestingly, in 1339 Lorenzetti painted his fresco in the Palazzo Pubblico in Siena using a skewed form of polyperspective. However, just three years later, in 1342, he produced The Birth of the Virgin and Saint Sabinus Before the Governor of Tuscany, both demonstrating a clear use of geometric linear perspective. The latter is particularly notable for its depiction of two arches framing a scene that unfolds behind them, creating a striking sense of depth.

[459] *Padua's fourteenth-century fresco cycles*, inscribed 2021, UNESCO World Heritage Centre, accessed August 24, 2023, https://whc.unesco.org/en/list/1623/

sequence begins with the work of Giotto di Bondone[460] an Italian painter and architect of the Middle Ages and pupil of Giovanni Cimabue[461]. Giotto is widely regarded as a pioneering figure whose artistic contributions anticipated the development of geometric perspective, a revolutionary principle that would be fully realised in the fifteenth century. His significance lies in his departure from the rigid conventions of the medieval style, adopting a greater emphasis on naturalism, spatial depth, and the accurate rendering of human anatomy[462]. This approach, later referred to as "Giottesque"[463] in relation to his followers, laid important foundations for the Renaissance pursuit of realism, especially in the depiction of three-dimensional space on a flat surface[464].

Among Giotto's most celebrated works[465] is the series of frescoes in the Scrovegni Chapel[466], also known as the Arena Chapel, in Padua, so named for its proximity to the remains of a Roman amphitheatre. Built in the early fourteenth century, the chapel became the site of Giotto's extensive decorative programme, executed around 1305, depicting episodes from the lives of Christ and the Virgin Mary. This cycle is considered one of the most important achievements of Italian Gothic painting, marking a decisive step in the transformation of mural art. The programme serves as a visual narrative of Christ's life and Passion, recalling the illustrative style of the *Biblia Pauperum*. Particularly striking is the monumental Last Judgement on the western wall, notable for its vivid and harrowing depiction of hell[467]. Throughout the chapel, figures are rendered with proportions far more accurate than those typical of medieval art, foreshadowing the anatomical precision later perfected in the Renaissance. In several scenes, such as *The Lamentation*, Giotto employs a proto-linear perspective and constructed orthogonal lines to create a convincing sense of depth[468]. In others, such as *The Presentation* at the Temple, he distorted perspective multiple viewpoints or polyperspective, similar to the example of Villa

[460] Janetta Rebold Benton, *Materials, Methods, and Masterpieces of Medieval Art*, Praeger Series on the Middle Ages, illustrated ed. (Santa Barbara, CA: Praeger, 2009), 62–65; Giorgio Vasari, *Żywoty najsławniejszych malarzy, rzeźbiarzy i architektów*, vol. 1 (Warszawa: Państwowe Wydawnictwo Naukowe, 1985), 282–305.

[461] Giorgio Vasari, *Żywoty najsławniejszych malarzy, rzeźbiarzy i architektów*, vol. 1 (Warszawa: Państwowe Wydawnictwo Naukowe, 1985), 223-231.

[462] Giorgio Vasari, *Żywoty najsławniejszych malarzy, rzeźbiarzy i architektów*, vol. 1 (Warszawa: Państwowe Wydawnictwo Naukowe, 1985), 282-305; Sarel Eimerl, *The World of Giotto: c. 1267–1337*, Time-Life Library of Art (New York: Time, Inc., 1967).

[463] Frederick Hartt and David Wilkins, *History of Italian Renaissance Art*, 7th ed. (Upper Saddle River, NJ: Pearson, 2011), 151–52; Giorgio Vasari, *Żywoty najsławniejszych malarzy, rzeźbiarzy i architektów*, vol. 1 (Warszawa: Państwowe Wydawnictwo Naukowe, 1985), 9-10.

[464] Kazimierz Bartel, *Perspektywa malarska: Zasady, zarys historyczny, estetyka*, vol. 2 (Warszawa: Polskie Wydawnictwo Naukowe, 1958), 294–300.

[465] There is an ongoing debate regarding the attribution of part of the fresco cycle in the Upper Church of San Francesco in Assisi, painted in the late 1290s, to Giotto. The attribution has been proposed due to the use of solid, three-dimensional figures, a comparable colour palette, the relatively realistic depiction of human emotions, and attempts at naturalistic perspective. However, modern art historians have questioned this on stylistic, technical, and documentary grounds. Even if not conclusively by Giotto, the frescoes share notable similarities with his confirmed works, particularly in the Scrovegni Chapel, Padua. Given the lack of conclusive evidence, the authorship remains unconfirmed, and this study does not engage with the debate in detail.

See Sarel Eimerl, *The World of Giotto: c. 1267–1337*, Time-Life Library of Art (New York: Time, Inc., 1967), 88-99; Samuel Y. Edgerton, *Renaissance Rediscovery of Linear Perspective* (New York: Joanna Cotler Books, 1976), 14–15.

[466] Sarel Eimerl, *The World of Giotto: c. 1267–1337*, Time-Life Library of Art (New York: Time, Inc., 1967), 108-131; Laura Jacobus, *Giotto and the Arena Chapel: Art, Architecture & Experience*, illustrated ed., *Studies in Medieval and Early Renaissance Art History* (Turnhout: Harvey Miller Publishers, 2008).

[467] Zachary Graham, "When I Paint My Masterpiece: Giotto's Last Judgement and Its Twelfth-Century Cultural Foundations," *Armstrong Undergraduate Journal of History* 11, no. 2 (2021): 50–70, https://doi.org/10.20429/aujh.2021.110204.

[468] Zeynep Murat, "Wall Paintings through the Ages: The Medieval Period (Italy, Twelfth to Fifteenth Century)," *Archaeological and Anthropological Sciences* 13, no. 11 (2021): article 191, https://doi.org/10.1007/s12520-021-01410-4

of Fannius Synistor in Pompeii, reflecting the transitional nature of early fourteenth-century spatial representation.

Fig. 54. Scenes from *Scrovegni Chapel* with linear perspective by Giotto. Source: author, 2023.

Fig. 55. Perspective analysis of Giotto's scenes, with multiple vanishing points and converging lines. Source: author.

Fig. 56. *Scrovegni Chapel* by Giotto di Bondone. Source: author.

The importance of the Scrovegni Chapel is immense, particularly when considered alongside Giotto's later works, confirm his pivotal role in advancing pictorial space, leaving an undeniable mark on the history of painting and European culture. These include the *Madonna and Child Enthroned with Angels*

and Saints (Ognissanti Maestà)[469] and the fresco cycle in the Bardi Chapel[470] of Santa Croce, Florence[471]. Painted between 1325 and 1328, the Bardi Chapel frescoes reveal Giotto's progressive development as a painter, with a more confident application of perspective[472]. In scenes such as the *Apparition at Arles*[473], he employs consistent rules of convergence and demonstrates an awareness of vanishing points, producing a convincingly constructed spatial setting. These works display a well-executed linear perspective that offers clear evidence of his growing understanding of spatial geometry.

In his 1550 work Lives of the Most Excellent Painters, Sculptors, and Architects, Giorgio Vasari, often regarded as the first art historian, praised Giotto di Bondone for his exceptional ability to imitate nature so convincingly that he surpassed the rigid, and as Vassari described, "awkward style of Greek painting"[474]. Vasari credited Giotto with introducing a new and superior artistic approach based on portraying figures from life, a practice largely unfamiliar before the thirteenth century. Giotto's influence extended well beyond his own era, establishing him as a highly sought-after artist and earning him recognition as a Proto-Renaissance master, with his enduring legacy is evident in the works of later Renaissance painters[475]. Acclaimed for his transformative impact on the course of Western art, Giotto remains an iconic figure in the history of painting. His mastery of spatial construction allowed him to create scenes of unprecedented realism for his time, transcending the flatness of medieval art through the fresco technique[476] and catalysing the evolution of mural painting in Padua.

Scuola Giottesca, followers of Giotto

Another artist from the Padua artistic circle, likely influenced by Giotto's work[477] , was Giusto de' Menabuoi, an Italian painter of the late Gothic period whose skill also places him within the Proto-Renaissance tradition. His most notable achievement is the fresco cycle in the *Battistero di San Giovanni Battista* in Padua[478].

---

[469] Madonna and Child Enthroned with Angels and Saints (Ognissanti Maestà), c. 1306–1310, by Giotto di Bondone, Uffizi Gallery, Florence, Italy. Notable for the surrounding scenes, which employ elements of linear perspective.

[470] During my visit in November 2024, the Bardi Chapel and its fresco cycle were undergoing restoration; therefore, I cannot include a satisfactory photograph of this work here.

[471] Frederick Hartt and David Wilkins, *History of Italian Renaissance Art*, 7th ed. (Upper Saddle River, NJ: Pearson, 2011), 88–91.

[472] Sarel Eimerl, *The World of Giotto: c. 1267–1337*, Time-Life Library of Art (New York: Time-Life Books, 1967), 136-137; Frederick Hartt and David Wilkins, *History of Italian Renaissance Art*, 7th ed. (Upper Saddle River, NJ: Pearson, 2011), 86-88.

[473] Sarel Eimerl, *The World of Giotto: c. 1267–1337*, Time-Life Library of Art (New York: Time-Life Books, 1967),139-145.

[474] "Awkward Greek painting style" is described as the Byzantine artistic representation of cult of the icons, which was later adopted in the Orthodox Church.

[475] Ibid. 187

[476] David Jiménez-Desmond, Juan S. Pozo-Antonio, and Alessandra Arizzi, "The Fresco Wall Painting Techniques in the Mediterranean Area from Antiquity to the Present: A Review," *Journal of Cultural Heritage* 66 (2024): 166–86, https://doi.org/10.1016/j.culher.2023.11.018.

[477] Possibly also student of Giotto.

[478] The Romanesque baptistery was constructed in the 12th century, probably inspired by Byzantine architecture. It features a dome on a drum supported by pendentives, and was possibly built on the site of an earlier structure adjacent to the *Basilica Cattedrale di Santa Maria Assunta*. Although the cathedral was later rebuild in the Renaissance style, altering its original Romanesque character, the baptistery itself remained unchanged. In 1370, the building was adapted to serve as a mausoleum for Prince Francesco il Vecchio da Carrara and his wife, Fina Buzzaccarini.

Included in the UNESCO List of World heritage as "Padua's fourteenth-century fresco cycles".

See *Padua's Fourteenth-Century Fresco Cycles*, inscribed 2021, UNESCO World Heritage Centre, accessed August 24, 2023, https://whc.unesco.org/en/list/1623/.

Fig. 57. Padua Baptistery frescos surrounding the entrance to the baptistery. Source: author, 2023.

The fresco cycle[479], painted between 1375 and 1376 by Giusto de' Menabuoi, frames each scene within rectangles, providing distinct linear perspectives with the characteristics of the Gothic style[480]. The depicted scenes revolve around Christ Pantocrator, encircled by a mesmerizing wheel featuring intricate spokes composed of angels and saints, reflecting remnants of Byzantine influence on Padova. The richly decorated baptistery or funerary chapel features scenes on the walls that showcase the use of linear perspective to create an immersive effect. The overall reception of the interior is significantly more immersive due to the illusion of depth, making it appear much larger than it really is. This effect, as demonstrated in previous examples, is achieved through the use of paint and art, dematerializing the structure of the Romanesque wall[481].

Among Giotto's notable artistic followers were Altichiero di Zevio[482] and Jacopo Avanzi[483], also members of Padua's artistic circle, who collaborated in 1384 on the interior decoration of a funerary chapel founded by Raimondino Lupi, Marquess of Soragna, built in 1377. Situated adjacent to the Basilica of Saint Anthony of Padua, the chapel later became known as the Oratory of Saint George (it. *Oratorio di San Giorgio*) due to its frescoes illustrating the legend of the saint. Within the chapel, Altichiero and Avanzi depicted narratives of Saint George, Saint Catherine, Saint Lucy, and the Crucifixion. Their work, while rooted in the late Gothic style, represents a remarkable advance beyond Giotto's achievements, combining his naturalism, architecture presentation with the ornamental richness of Gothic decoration and the much advanced practice[484] in application of linear perspective[485]. The spatial depth and compositional clarity in these frescoes not only demonstrate the technical

[479] The frescoes depict scenes from the lives of St John the Baptist, the Virgin Mary, and Christ, integrating lively and detailed representations of architecture, landscapes, and figures. The programme offers a visual narration of biblical history reminiscent of the *Biblia Pauperum*.

[480] Drawing on the influence of Byzantine art, he incorporated the Christ Pantocrator motif into the dome decoration of the baptistery. This imposing central image is surrounded by concentric rows of angels and saints, creating a celestial vision.

[481] Giusto de' Menabuoi's style, akin to that of Giotto, combines Gothic elements with emerging innovations of perspective. His work embodies the transition from medieval to Renaissance artistic traditions in fourteenth-century northern Italy. Although less renowned than some of his contemporaries from Florence or Siena, he made significant contributions to the artistic developments of his time and region.

[482] Giorgio Vasari, *Żywoty najsławniejszych malarzy, rzeźbiarzy i architektów*, vol. 3 (Warszawa: Państwowe Wydawnictwo Naukowe, 1985), 218.

[483] Ibid. 219.

[484] Similar to certain examples in Pompeii, the artists employed multiple vanishing points for different architectural elements within the composition. In some instances, the vanishing point lies beyond the painted surface, producing the unusual, at the time, effect of perspective lines converging toward a point located outside the depicted scene.

[485] According to Vasari, Andrea Mategna, Renaissance master of illusory painting described in following paragraphs, praised the cycle for the realism.

mastery of the artists but also mark a decisive step towards the Renaissance treatment of pictorial space.

Fig. 58. Interior of *Oratory of San Giorgio,* Padova. Source: author, 2023.

Fig. 59. Detailed scenes of the *Oratory of San Giorgio* in Padova, showing the use of linear perspective and the depth effect. Source: author, 2023.

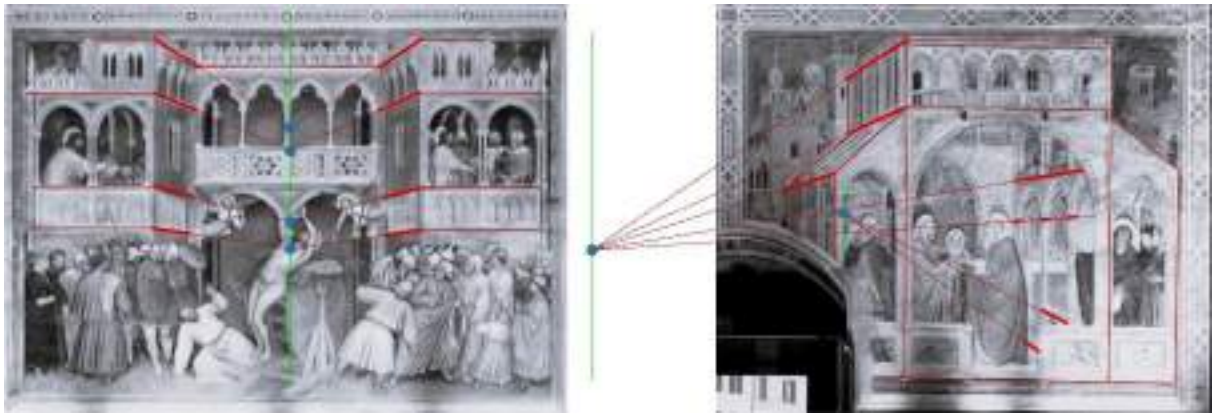


Fig. 60. Perspective analysis of scenes in of *Oratory of San Giorgio*. Source: author.

The works of Giotto and his artistic followers, including Giusto de' Menabuoi, Altichiero di Zevio, Jacopo Avanzi, and Jacopo da Verona[486], in Padua[487], Italy, are recognised as unique in the history of art and are included on the UNESCO World Heritage List. While Giotto experimented with the use of linear perspective, his followers had mastered the technique developed by their artistic predecessor, marking an important moment in art history. This period represents a clear reflection of the transition from Giotto's medieval rediscovery of spatial depth to the flourishing of Renaissance art, when artistic

[486] Author of Frescoes in of the San Michele Oratory in Padua, build in 1397, also Included in the UNESCO List of World heritage as "Padua's fourteenth-century fresco cycles". Due to the late construction and paining in the San Michele Oratory and already quite lengthy description of Padova Circle I decided to skip this figure.

[487] Also the listing include the frescoes in Palazzo della Ragione painted 1425 to 1440, not mentioned by author, due to the length of this paragraph.

expression reached new levels of sophistication. Padua was a leading centre in the conscious revival and application of perspective to depict more realistic scenes, creating a late medieval form of artistic illusion. Although the systematic formulation of perspective is usually attributed to Renaissance artists, it was the influence of Padua's artistic circle that ensured the widespread adoption of the technique. This innovation not only shaped the future of European painting but also laid conceptual foundations for later mathematical and scientific approaches to descriptive geometry in art, with long-reaching implications for visual technologies such as modern virtual reality.

3.1.3. Renaissance rediscovery of perspective[488]

Quattrocento in Florence

Renowned as both architect and engineer of the early Renaissance, Filippo Brunelleschi is credited with formulating the principles of linear perspective around 1415[489]. According to contemporary accounts, notably by Antonio Manetti[490], he demonstrated his discovery by painting a highly accurate depiction of the Florence Baptistery on a panel and positioning it before the building, viewed through a mirror, so that observers could directly compare the painted image with the real structure[491]. Drawing on geometry and mathematical principles, Brunelleschi devised a method for realistically representing space and depth in two-dimensional art, showing how parallel lines, when extended into the distance, converge at a single vanishing point on the horizon[492]. Central to his approach were key concepts that remain fundamental: the single vanishing point, located on the horizon line representing the viewer's eye level, and orthogonals, which are imaginary lines converging towards that point and which together

[488] Due to the vast scope of the subject concerning the emergence and spread of perspective during the Renaissance. Author will focus on examples related to architecture, particularly frescoes, which act as a bridge between painting and architecture.

[489] As mentioned in the previous paragraph, credit should be given to the Padova art circle and their 14th-century fresco cycles, as they were the pioneers and documented users of perspective.

See Kazimierz Bartel, *Perspektywa malarska: Zasady, zarys historyczny, estetyka*, vol. 2 (Warszawa: Polskie Wydawnictwo Naukowe, 1958), 313–15; Samuel Y. Edgerton, *Renaissance Rediscovery of Linear Perspective* (New York: Joanna Cotler Books, 1976), 4.

[490] Amanda Lillie, *"Place Making,"* introduction to *Building the Picture: Architecture in Italian Renaissance Painting*, National Gallery, accessed October 18, 2023, https://www.nationalgallery.org.uk/research/research-resources/exhibition-catalogues/building-the-picture/place-making/introduction.

[491] Samuel Y. Edgerton, *Renaissance Rediscovery of Linear Perspective* (New York: Joanna Cotler Books, 1976), 4-6; Frederick Hartt and David Wilkins, *History of Italian Renaissance Art*, 7th ed. (Upper Saddle River, NJ: Pearson, 2011), 161-164.

[492] Giorgio Vasari, *Żywoty najsławniejszych malarzy, rzeźbiarzy i architektów*, vol. 2 (Warszawa: Państwowe Wydawnictwo Naukowe, 1985), 108.

"Filippo Brunelleschi gave considerable attention to the study of perspective, the rules of which were then very imperfectly understood, and often falsely interpreted; and in this he expended much time, until at length he discovered a perfectly correct method, that of taking the ground plan and sections by means of intersecting lines, a truly ingenious thing, and of great utility to the arts of design. In these inquiries Filippo found so much pleasure that be executed a drawing of the Piazza San Giovanni, wherein he portrayed all the compartments of the incrustation in black and white marble, the foreshortening being managed with singular felicity and grace. He represented the house of the Misericordia a in like manner, with the shops of the wafer-makers and the arch of the Pecori, giving the column of San Zanobi on the other side. This work having been highly commended by artists, and all who were capable of judging in matters of the kind, gave Filippo so much encouragement, that no long time elapsed before he commenced another, and made a view of the Palace, the Piazza, the Loggia de' Signori, with the roof of the Pisani, and all the buildings erected around that Square, works by which die attention of artists was so effectively aroused, that they afterwards devoted themselves to the study of perspective with great zeal[492]. To Masaocio in particular, who was his friend, Filippo taught this art the painter being then very young; but that he did much credit to his teacher is sufficiently manifest from the edifices depicted in his works."

create the illusion of depth and spatial coherence[493]. Furthermore, Brunelleschi's work laid the foundation for subsequent Renaissance artists, who not only embraced but also expanded and refined the principles of linear perspective, applying them extensively in their works. The widespread use of linear perspective became a defining feature of Renaissance art, revolutionising the depiction of space and offering viewers a more realistic and immersive visual experience[494].

Fig. 61. Brunelleschi's perspective analysis. Left: Diagram reconstructed by Edgerton illustrating Filippo Brunelleschi's mirror perspective technique from a lost painting of the Battistero di San Giovanni (source: Edgerton 1975[495]). Right: Todays view. Source: author, 2022.

The subsequent major advancement in linear perspective can be seen in the frescoes executed jointly by Masolino da Panicale and Masaccio. Created as part of a larger decorative programme, these works demonstrate a precise and deliberate application of correct linear perspective in mural painting. Their innovative approach, which convincingly conveyed depth and three-dimensionality on a flat surface, marked a turning point in the way artists conceived composition and spatial representation.

Their collaboration on the Brancacci Chapel frescoes[496] in the Church of Santa Maria del Carmine[497], Florence, is widely recognised as a pivotal development in Renaissance art. By integrating perspective, naturalism, and a more accurate depiction of space and human anatomy, they broke decisively with the Gothic style and helped to shape the emerging Renaissance aesthetic[498]. Despite later challenges, including damage from the 1746 fire and subsequent restoration campaigns, the Brancacci Chapel remains an essential site for the study of early Renaissance painting[499]. Among its notable works is

[493] Samuel Y. Edgerton, *Renaissance Rediscovery of Linear Perspective* (New York: Joanna Cotler Books, 1976), 124-152; Kirsti Andersen, *The Geometry of an Art: The History of the Mathematical Theory of Perspective from Alberti to Monge*, Sources and Studies in the History of Mathematics and Physical Sciences (New York: Springer, 2007), 11-15.

[494] Just two years after Brunelleschi's presumed discovery of linear perspective, the Italian sculptor Donatello created Saint George and the Dragon, completed around 1417. This work is widely regarded as the first known example of linear perspective applied in relief sculpture. Donatello integrated perspective into the architectural framework surrounding the figure of Saint George on the left and further suggested depth through the optical effects of his carving. These techniques create a convincing illusion of space and contribute to a lifelike representation of the figures. The carving technique, known as stiacciato (often referred to as "flattened relief"), enhances the realism by allowing subtle gradations in depth, thereby reinforcing the overall illusion.

See Giorgio Vasari, *Żywoty najsławniejszych malarzy, rzeźbiarzy i architektów*, vol. 2 (Warszawa: Państwowe Wydawnictwo Naukowe, 1985), 150.

[495] Samuel Y. Edgerton, *The Renaissance Rediscovery of Linear Perspective* (New York: Basic Books, 1975), 146.

[496] Umberto Baldini and Ornella Casazza, *The Brancacci Chapel* (Milan: Mondadori Electa, 1994).

[497] During my visit to the Brancacci Chapel in December of 2023, unfortunately, the chapel was undergoing restoration works since 2022. Despite this, I had a great opportunity to admire the works of Masolino and Masaccio from the scaffolding inside the chapel, almost in front of my eyes. However, I was unable to capture a satisfactory photograph showcasing the artwork.

[498] Giorgio Vasari, *Żywoty najsławniejszych malarzy, rzeźbiarzy i architektów*, vol. 2 (Warszawa: Państwowe Wydawnictwo Naukowe, 1985), 11-14

[499] Samuel Y. Edgerton, *Renaissance Rediscovery of Linear Perspective* (New York: Joanna Cotler Books, 1976), 24-25

Masolino's St Peter Healing a Cripple (1425), which vividly illustrates a passage from the Acts of the Apostles. In this composition, St Peter, adorned in elaborate papal robes, reaches out to a lame man begging at the gate of the temple in Jerusalem, capturing both the emotional and physical transformation of the beggar[500].

Fig. 62. *The Tribute money* by Masaccio in Santa Maria del Carmine in Florence, Florence, Italy (source: Wikimedia commons[501]).

Fig. 63. Perspective analysis of *The Tribute money* by Masaccio. Source: author.

Complementing Masolino's refined narrative style, Masaccio's The Tribute Money (1425–1428) demonstrates a bolder and more structurally rigorous approach to perspective. Depicting the episode from the Gospel of Matthew in which tax collectors question Peter about whether Jesus pays the temple tax, the fresco shows Jesus instructing Peter to retrieve a coin from the mouth of a fish to settle the payment. Masaccio's masterful use of linear perspective, with a single vanishing point strategically placed on the head of Christ, is a defining feature of this work. The carefully foreshortened architectural elements, including buildings and a porch, create a compelling sense of depth, guiding the viewer's

Frederick Hartt and David Wilkins, *History of Italian Renaissance Art*, 7th ed. (Upper Saddle River, NJ: Pearson, 2011), 206-215.

[500] Umberto Baldini and Ornella Casazza, *The Brancacci Chapel* (Milan: Mondadori Electa, 1994), 47-56.

[501]Masaccio, *The Tribute Money*, fresco, c. 1424-1427, Brancacci Chapel, Santa Maria del Carmine, Florence. Wikimedia Commons, accessed June 6 2023.
https://upload.wikimedia.org/wikipedia/commons/b/b3/The_Tribute_Money_by_Masaccio.jpg.

gaze towards Christ[502]. Moreover, the horizon line is positioned at the eye level of the depicted figures, producing the effect that the viewer is of the same height and observing the scene from a natural standpoint, as the characters are rendered at life-size scale[503]. His application of chiaroscuro establishes a directional light source, producing naturalistic shadows and highlights. This technique enhances the three-dimensionality of the figures and objects, imbuing the scene with a convincingly lifelike atmosphere.[504]

Another important example from Masaccio's oeuvre is The Holy Trinity (c. 1427–1428), located in the Dominican church of Santa Maria Novella in Florence, Italy. It is esteemed for its artistic merit and for its groundbreaking contributions to the development of linear perspective, centralised composition, and immersive experience, as well as for its treatment of religious themes on the flat surface of a church wall.

The fresco creates the illusion of a three-dimensional sculpted altar, although it is painted entirely on a flat wall surface. Its composition follows the form of a triumphal arch, framed by rendered architectural elements, including a semicircular arch, Corinthian capitals, and pilasters[505]. These details reflect the emerging early Renaissance interest in classical architecture and mark a clear break from f the Gothic style. The scene is arranged in two horizontal sections. The upper section shows life-sized figures: Christ crucified, with God the Father, depicted as an elderly, bearded man, supporting the cross from behind. The Virgin Mary and Saint John the Evangelist stand on either side, while the fresco's donors are placed at the edges. The lower section depicts a skeleton in a painted sarcophagus, reinforcing the message of mortality and the promise of salvation through Christ's sacrifice.

Masaccio's use of linear perspective in *The Holy Trinity* marks a major advancement, even beyond his earlier achievement in *The Tribute Money*[506]. Architectural features such as the coffered barrel vault above the crucified Christ generate a powerful illusion of depth and three-dimensional space[507]. The perspective is calculated so that the vanishing point coincides with the viewer's eye level when standing on the floor of the Dominican church, creating a natural and immersive viewing experience. Particularly innovative is the way Masaccio integrates familiar elements of church interior decoration with a fictive space that extends beyond the crucified Christ, most notably the tomb and skeleton below. The fresco is harmoniously integrated with the real architecture of Santa Maria Novella, its composition aligning precisely with the surrounding structural features, in the manner of other altars in the church. This seamless correspondence between painted and physical space draws the viewer's gaze toward the vanishing point, intensifying the sense of depth and realism. The Holy Trinity stands as a landmark

[502] It is one of the earliest examples of Renaissance painting to redefine the purpose of linear perspective in art, following the Gothic period and the Proto-Renaissance, when artists often employed multiple vanishing points aligned along a vertical axis.

[503] Interestingly, the effect is less striking when viewed from the chapel floor, as the fresco is positioned approximately four metres above the pavement of the Brancacci Chapel, reducing its immersive quality. The author was able to observe its full impact during restoration works, when scaffolding at the level of the fresco allowed for a first-hand experience of the remarkable immersive effect created by this ingenious use of perspective.

[504] Umberto Baldini and Ornella Casazza, *The Brancacci Chapel* (Milan: Mondadori Electa, 1994), 31-39

[505] Interestingly, the composition closely mirrors that designed by Filippo Brunelleschi for the Ospedale degli Innocenti, particularly in the gate passage with Corinthian pilasters and tondi. Both examples were created around the same time that the fresco was painted.

[506] Samuel Y. Edgerton, *Renaissance Rediscovery of Linear Perspective* (New York: Joanna Cotler Books, 1976), 27

[507] John A. Aiken, "The Perspective Construction of Masaccio's *Trinity* Fresco and Medieval Astronomical Graphics," *Artibus et Historiae* 16, no. 31 (1995): 171, https://doi.org/10.2307/1483503.

achievement in the evolution of perspective during the Renaissance[508]. Despite Masaccio's short-lived career, as he died in Rome in 1428 at the age of twenty-seven, his and Masolino's[509] contributions to the development of illusionistic art were highly influential.

Fig. 64. *The Holy Trinity, with the Virgin and Saint John and donors* by Masaccio in *Santa Maria Novella*, Florence, Italy. Left: Pre-restoration view (source: Britannica[510]). Middle: Perspective analysis, source: author. Right: Holy trinity with a viewer (source: Flickr[511]).

Paolo Uccello, likely influenced by Masaccio's The Holy Trinity, employed a comparable illusionistic technique in 1436, painting architectural and sculptural elements directly onto a flat church wall[512]. His fresco, *Funerary Monument to Sir John Hawkwood*[513], dedicated to the English mercenary captain (Italian: condottiero) John Hawkwood, is located in Santa Maria del Fiore, Florence. The composition

[508] Frederick Hartt and David Wilkins, *History of Italian Renaissance Art*, 7th ed. (Upper Saddle River, NJ: Pearson, 2011), 218–20, 223–24.

[509] After Masaccio's death, Masolino continued to work as an independent artist, although he never attained the same level of recognition as his younger colleague. He nevertheless applied the principles of linear perspective in works such as The *Annunciation* (1430), a tempera on panel now in the National Gallery of Art, and in his fresco cycle in the Chapel of St Catherine in the church of San Clemente, Rome, which features a similar *Annunciation* positioned above the Gothic arch. Notably, Giorgio Vasari, in the first edition of his *Lives of the Most Excellent Painters, Sculptors, and Architects* (1550), attributed this work to Masaccio, an error that persisted until 1908, when Pietro Toesca correctly identified Masolino as the author of the polychrome. This long-standing misattribution underscores the extent to which Masolino's works remained in the shadows of his more celebrated contemporary.

[510] Masaccio, *The Holy Trinity*, fresco, c. 1425–27, Santa Maria Novella, Florence. Britannica image, accessed June 12, 2024, https://cdn.britannica.com/93/248693-050-47CAFBCA/The-Trinity-fresco-by-Masaccio.jpg.

[511] Masaccio, *The Holy Trinity*, fresco, c. 1425–27, Santa Maria Novella, Florence. Flickr image, accessed June 12, 2024, https://live.staticflickr.com/65535/49947441171_7096df7a1f_h.jpg.

[512] Frederick Hartt and David Wilkins, *History of Italian Renaissance Art*, 7th ed. (Upper Saddle River, NJ: Pearson, 2011), 267-263.

[513] John Hawkwood (c. 1323 – 1394) (aka. Giovanni Acuto) was an English mercenary and condottiero who gained fame for his military prowess in Italy during the 14th century. He commanded the White Company, a renowned band of mercenaries, and served various Italian city-states, including Milan and Florence.

depicts a horse, based on the Quadriga from the Basilica of San Marco in Venice, carrying a fully armoured rider positioned above a painted tomb. This is regarded as the earliest known representation of a mounted horseman in Florentine painting[514]. The work applies a single-point perspective system, with all orthogonals converging at the eye level of a viewer standing on the church floor, creating a coherent spatial illusion[515].

Fig. 65. Illusory *condottieri* epitaphs in Santa Maria del Fiore in Florence. Left: *Funerary Monument to Sir John Hawkwood* by Paolo Uccello. Right: *Epitaph of Niccola da Tolentino* by Andrea del Castagno. Source: author, 2022.

In 1456, Andrea del Castagno[516] executed the *Epitaph of Niccolò da Tolentino* on the same wall of the same church, adjacent to Uccello's monument. This placement formed a paired commemorative display, with almost the same scene, including the sarcophagus with horse rider placed on top[517].

[514] Giorgio Vasari, *Żywoty najsławniejszych malarzy, rzeźbiarzy i architektów*, vol. 2 (Warszawa: Państwowe Wydawnictwo Naukowe, 1985), P. 58.

[515] It is worth noting Giorgio Vasari's description of Paolo Uccello's life, in which he criticises Uccello's obsession with perspective. Despite Vasari's disapproval, Uccello had mastered the technique to perfection, as demonstrated in his Funerary Monument to Sir John Hawkwood

Giorgio Vasari, *Żywoty najsławniejszych malarzy, rzeźbiarzy i architektów*, vol. 2 (Warszawa: Państwowe Wydawnictwo Naukowe, 1985), 51.

"Paolo Uccello would have been the most gracious and fanciful genius that was ever devoted to the art of painting, from Giotto's day to our own, if he had laboured as much at figures and animals as he laboured and lost time over the details of perspective; for although these are ingenious and beautiful, yet if a man pursues them beyond measure he does nothing but waste his time, exhausts his powers, fills his mind with difficulties, and often transforms its fertility and readiness into sterility and constraint, and renders his manner, by attending more to these details than to figures, dry and angular, which all comes from a wish to examine things too minutely; not to mention that very often he becomes solitary, eccentric, melancholy, and poor, as did Paolo Uccello. This man, endowed by nature with a penetrating and subtle mind, knew no other delight than to investigate certain difficult, nay, impossible problems of perspective, which, although they were fanciful and beautiful, yet hindered him so greatly in the painting of figures, that the older he grew the worse he did them."

[516] Frederick Hartt and David Wilkins, *History of Italian Renaissance Art*, 7th ed. (Upper Saddle River, NJ: Pearson, 2011), 271-278.

[517] Interestingly, the horse's pose, with one foreleg raised and the remaining three firmly on the ground, closely follows a well-known arrangement in monumental sculpture. It first appeared in the bronze statue of Marcus Aurelius (c. AD 175), now in the Capitoline Museums with a replica displayed on the Capitoline Hill. This ancient work survived largely because it was mistakenly believed during the Middle Ages to depict the Christian emperor Constantine the Great. The same pose and

Castagno adopted a similar approach, with illusory epitaph depicting a mounted condottiero above a tomb, painted to resemble a marble equestrian statue.

Perspective treaties

The earliest known systematic attempt to record the artistic discoveries of previous epochs is *De Pictura*[518] by Leon Battista Alberti in 1435[519]. In this treatise, Alberti offers a comprehensive discussion of the principles of linear perspective, a groundbreaking method for the scientific representation of spatial relationships in art. He explains how artists can apply mathematical principles, particularly descriptive geometry, to create the illusion of depth and three-dimensional space. Alberti acknowledges that perspective had been explored by earlier masters[520] and, in his prologue, reflects on the perceived decline of the arts and sciences since antiquity. He laments that many once-flourishing disciplines had been lost or diminished, partly attributing this to Nature having grown "aged and weary"[521].

In addition to technical instruction, the treatise examines optical principles, particularly how the human eye perceives objects. This demonstrates an early understanding of the science of vision and its potential to enhance realism in art. Alberti advocates a methodical, scientific approach to painting, urging artists to observe nature directly and to study anatomy, proportion, and the effects of light to achieve greater accuracy and lifelikeness. The ideas in *De Pictura* had a lasting impact, transforming painting into a more intellectual and scientific discipline. Alberti's work was instrumental in the rapid dissemination of perspective techniques among Italian artists and in their spread across Europe[522]. Following Alberti, several notable artists and scholars produced treatises that further developed the theory and practice of perspective[523]. The influence of Alberti can be seen in numerous renaissance artworks, particularly in the *Annunciation* motif, where many artists produced similar versions in which perspective plays an important role[524].

---

compositional arrangement casted in bronze were later revived in Donatello's Equestrian Statue of Gattamelata (1447–1453) in Padua.

[518] Translated into Italian one year later as *Della Pittura* in 1436.

[519] Leon Battista Alberti, *On Painting: A New Translation and Critical Edition*, ed. and trans. Rocco Sinisgalli (Cambridge: Cambridge University Press, 2011).

It is one of his three treatises on art, alongside "De statua" and "De re aedificatoria", which together established the Renaissance framework for the fine arts: painting, sculpture, and architecture. Interestingly, in Baroque art, these three disciplines would merge into a unified form, blending painting, sculpture, and architecture into one cohesive expression.

[520] Alberti also praises contemporary figures such as Filippo Brunelleschi, Donatello, and Masaccio, considering their intellect and innovation to rival that of the ancients, despite their lack of original classical models to imitate.

[521] In this context it can be related to the illusory painting in Pompeii, described earlier.

[522] Kazimierz Bartel, *Perspektywa malarska: Zasady, zarys historyczny, estetyka*, vol. 2 (Warszawa: Państwowe Wydawnictwo Naukowe, 1958), 324–28; Kirsti Andersen, *The Geometry of an Art: The History of the Mathematical Theory of Perspective from Alberti to Monge*, Sources and Studies in the History of Mathematics and Physical Sciences (New York: Springer, 2007), 17-34.

[523] These include *De Prospectiva Pingendi (On the Perspective of Painting)* by Piero della Francesca (c. 1474–1475); Leonardo da Vinci's Treatise on Painting (a compilation of loose manuscripts rather than a systematic manual, not published until 1651, Albrecht Dürer's *Underweysung der Messung (A Course in the Art of Measurement*, 1525) and *Institutionum Geometricarum Libri Quatuor (Four Books on Geometric Institutions*, 1532); and Giacomo Barozzi da Vignola's *Le due regole della Prospettiva Pratica (The Two Rules of Practical Perspective,* 1583). Each of these works expanded upon the mathematical and artistic foundations of perspective, influencing both contemporary practice and subsequent generations of artists and architects.

[524] It is worth noting the broader motif of the Annunciation in art, which often features comparable compositions and figures, and frequently makes extensive use of perspective in architectural backgrounds or interior settings. Notable examples include those by Paolo Uccello (1425), Fra Angelico (1432), widely regarded as the most influential, Fra Filippo

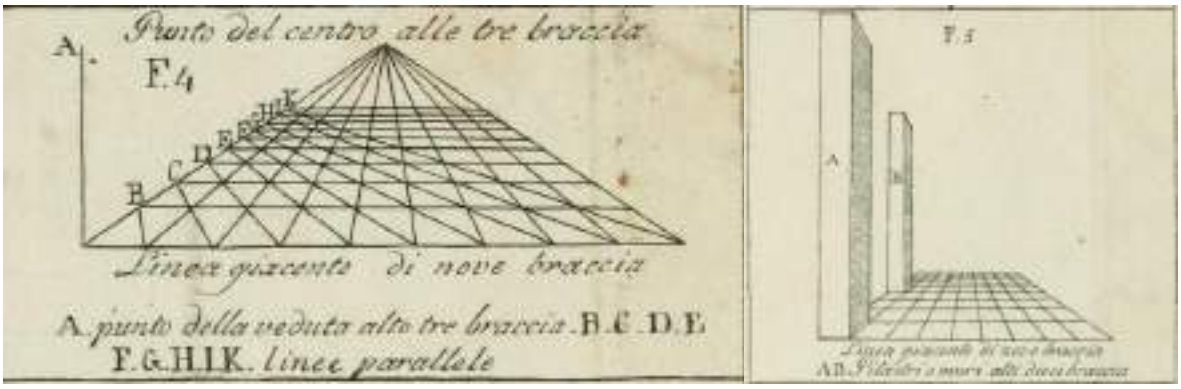


Fig. 66. Linear divisions in one-point perspective by Leon Battista Alberti, from *De Pictura*, reissued in 1804 by Società Tipografica de' Classici Italiani, Milan (source: Internet Archive[525]).

Andrea Mategna

Andrea Mantegna[526], a Northern Italian painter active in Padua and Mantua[527] during the late Quattrocento, played an important role in the development of Renaissance perspective and illusionism, particularly through his integration of architectural representation with complex multi-scene compositions encompassing both religious narratives and courtly subjects[528]. His early artistic training took place in Padua, the birthplace of Giotto and the Paduan school, renowned for its pioneering use of perspective in painting, where he studied under Francesco Squarcione[529]. Mantegna's style is characterised by precision and a deep engagement with classical antiquity, drawing extensively on ancient Roman art. One of his principal aims was to achieve optical illusion through the rigorous application of perspective, making his work particularly relevant to the focus of this thesis. His exceptional abilities are exemplified in the *Lamentation of Christ*[530] (c. 1480), where the extreme foreshortening of Christ's body demonstrates a boldness and intellectual depth unprecedented at the time. Despite the challenging viewpoint, Mantegna maintained accurate anatomical proportions, resulting in a highly naturalistic depiction. In addition to his achievements in painting, Mantegna was an accomplished engraver, making significant contributions to the advancement of the medium[531].

Lippi (three versions: 1445, 1450, and 1450), Domenico Veneziano (1448), Leonardo da Vinci (1476), Sandro Botticelli (1489), Titian (1564), among others.

525 Leon Battista Alberti, *Della pittura e della statua di Leonbatista Alberti*, translated by Cosimo Bartoli, Milano: Società tipografica de' Classici Italiani, 1804, accessed May 1, 2023, https://archive.org/details/dellapitturaedel00albe/page/n177/mode/2up.

526 Giorgio Vasari, *Żywoty najsławniejszych malarzy, rzeźbiarzy i architektów*, vol. 2 (Warszawa: Państwowe Wydawnictwo Naukowe, 1985), 161-169; Frederick Hartt and David Wilkins, *History of Italian Renaissance Art*, 7th ed. (Upper Saddle River, NJ: Pearson, 2011), 397-410.

526 Ronald Lightbown, *Andrea Mantegna: With a Complete Catalogue of the Paintings, Drawings, and Prints* (Berkeley: University of California Press, 1992).

527 Known for his long service at the Gonzaga court, where he developed the Mantua artistic style.

528 Within the scope of my research on Renaissance art and perspective, Andrea Mantegna stands out as the most influential figure, whose innovative approach and technical mastery have left a deep and enduring impression on me.

529 Ronald Lightbown, *Andrea Mantegna: With a Complete Catalogue of the Paintings, Drawings, and Prints* (Berkeley: University of California Press, 1992), 13-29.

530 Today in collection of *Pinacoteca Brera* in Milano, Italy, where I had change to visit in 2023.

531 Ronald Lightbown, *Andrea Mantegna: With a Complete Catalogue of the Paintings, Drawings, and Prints* (Berkeley: University of California Press, 1992), 234-242.

Fig. 67. Ovetari Chapel by Andrea Mategna. Source: author, 2023[532].

One of Mantegna's earliest significant commissions was a cycle of frescoes for the *Ovetari Chapel* in the *Church of the Eremitani*, Padua[533]. Commissioned in the 1440s by Taddeo degli Ovetari, a Paduan nobleman, the chapel was intended as the burial place for his family. Situated only 150 metres from the renowned Scrovegni Chapel discussed earlier, it provided Mantegna with an important opportunity to demonstrate his developing artistic skill. Working alongside his assistants, he produced frescoes depicting episodes from the lives of Saints James, Christopher, and Vincent, as well as other religious subjects.

[532] Owing to the restricted access to the chapel, the only photographs obtainable were tilted and skewed.

[533] Regrettably, the chapel sustained severe damage during an Allied air raid on Padua in the Second World War, resulting in the destruction of much of its structure and fresco decoration. Extensive restoration efforts have since been undertaken to preserve and reconstruct the surviving artwork. The restored interior serves as a compelling example of the reintegration of partially lost works, with non-original areas reconstructed in neutral tones, often in black or monochrome, ensuring that the preserved fragments remain visually distinct from later additions. This approach allows viewers to appreciate the original elements while maintaining transparency regarding the extent of modern intervention, thereby respecting both the material integrity and the historical authenticity of the work.

See Ronald Lightbown, *Andrea Mantegna: With a Complete Catalogue of the Paintings, Drawings, and Prints* (Berkeley: University of California Press, 1992), 30-57.

Fig. 68. Scene From Ovetari Chapel by Andrea Mantegna. Left: Martyrdom of St. James, (source: Wikimedia commons[534]). Right: Transportation of St. Christopher Beheaded Body, (source: Wikimedia commons[535]).

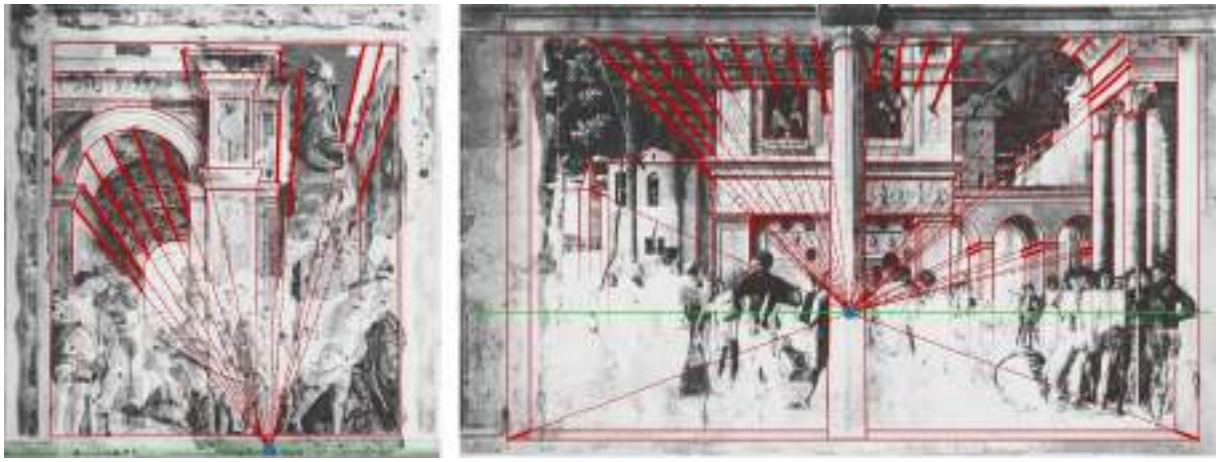


Fig. 69. Perspective analysis, on Mantegna's works in Ovetari Chapel. Source: author.

These works reveal his knowledge of perspective, anatomical accuracy, and classical motifs. Particularly striking is his innovative treatment of architectural details and spatial depth. In a manner comparable to Masaccio's Holy Trinity, Mantegna positioned the horizon lines on the bottom scenes, especially on the example of *Martyrdom of St. James,* so that the scenes appeared naturally proportioned to a viewer standing on the chapel floor. Drawing on his studies of classical antiquity, Mantegna also employed illusionistic architectural features, such as painted columns, as in the example of *Transportation of St. Christopher Beheaded Body* to divide the narrative scenes, integrating them seamlessly into the pictorial scheme and blurring the boundary between the real and the represented space[536].

Another notable example of Mantegna's mastery of descriptive geometry and illusion is the *San Zeno Altarpiece*, executed in tempera on wooden panels. It is housed in the early *Romanesque Basilica of*

[534] Interior view of the Cappella Ovetari, Stories of St. James by Andrea Mantegna, Church of the Eremitani, Padua. Wikimedia Commons, accessed March 21, 2023, https://upload.wikimedia.org/wikipedia/commons/7/79/Church_of_the_Eremitani_%28Padua%29_-_Interior_-_cappella_Ovetari_-_storie_di_san_giacomo.jpg.

[535] Andrea Mantegna, *Stories of St. Christopher* (fresco, c. 1447-56), south wall, Cappella Ovetari, Church of the Eremitani, Padua. Wikimedia Commons, accessed March 21, 2023, https://upload.wikimedia.org/wikipedia/commons/6/61/Ovetari%2C_storie_di_san_cristoforo.JPG.

[536] Kazimierz Bartel, *Perspektywa malarska: Zasady, zarys historyczny, estetyka*, vol. 2 (Warszawa: Państwowe Wydawnictwo Naukowe, 1958), 343–49.

San Zeno Maggiore in Verona, Italy. Commissioned by the Franciscan friars in 1456 and completed around 1459, the altarpiece centres on the Madonna and Child seated on a marble throne, surrounded by angels singing and playing musical instruments. Mantegna skilfully integrated the painted scene with its frame and the four sculpted wooden Corinthian columns that divide the altar into three sections. Through the precise application of proportion and linear perspective, he created an illusion of depth, aligning the painted elements with the architectural features. This technique produces the impression of an interior room in which the Madonna is situated, further enhancing the realism of the composition. His expert handling of perspective makes the painted space appear to continue seamlessly behind the columns, heightening the overall sense of verisimilitude for the viewer. Additionally, the figures seem to interact with the architectural framework, giving the impression that they are stepping beyond the confines of the altarpiece. This work is yet another example of Mantegna's anticipation of the Baroque integration of architecture, sculpture, and painting, a concept that would flourish in the centuries to come. From the viewer's vantage point, the triptych creates the sensation that the depicted figures are emerging into the viewer's space, while the distant background, with its lush greenery, provides a compelling illusion of depth[537].

Fig. 70. *San Zeno Altarpiece* by Andrea Mategna, with perspective analysis. Source: author, 2023.

Mantegna served a number of patrons throughout his career, most notably the Gonzaga family of Mantua. As court painter to the Gonzaga rulers, he produced frescoes and other works for their residences. One of his most celebrated achievements, demonstrating advanced techniques in illusion and perspective far ahead of its time, is the decoration of the *Camera degli Sposi* (Bridal Chamber), also known as the *Camera Picta*, in the Palazzo Ducale, Mantua. This remarkable example of illusionistic interior decoration, employing innovative perspectival devices, was executed between 1465 and 1474. The chamber occupies the northern defence tower of the medieval Castello di San Giorgio and has an almost square plan, with a vaulted ceiling and three lunettes on each wall.

Commissioned as a ceremonial reception space, the chamber's frescoes portray episodes from the life and festivities of Ludovico III Gonzaga, Marquess of Mantua, and his family. Mantegna integrated the painted decoration seamlessly with the existing architecture, aligning life-sized figures, columns, and architectural features to create convincing spatial depth. He ingeniously incorporated real structural

[537] Ronald Lightbown, *Andrea Mantegna: With a Complete Catalogue of the Paintings, Drawings, and Prints* (Berkeley: University of California Press, 1992), 65-66.

elements into the illusion: angels appear to stand upon the actual cornice above the entrance, while a courtly gathering is painted so that its figures seem to occupy the real fireplace. In some scenes, figures extend beyond the pictorial plane, such as the paw of a dog reaching into the viewer's space. The immersive quality of the room is further enhanced by his strategic use of draperies. Two walls are painted with open curtains revealing narrative scenes, while the remaining walls show closed curtains, suggesting hidden episodes and adding a sense of intrigue. By allowing figures and draperies to overlap painted architectural elements, Mantegna blurred the boundaries between actual space and pictorial invention, creating one of the most sophisticated integrations of architecture and painting in the fifteenth century[538].

Fig. 71. *Camera Degli Sposi* in Mantua Castle incorporated in Palazzo Ducale by Andrea Mantegna, Source: ZeuxisVR[539]). Orthophotos based on 3D model created by *ZeuxisVR,* postproduction Szymon Kowalski.

Fig. 72. Fresco on the vault of *Camera Degli Sposi* in Mantua Castle incorporated in Palazzo Ducale by Andrea Mantegna. Source: author, 2023.

[538] Ronald Lightbown, *Andrea Mantegna: With a Complete Catalogue of the Paintings, Drawings, and Prints* (Berkeley: University of California Press, 1992), 98-117; Ettore Camesasca, *Mantegna* (New York: Riverside Book Company, 1992), 36–51; Frederick Hartt and David Wilkins, *History of Italian Renaissance Art*, 7th ed. (Upper Saddle River, NJ: Pearson, 2011), 405–7.

[539] "Mantegna, *Camera degli Sposi (Camera Picta)*," 3D model, Sketchfab, accessed April 1, 2024, https://sketchfab.com/3d-models/mantegna-camera-degli-sposi-camera-picta-3481c0e518a44e839e6774118c0fe68f.

The vault of this interior represents another of Mantegna's masterpieces of illusion and merits separate discussion. Apart from the consoles, which are sculptured element, all of the apparent stonework, including the ribs that appear to support the vault, is painted. At its centre, Mantegna depicted an oculus framed by a painted balustrade, creating a playful and humorous illusion. Through this fictive opening, numerous *putti* and curious onlookers seem to peer into the room, while beyond them a blue sky with scattered clouds is rendered, giving the impression that the vault has been visually dissolved.

All of the frescoes in this chamber are renowned for their artistic brilliance and technical innovation, exemplifying Mantegna's mastery in constructing convincing three-dimensional spaces that appear to expand the actual volume of the medieval tower interior. This illusion is achieved through the combined use of wall painting and the central oculus. The optimal vantage point lies at the centre of the floor, where the illusion is most effective. This introduces the concept of *punto stabile*, a fixed viewing position, and an illusory approach later perfected in the Baroque period. The technique employed, known as *di sotto in sù* (Italian for "seen from below"), relies on foreshortened figures and an architectural vanishing point to create the impression of real space on a painted ceiling, producing a striking sense of depth when viewed from beneath.

Leonardo da Vinci

Familiar with the achievements of earlier artists, Leonardo da Vinci[540] applied the principles of linear perspective with great sophistication in his works[541]. One of his most renowned and iconic frescoes is The Last Supper[542], commissioned by Ludovico Sforza during Leonardo's first Milanese period (1482–1499) and painted between 1495 and 1498. The mural is located on the wall of the refectory of the Convent of *Santa Maria delle Grazie* in Milan, Italy[543].

The Last Supper depicts the moment when Jesus announces that one of his disciples will betray him during their final meal together. He adopted a similar composition to that of Andrea del Castagno, with Christ and the Apostles seated on one side of a long table. This arrangement fostered an interaction between the painted scene and the Dominican friars who dined in the refectory, allowing them to feel as though they were sharing a meal with the figures in the fresco, thereby enhancing the immersive quality of the space.

---

[540] Giorgio Vasari, *Żywoty najsławniejszych malarzy, rzeźbiarzy i architektów*, vol. 4 (Warszawa: Państwowe Wydawnictwo Naukowe, 1985), 13-31; Frederick Hartt and David Wilkins, *History of Italian Renaissance Art*, 7th ed. (Upper Saddle River, NJ: Pearson, 2011), 443-468.

[541] Other works by Leonardo that make extensive use of linear perspective, employing architectural elements to convey depth, include *Annunciation* (1472–1476), *Madonna Litta* (1481–1495), *Madonna of the Carnation* (1472–1478), and the unfinished *Adoration of the Magi* (c. 1482), among others.

See Kirsti Andersen, *The Geometry of an Art: The History of the Mathematical Theory of Perspective from Alberti to Monge*, Sources and Studies in the History of Mathematics and Physical Sciences (New York: Springer, 2007), 81-112.

[542] Over the centuries, *The Last Supper* has faced numerous challenges, including deterioration, damage caused by earlier restoration attempts, and bombing during the Second World War. Despite these setbacks, the painting endures as a cultural and artistic masterpiece, celebrated for its innovation, symbolism, and narrative power. It has become the most reproduced religious artwork in history. Conservation efforts have been extensive, with interventions recorded as early as the 18th century, many of which unintentionally accelerated its degradation due to the experimental materials and methods employed. The most significant modern restoration, conducted between 1978 and 1999, adopted a principle of distinguishability, in which missing areas were reintegrated using neutral watercolor tones to differentiate them from Leonardo's original work. This ensured that viewers could appreciate both the surviving Renaissance masterpiece and the extent of modern intervention.

[543] An important precedent is Andrea del Castagno's Cenacolo di Sant'Apollonia, painted between 1445 and 1450 in the refectory of the convent of Sant'Apollonia in Florence. This earlier work employs linear perspective in a similar compositional arrangement and predates Leonardo's fresco by nearly forty years.

Fig. 73. *The Last Supper* by Leonardo da Vinci, seen from standing perspective. Source: author, 2023.

Leonardo, in his fresco, employed linear perspective to create a convincing illusion of depth and three-dimensionality on a flat surface. The vanishing point is positioned directly behind Christ's head, naturally directing the viewer's gaze toward the central figure. The symmetrical composition places Christ at the centre, framed by the twelve disciples in four groups of three. The architectural background, with its windows and recesses, reinforces the depth of the scene. Orthogonal lines extend from the edges of the composition and converge at the vanishing point, systematically organising the space. Architectural features, such as the coffered ceiling and tiled floor, incorporate these receding lines seamlessly, guiding the viewer's eye into the painted space. Leonardo also applied the principle of relative scale, rendering figures and objects smaller as they recede in space[544]. This can be seen in the slight diminution of the disciples' proportions toward the ends of the table, which enhances the depth effect[545]. The back wall of the depicted room, with its two windows and a central doorway, creates the illusion that the painted space extends beyond the actual wall of the refectory. The careful placement of the fresco in the dining hall thus dematerialises the physical wall, making the space feel larger and more open[546].

Raphael Santi

With the artistic advancements of the High Renaissance, one of the masters who perfected the use of perspective to create immersive compositions was Raffaello Sanzio da Urbino[547], better known as Raphael. Among his most celebrated works is The School of Athens, painted between 1509 and 1511

[544] Kazimierz Bartel, *Perspektywa malarska: Zasady, zarys historyczny, estetyka*, vol. 2 (Warszawa: Państwowe Wydawnictwo Naukowe, 1958), 383-385.

[545] In addition, he employed *chiaroscuro* to model forms through light and shadow, a technique he would later refine and popularise.

[546] D. M. Field, *Leonardo Da Vinci* (London: Grange Books, 2007), 208–31.

[547] Giorgio Vasari, *Żywoty najsławniejszych malarzy, rzeźbiarzy i architektów*, vol. 4 (Warszawa: Państwowe Wydawnictwo Naukowe, 1985), 124–63; Frederick Hartt and David Wilkins, *History of Italian Renaissance Art*, 7th ed. (Upper Saddle River, NJ: Pearson, 2011), 480–84, 515–42; 3. Stephanie Buck and Peter Hohenstatt, *Masters of Italian Art: Raphael* (Potsdam: Ullmann Publishing, 2013).

as part of a series of frescoes adorning the walls of the *Stanza della Segnatura* in the Vatican's Apostolic Palace, commonly referred to as the Raphael Rooms. Positioned on the east wall, this fresco represents the discipline of philosophy, bringing together great philosophers from different eras within an imagined classical architectural setting. At the centre of the composition stand Plato and Aristotle, engaged in profound dialogue, surrounded by numerous other intellectual figures[548]. Although this gathering is not a historical event, it functions as an idealised vision, symbolising the continuity and enduring legacy of philosophical thought.

The architectural setting of The School of Athens is fundamental to its effective use of linear perspective, building upon and refining principles established by Raphael's predecessors[549]. He skilfully incorporates the physical architecture of the *Stanza della Segnatura*, including the supporting arch, into the composition of the fresco, thereby reinforcing the illusion of depth. Colour contributes equally to this effect: the decoration of the arch and vaults mirrors the palette employed within the fresco itself, producing a cohesive visual harmony that dissolves the boundary between the tangible space of the room and the painted, illusionistic realm. The depicted grand hall, with its classical architecture, provides the structural framework for the perspectival design, while the patterned floor tiles and coffered barrel vault guide the viewer's gaze towards the vanishing point, enhancing the sense of spatial recession, depth, and overall immersion. The vanishing point is located between the Plato and Aristotle heads, thus drawing viewers' attention to the most important character depicted by the artist. The scene unfolds within a vast architectural setting inspired by ancient Greek and Roman models, reinforcing both the compositional balance and the classical ideals embodied in the work.

Fig. 74. *The School of Athens* by Raphael Santi. Source: author, 2022.

[548] Plato, depicted with the likeness of Leonardo da Vinci, points upwards to symbolise his focus on the realm of ideas, while Aristotle gestures towards the earth, emphasising empirical observation. Surrounding them are prominent philosophers, scientists, and mathematicians, including Pythagoras, Euclid, Heraclitus, and Diogenes, each portrayed engaging in activities that reflect their contributions to various fields of knowledge.

[549] Kazimierz Bartel, *Perspektywa malarska: Zasady, zarys historyczny, estetyka*, vol. 2 (Warszawa: Państwowe Wydawnictwo Naukowe, 1958), 367–69.

Forced Perspective in Renaissance

While the previously discussed examples focused on painting techniques, or on the combination of painting and sculpture, to enhance immersive effects, the history of art also provides significant examples of architectural illusion. One of the earliest and most notable is found in Donato Bramante's[550] rebuilding of the Church of *San Satiro* in Milan, Italy, completed in 1482[551]. The rebuilding of the church presented a particular challenge: it needed to be larger than the original, yet the constraints of Milan's urban layout made it impossible for Bramante to construct a full presbytery and complete the Latin cross floor plan. In response, Bramante devised a solution that relied on illusion rather than physical extension. He designed a shallow presbytery incorporating a highly realistic perspectival representation of an elongated, sculpted, barrel-vaulted chancel with three arcades, replicating the proportions and composition of the transept. This solution extends the viewer's perception of depth, making it appear as though the space continues far beyond its actual dimensions. The illusion, however, is revealed when the viewer moves away from the carefully calculated vantage point (*punto stabile*), exposing the architectural artifice. The Church of San Satiro is celebrated for this ingenious use of perspective, which creates the optical impression of an interior far more expansive than its physical size, establishing it as a crucial example of architectural illusion in Renaissance architectural design.

Fig. 75. Illusory presbytery of *Church of Santa Maria presso San Satiro* (1476-1482), Milano, Italy. Source: author, 2023.

Laurentian Library and Teatro Olimpico

A similar approach to that used by Bramante in San Satiro, in which perspective is employed to create immersive designs and illusions of depth, can be observed in the staircase of the Laurentian Library, a project that would later influence the optical effects incorporated into Baroque staircases in the Vatican. Located within the cloister of the Basilica di San Lorenzo, the library was commissioned by the Medici family, particularly Pope Clement VII. Construction began in 1524, and Michelangelo directed the project until 1534, focusing on the design of the vestibule and staircase. The staircase, leading up to the reading room, occupies half of the vestibule's floor space. Although the vestibule is modest in scale, spanning only two storeys, the staircase's trapezoidal plan contributes to its dramatic effect. The central flight features curved treads of varying widths, flanked by straight outer flights. The first three steps of the central flight are both wider and higher than the rest, resembling concentric ovals. As the stairs descend, they divide into three separate flights, creating a visually dynamic arrangement. The

[550] Frederick Hartt and David Wilkins, *History of Italian Renaissance Art*, 7th ed. (Upper Saddle River, NJ: Pearson, 2011), 489–95.

[551] The bell tower from the earlier Romanesque structure remains preserved to this day.

architectural configuration, combined with the depth of the reading room corridor beyond, enhances the perception of elongation and lends the relatively small space an imposing sense of grandeur[552].

Fig. 76. *Vestibule of the Laurentian Library*, source: author, 2025. Plan based on 3D model, (Source: ZeuxisVR[553], postprocessed by author).

An innovative example of theatrical stage design employing perspective can be seen in the *Teatro Olimpico*[554] in Vicenza, designed by Andrea Palladio[555] and built between 1580 and 1585. It was Palladio's final work, completed after his death by his pupil Vincenzo Scamozzi. Commissioned by the *Accademia Olimpica*, the theatre represents a Renaissance reinterpretation of the classical Roman theatre. The auditorium, with its semi-circular seating, faces a monumental *scaenae* frons and *pulpitum* adorned with statues of gods and historical figures. Although the theatre is indoors, its ceiling is painted to resemble a blue sky, referencing the open-air Roman prototypes and creating a partial illusion of an exterior space. The most innovative element is Scamozzi's stage design, known as the "Scamozzi Perspective." This employs forced perspective to create the impression of streets and buildings receding towards a distant vanishing point, representing the ancient city of Thebes. In reality, the sets extend only a few metres, yet the arrangement of diminishing passageways produces a powerful illusion of depth[556]. This was the first practical application of perspective in Renaissance theatre, a device that subsequently became standard in stage scenery. The Teatro Olimpico represents a unique

[552] David Watkin, *A History of Western Architecture*, 2nd ed. (London: Laurence King Publishing, 1996), 196–98; Frederick Hartt and David Wilkins, *History of Italian Renaissance Art*, 7th ed. (Upper Saddle River, NJ: Pearson, 2011), 550–52.

[553] ZeuxisVR. *Michelangelo: Vestibule of Laurentian Library*. Sketchfab. Accessed September 13, 2025. https://sketchfab.com/3d-models/michelangelo-vestibule-of-laurentian-library-6175567cd0f54ede90c16e560cbf7194.

[554] During my visit to Vicenza, the theatre was unfortunately closed, so I was unable to access the interior or take a proper photograph.

[555] Frederick Hartt and David Wilkins, *History of Italian Renaissance Art*, 7th ed. (Upper Saddle River, NJ: Pearson, 2011), 643–47.

[556] Licisco Magagnato, "The Genesis of the Teatro Olimpico," *Journal of the Warburg and Courtauld Institutes* 14, no. 3–4 (1951): 209–20, https://doi.org/10.2307/750339; Giuseppe Amoruso, Alberto Sdegno, and Andrea Manti, "Surveying and 3D Modelling of the Andrea Palladio's Teatro Olimpico in Vicenza: First Studies on Geometric Analysis and Perspectives," in *Graphic Imprints*, 427–38 (Cham: Springer International Publishing, 2019).

synthesis of Palladian architecture and Scamozzi's optical ingenuity, and is inscribed on the UNESCO World Heritage List along with other works by Palladio in Vicenza[557].

Fig. 77. Interior of *Teatro Olimpico*, (source: Wikimedia commons[558]).

3.1.4. Baroque illusion

The next significant stage in the evolution of illusionistic art, building on the technical and theoretical advances of the Renaissance, occurred during the Counter-Reformation within the Catholic Church and is widely regarded as marking the beginning of the Baroque period. An influential figure in shaping early Baroque design was Carlo Borromeo, Archbishop of Milan, whose treatise *Instructiones Fabricae et Supellectilis Ecclesiasticae* (1577) set out guidelines for church construction and furnishing. His emphasis on clear liturgical space, direct visibility of the altar, and the didactic role of architecture had a lasting impact on subsequent ecclesiastical design. This era coincided with the emergence of a distinct architectural vocabulary, the development of new approaches to illusionistic painting, and the founding of the Society of Jesus (Jesuits), which became one of the principal promoters of the new style.

The artistic groundwork for Baroque illusionism was established earlier in the sixteenth century by artists of the late Renaissance and Mannerist periods. Antonio da Correggio pioneered large-scale dome decoration with some of the earliest examples of illusionistic dome decoration, while Giulio Romano developed immersive fresco schemes characterised by continuous spatial illusion, dynamic composition, and the integration of painting with architecture. These innovations anticipated the Baroque aim of dissolving structural boundaries to create unified, theatrical environments.

[557] UNESCO World Heritage Centre, "City of Vicenza and the Palladian Villas of the Veneto," *UNESCO World Heritage List*, inscribed 1994 (extended 1996), https://whc.unesco.org/en/list/712/.

[558] Wikimedia Commons. *Interior of Teatro Olimpico (Vicenza), scena*. Accessed August 15, 2024. https://commons.wikimedia.org/wiki/File:Interior_of_Teatro_Olimpico_(Vicenza)_scena_.jpg.

Mannerism foundations

A significant early example of dome decoration[559] is the *Assumption of the Virgin*, painted by Antonio da Correggio[560] between 1526 and 1530 for the dome of the Romanesque Cathedral of Parma in Italy[561]. The fresco employs calculated foreshortening and perspective to organise figures and clouds in the vortex formation depicting the Virgin Mary's ascent into heaven[562], aligned with the dome's curvature. Forming a coherent spatial arrangement when viewed from below, the spiral composition leads the viewer's gaze upward along a continuous path, creating a strong sense of vertical movement[563].

Fig. 78. Parma Illusory Dome by Antonio da Correggio's *Assumption of the Virgin*[564]. Source: author, 2023.

Correggio's design extends the apparent height of the dome and obscures its structural form, giving the impression of an open sky. The adaptation of the composition to the octagonal dome required precise planning and the application of descriptive geometry to maintain correct proportions across its facets. Unlike his predecessors, who typically worked on flat surfaces, Correggio successfully mapped

[559] A similar motif appears in Correggio's earlier work, the decoration of the dome of the Mannerist church of San Giovanni Evangelista in Parma (1520–1522), located adjacent to the cathedral, in the fresco The Vision of St John the Evangelist.

[560] Giorgio Vasari, *Żywoty najsławniejszych malarzy, rzeźbiarzy i architektów*, vol. 4 (Warszawa: Państwowe Wydawnictwo Naukowe, 1985), 39–45; Frederick Hartt and David Wilkins, *History of Italian Renaissance Art*, 7th ed. (Upper Saddle River, NJ: Pearson, 2011), 480–84, 572–76.

[561] Danilo Bersani, Michela Berzioli, Simone Caglio, Antonella Casoli, Pier Paolo Lottici, Laura Medeghini, Gianluca Poldi, and Paolo Zannini, "An Integrated Multi-Analytical Approach to the Study of the Dome Wall Paintings by Correggio in Parma Cathedral," *Microchemical Journal* 114 (2014): 80–88, https://doi.org/10.1016/j.microc.2013.11.014

[562] The composition depicts the Virgin Mary encircled by angels, saints, and prophets positioned along a spiral path of clouds. At the apex, God the Father receives her, while the apostles, situated below, witness the event.

[563] Antonio da Correggio's Assumption of the Virgin, became a key artistic model. Giovanni Lanfranco adopted its spiralling composition for his *Glory of Paradise* in the dome of *Sant'Andrea della Valle* in Rome, completed in 1627 to Carlo Maderno's design. The same dynamic arrangement also informed Orazio Riminaldi's *Virgin in Glory with Saints* in the dome of Pisa Cathedral, painted between 1627 and 1630 and completed after his death by his brother Girolamo.

See Rolf Toman, *Baroque* (Königswinter, Germany: Könemann, 1998), 142–44.

[564] The view was limited by the restoration works inside the cathedral.

a complex illusion across a three-dimensional, faceted form. Similar to Mantegna, Correggio integrated existing architectural elements with painted figures, positioning them so that they partially obscure the architecture to heighten the sense of immersion. His *Assumption of the Virgin* is among the earliest examples of elaborate illusionistic decoration on a vaulted or domed surface, establishing a precedent that would be expanded in Baroque church interiors and foreshadowing the development of *quadratura.*

Giulio Romano[565], a Mannerist artist and protégé of Raphael, conceived a fully immersive painted environment in the Palazzo del Te, Mantua, noted for its extensive illusionistic frescoes executed between 1532 and 1534. The *Sala dei Giganti* (Room of the Giants) presents the dramatic mythological narrative of the Gigantomachy[566] in a manner that envelops the viewer in the scene. The fresco cycle employs a continuous, unframed composition with no clear narrative panels or divisions, a format that was unusual for the time. Without the technological aids of cameras, screens, or rendering systems, the space engages the observer both psychologically and perceptually, achieving effects comparable to the objectives of contemporary virtual reality.

Although the Sala dei Giganti measures only about 8.7 × 8.7 metres with a height of around 10 metres, Romano's illusionistic treatment creates a powerful sense of monumentality. he frescoes cover the entire interior, extending without interruption from the walls to the ceiling to create an immersive, 360-degree visual experience. The illusionistic design dissolves architectural boundaries: wall corners are visually softened, and transitions between the vertical surfaces and the dome are imperceptible, giving the space a boundless and slightly disorienting quality. Painting and architecture are fully integrated so that the depicted structures appear to collapse as part of the battle scene. The ceiling is rendered as if giving way, while the dynamic postures of the defeated Giants intensify the sense of drama. *Trompe-l'œil*[567] techniques further enhance this effect, with painted architectural lines aligning with the actual structure to suggest that the walls and ceiling are in the process of collapse. On the flattened dome, an illusory architectural lantern and dome, reminiscent of Andrea Mantegna's Camera degli Sposi, where painted figures gaze down at the viewer from the sky, further blur the boundary between real and painted space.

In reference to Correggio's dome in Parma Cathedral, which stands as an earlier precedent for enveloping spatial illusion projected on curvilinear surface, Romano extends this approach into a fully encased environment rather than a single overhead illusion. The result is a work characterised by deliberate exaggeration, distortion, and drama, anticipating the heightened theatricality of the Baroque style that followed, achieved through the complete integration of architecture and painting.

[565] David Watkin, *A History of Western Architecture*, 2nd ed. (London: Laurence King Publishing, 1996), 194–196; Kathleen Kuiper, ed., *The 100 Most Influential Painters & Sculptors of the Renaissance* (New York: Rosen Education Service, 2010), 276–78; Frederick Hartt and David Wilkins, *History of Italian Renaissance Art*, 7th ed. (Upper Saddle River, NJ: Pearson, 2011), 586–89.

[566] The mythological battle in which the Giants, led by their king, attempt to storm Mount Olympus and overthrow the gods. In response, Zeus and the other Olympians cast them down, fracturing the earth and creating scenes of disorder.

[567] During the Baroque period, *trompe-l'œil,* a French term meaning "deceive the eye", was widely employed to create convincing three-dimensional illusions on both flat and curved surfaces. Applied to walls, vaults and domes, it expanded perceived spatial boundaries and depicted scenes or vistas not physically present, enhancing the sense of depth and contributing to the immersive character of ecclesiastical interiors.

Fig. 79. *The fall of the Giants*, frescos in *Sala dei Giganti*, Palazzo del Te, Mantua. Source: author, 2023.

Fig. 80. Orthographic elevations with cross section and view from the bottom to the dome, with plan cross section of frescos in *Sala dei Giganti*, Palazzo del Te, Mantua, (source: VR[568], postproduction by Szymon Kowalski).

Baroque illusion

With the progressive transition from Mannerism to the Baroque, artistic mastery was increasingly expressed through complex compositions projected onto more elaborate surfaces, culminating in the achievements of Andrea Pozzo. Before this pinnacle, however, several notable examples demonstrate Baroque decorative schemes executed on flat surfaces. One such example is Agostino Tassi's work in the Palazzo Lancellotti in Rome, completed around 1621. In this project, Tassi painted an entire loggia using perspective to extend the viewer's perception of real space. The result was a simulated interior

[568] ZeuxisVR. *Giulio Romano, Sala dei Giganti, Palazzo Te*. 3D model. Sketchfab. Published August 9, 2022. Accessed December 28, 2024. https://sketchfab.com/3d-models/giulio-romano-sala-dei-giganti-palazzo-te-f79391c524e644f5ac95272d2e1b331f.

that, through descriptive geometry and pictorial skill, functioned as an early form of an immersive environment, richly adorned with classical Baroque details[569].

Fig. 81. Painted loggia architecture with landscape views 1619-21 by Agostino Tassi in Palazzo Lancellotti, (source: Web gallery of Art[570]).

One of the earliest examples of the Baroque form of *quadratura*[571] projected onto a curvilinear ceiling surface is *The Allegory of Divine Providence and Barberini Power*, located in the Palazzo Barberini in Rome. Commissioned by Pope Urban VIII, the palace was designed by Carlo Maderno, and the fresco, painted by Pietro da Cortona between 1633 and 1639 in the grand salon, serves as a celebration of both divine will and the power of the Barberini family. At the centre of the composition, *Divine Providence* is depicted, surrounded by allegorical figures representing virtues such as Justice, Power, and Fame, each celebrating the achievements of the Barberini family and their role in supporting the Church. The dynamic arrangement of swirling clouds and figures creates a sense of movement and dramatic expression characteristic of Baroque art. This fresco exemplifies the "open heavens" motif that would become a defining feature of Baroque decoration, especially the *quadratura* employing illusionistic architectural elements to generate a convincing sense of depth and space[572].

---

[569] Riccardo Migliari and Jessica Romor, "Theories and Experiments on the 'Veduta Vincolata,'" *Journal for Geometry and Graphics* 19, no. 1 (2015): 57–77.

[570] Web Gallery of Art. Agostino Tassi, *Simulated Loggia Architecture with Landscape Views*, fresco (1619–1621), Palazzo Lancellotti, Rome. Accessed March 30, 2023. https://www.wga.hu/html_m/t/tassi/lancelot.html.

[571] A specialised form of *trompe-l'œil* known as *quadratura* focused on the illusionistic extension of real architecture through perspectival accurate painted architectural elements such as columns, arches and vaults, often integrated with the actual structural framework to create a unified spatial composition. In Baroque church decoration, *quadratura* was frequently employed in ceiling painting, with real or painted stucco frames enclosing complex compositions in which architectural features appeared to extend beyond their physical limits. Figures such as saints, angels and allegories were incorporated into the fictive architecture, while painted Atlantes beneath cornices could seem to bear the weight of the ceiling. Unlike example of Michelangelo's *Sistine Chapel*, where each scene is designed with its own perspective, Baroque ceiling paintings were calculated from a single, unified viewpoint on the church floor, ensuring that the illusion operated as a coherent whole.

[572] Rolf Toman, *Baroque* (Königswinter, Germany: Könemann, 1998), 18–22, 153–55; Paolo Portoghesi, *Rome Baroque: The History of an Architectonic Culture* (Cambridge, MA: MIT Press, 1970), 13–14.

Fig. 82. *The Allegory of Divine Providence and Barberini Power* by Pietro da Cortona, (source: egiptologo91[573], post production by author).

Quadratura

The Church of *Il Gesù* in Rome, Italy, is regarded as the seminal monument of Baroque architecture and art. As the mother church of the Society of Jesus (Jesuits), it holds a position of great significance and served as a model for Jesuit churches worldwide[574]. The architectural design was by Giacomo Barozzi da Vignola, whose plan has its roots in the Renaissance, with construction beginning in 1568. Its façade, later completed by Giacomo della Porta, stands as a notable example of the transitional phase between Renaissance and Baroque architectural styles[575].

The interior of the church features the celebrated decoration by Giovanni Battista Gaulli, known as *Baciccio*, who painted *The Triumph of the Name of Jesus* on the nave ceiling between 1672 and 1685. This monumental fresco is one of the most celebrated works of Baroque illusionism and exemplifies the artistic ideals of the Counter-Reformation, with unified and immersive visual programme. Commissioned by the Jesuit Order as part of their wider programme to employ art as a persuasive tool for engaging the faithful, it was conceived to inspire devotion and reaffirm Catholic doctrine in the wake of the Reformation[576].

---

[573] egiptologo91. *Allegory of Divine Providence and Barberini Power*. 3D model. Sketchfab. Published March 31, 2017. Accessed August 20, 2025. https://sketchfab.com/3d-models/allegory-of-divine-providence-and-barberini-55404887774c45d8be3068ffeab39f21.

[574] Baroque churches, particularly those built for the Jesuit Order, were designed to heighten congregational engagement with the liturgy, aligning with the Counter-Reformation emphasis on persuasive and emotionally compelling religious art. Plans often incorporated expansive central spaces that directed sightlines towards the altar. A centrally placed dome or cupola admitted natural light and symbolised the link between the earthly and the divine. Interiors frequently combined frescoes of angels, saints, and heavenly visions with stucco sculpture to create the illusion of an open sky. Architecture, painting, and sculpture were integrated into a single visual programme, with spatial complexity, curvilinear forms, and dynamic compositions replacing the balanced symmetry and proportional order of the High Renaissance, producing unified and thematically consistent environments that reinforced Jesuit theological and didactic aims.

[575] David Watkin, *Historia architektury zachodniej* (Warszawa: Arkady, 2001), 203–6.

[576] Anthony Blunt, ed., *Baroque and Rococo: Architecture and Decoration* (Ware, England: Wordsworth Editions, 1988), 56–58; Rolf Toman, *Baroque* (Königswinter, Germany: Könemann, 1998), 79–82.

The composition is framed in the form of a cartouche, painted directly onto the curvature of the barrel vault to create the illusion of the heavens opening above the main nave. Departing from the Renaissance preference for flat surfaces, Gaulli exploited the vault's form to intensify the perception of depth and movement. The scene depicts a celestial realm where angels, saints, and other heavenly figures descend towards the earthly congregation, embodying the Baroque emphasis on uniting the divine with the human. Gaulli employed *quadratura,* combined with *trompe-l'œil* figure painting technique to make the figures appear as if they were bursting through the ceiling into the church's space, generating an immediate and dramatic effect. The illusion is extended by painted angels on flat surfaces that intersect with the cartouche, creating a convincing three-dimensional effect. It is further enriched by stucco figures, executed in collaboration with the sculptor Antonio Raggi, whose forms merge seamlessly with the painted elements, intensifying the illusion and exemplifying the Baroque principle of uniting architecture, sculpture, and painting into a coherent whole. The decorative scheme continues beyond the nave vault to the cupola, lantern, pendentives, central vault, window recesses, and transept ceilings, where painted and real architectural forms merge seamlessly, blurring the line between reality and illusion.

The decorative illusory programme also extends to the cupola, following the precedent set by Correggio in Parma. The fresco *Vision of Heaven* depicts a radiant celestial gathering arranged around the lantern, with angels, saints, and allegorical figures bathed in light, drawing the viewer's gaze upward. This dome fresco forms part of a unified decorative scheme that also encompasses the pendentives, transept vaults, and the previously described nave vault.

Gaulli's frescoes at Il Gesù became a model for Jesuit church decoration across Europe and the Spanish Americas, influencing later artists such as Andrea Pozzo and cementing his reputation as a master of integrated Baroque illusionism.

Fig. 83. Perspective of vault and dome decoration of Il Gesu church in Rome, (source: Matthew Brennan[577], post production by author).

[577] Matthew Brennan. *Church of the Gesù / Chiesa del Gesù*. 3D model. Sketchfab. Published September 18, 2015. Accessed August 20, 2025. https://sketchfab.com/3d-models/church-of-the-gesu-chiesa-del-gesu-fdd3f0aa834e45068b1f7a5e2a2644db.

Fig. 84. Decorative interior of Il Gesu church in Rome, Italy. Left: "The Triumph of the Name of Jesus," Right interior of painted cupola and pendentives. Source: author, 2022.

The evolution of the *illusory* dome decoration and the refinement of the *trompe-l'œil* technique, grounded in the philosophical and theological foundations of the Baroque, found a particularly fertile context within the Jesuit artistic programme. Gaulli's integration of painting, sculpture, and architecture at *Il Gesù* set a new standard for immersive religious imagery, aligning with the Jesuit aim of engaging the faithful through dramatic and emotionally charged visual experiences[578]. This approach paved the way for the work of Jesuit brother Andrea Pozzo, whose ceiling paintings in the *Church of Sant'Ignazio* in Rome represent the pinnacle of Baroque illusionism. Pozzo's *Apotheosis of Saint Ignatius*, in the Jesuits' second major church in Rome dedicated to the order's founder[579], is an ambitious work of illusionistic painting executed between 1685 and 1694. Spanning the entire barrel vault of the nave, the fresco presents a vision of the heavens opening above, integrating *trompe-l'œil* and *quadratura* with perspective to create one of the most celebrated achievements in Baroque art and illusions.

The *Church of Sant'Ignazio di Loyola*, designed by the Jesuit architect Orazio Grassi, is an example of Baroque architecture, employing a Latin cross plan with a single nave and side chapels. Modelled on the Jesuits' mother church, *Il Gesù*, it was originally intended to feature a dome. However, financial constraints led to the abandonment of this plan in 1642, leaving only a blank tondo. Drawing on descriptive geometry, Andrea Pozzo compensated for the absence of a real dome by painting an

[578] David Watkin, *Historia architektury zachodniej* (Warszawa: Arkady, 2001), 248–52.

[579] Paolo Portoghesi, *Rome Baroque: The History of an Architectonic Culture* (Cambridge, MA: MIT Press, 1970), 304–6; Rolf Toman, *Baroque* (Königswinter, Germany: Könemann, 1998), 144–46.

illusionistic one, seamlessly integrating it into the church's decorative programme[580]. The dissolution of the vault into the heavens visually enacted the Jesuit theological message of transcendence and direct access to the divine, aligning with the order's Counter-Reformation pedagogy. He also decorated the large *concha* in the presbytery with illusionistic architecture framing the Holy Trinity surrounded by angels, extending the celestial vision of the vault into the sanctuary and reinforcing the unity of the spatial composition.

Employing descriptive geometry to project images onto the curved surfaces of the vault and tondo, Pozzo achieved a three-dimensional effect. His fresco reproduces the church's architectural details with columns, friezes, and cornices and even includes painted arches with coffers, creating the illusion of an additional storey that perceptually dissolves the material vault. Above these illusory architectural details, clouds are depicted, symbolising the celestial realm. The central theme of the fresco is the *Apotheosis of Saint Ignatius*, portraying the moment when the founder of the Jesuit order is welcomed into heaven by Christ. Surrounding scenes feature angels, saints, and allegorical figures, further enhancing the sense of divine glory. Pozzo carefully calculated his fresco so that the illusion appears in correct perspective only from this precise spot, the punto stabile or *point of perspective*, marked by a marble circle embedded in the pavement near the centre of the nave. From here the painted architecture aligns seamlessly with the real architecture, and the illusion of the dome becomes fully convincing; viewed from elsewhere, however, the perspective breaks down and the artifice of the painting is revealed.

Pozzo's research culminated in his treatise, Perspectiva Pictorum et Architectorum[581], with the first volume published in 1693 and the second in 1700. In this work, he explored his theories of perspective, explaining how he used geometry and mathematics to create lifelike spatial effects in both painting and architecture. Pozzo's publication was not the first to address perspective but his innovative approach to tracing images on curvilinear surfaces made it a crucial contribution[582]. One of the most notable aspects of his work was his skill in foreshortening, or *di sotto in sù*. This technique, masterfully applied in his frescoes, gave architectural elements and figures a compelling three-dimensional appearance, expanding the perceived space of ceilings. The treatise, filled with vivid illustrations, provided templates for creating frescoes on curved surfaces and included detailed methods for delineating illusory domes on concave ceilings. Pozzo's work became a crucial resource for artists and architects, offering insight into the complex process of interior decoration, particularly through the use of stencils and matrices for colourful *quadratura* patterns. Its influence extended far beyond Rome, inspiring Jesuit painters and architects in Central Europe and Latin America, where illusionistic ceilings became a hallmark of Jesuit churches.

[580] Marco Fasolo and Matteo Flavio Mancini, "The 'Architectural' Projects for the Church of St. Ignatius by Andrea Pozzo," *Diségno*, no. 4 (2019): 79–90, https://doi.org/10.26375/disegno.4.2019.09

[581] Andrea Pozzo, *Perspectiva pictorum et architectorum. Pars prima* (Rome: Joannis Jacobi Komarek Bohemi, 1693) ; Andrea Pozzo, *Perspectiva pictorum et architectorum. Pars secunda* (Rome: Joannis Jacobi Komarek Bohemi, 1700).

[582] Kazimierz Bartel, *Perspektywa malarska: Zasady, zarys historyczny, estetyka*, vol. 2 (Warszawa: Państwowe Wydawnictwo Naukowe, 1958), 548–54.

Fig. 85. Andrea Pozzo, *Apotheosis of Saint Ignatius*, illusionistic barrel vault with quadratura and painted dome, *Church of Sant'Ignazio di Loyola*, Rome. Source: author, 2022.

Pozzo's artistic achievements exemplified the integration of Baroque art, architecture, mathematics, and descriptive geometry. His understanding of perspective influenced not only his paintings but also architectural design. His treatise spread the concept of *quadratura* ideas far and wide, influencing subsequent artists and architects across the world[583]. As a Baroque master of illusion, Andrea Pozzo's work remains unsurpassed, establishing him as one of the most significant figures in the development of illusionism during the Baroque period[584].

[583] Quadratura painting was highly influential in the development of curvilinear perspective, as the illusionistic decoration of domes and vaults required the adaptation of projection systems to curved architectural surfaces. Unlike linear perspective, which projects onto a flat plane, curvilinear perspective translates vision onto a spherical or cylindrical surface, aligning more closely with the physiology of human sight. Early artistic experiments include the convex mirror detail in Jan van Eyck's *Arnolfini Portrait* (1434). During the Renaissance, Parmigianino produced his Self-Portrait in a *Convex Mirror* (c. 1524), which fully exploited the possibilities of curvilinear representation. This lineage continued through panoramic and cycloramic paintings of the eighteenth and nineteenth centuries and was later reinforced by the optical distortions of wide-angle and fisheye photography. In the twentieth century, M. C. Escher became the most prominent artist to investigate spherical reflections, as seen in Hand with *Reflecting Sphere* (1935), *Balcony* (1945), and the *Other World* series. He systematically formalized curvilinear grid systems, drawing on spherical geometry and cartographic projections to construct his images

[584] Other examples of illusionistic vault decoration:

Melozzo da Forlì, Sacristy of San Marco, Loreto, Cupola (1477–1479), fresco with Angels and Prophets.

Giovanni Lanfranco, Dome of Sant'Andrea della Valle, Rome (1621–1625), fresco Glory of Paradise.

Domenichino (Domenico Zampieri), Chapel of San Gennaro (St. Januarius), Naples Cathedral (1631–1641), frescoes of the life of St. Januarius.

Angelo Michele Colonna, San Lorenzo in Lucina, Rome, fresco Glory of St. Lawrence (c. mid-17th century).

Andrea Pozzo, San Francesco Saverio, Mondovì (1676–1678), ceiling fresco depicting The Mission of St. Francis Xavier and his ascent into heaven.

Notably, in Poland there is a series of late Baroque illusionistic frescoes, primarily concentrated in Silesia, which at the time formed part of the Habsburg-ruled Holy Roman Empire[585]. A characteristic feature of Polish architectural history is that the models for these frescoes were directly imported from Italy, together with the painters themselves, illusionists trained in the Italian artistic tradition. As a result, many of these works are as compelling as their Italian prototypes, yet, given the period of their execution, they reflect a conscious adaptation of Italian masterpieces, often realised with the aid of treatises and stencils[586].

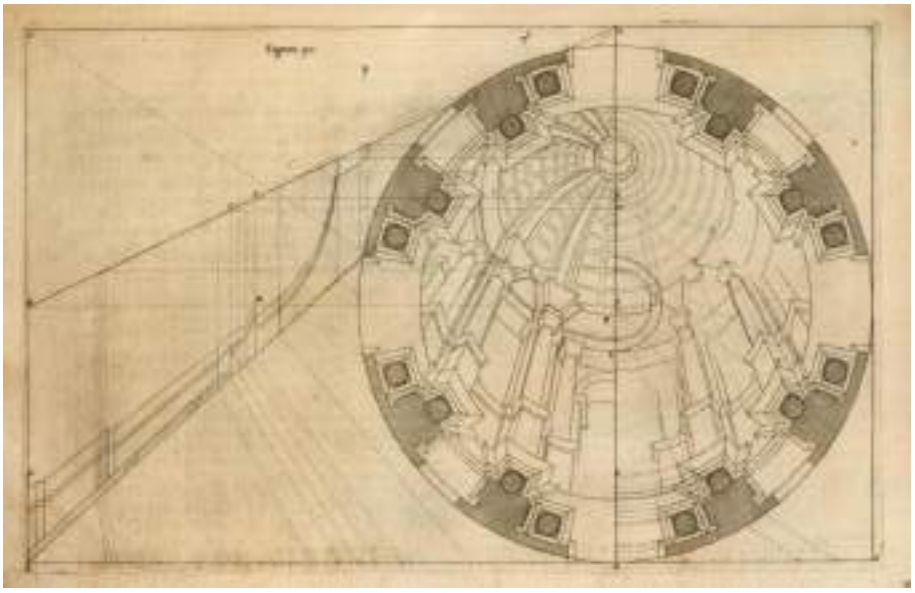


Fig. 86. Scheme of tracing the illusory dome by Andrea Pozzo, from his book *Perspectiva Pictorum et Architectorum*, (source: Pozzo 1693[587]).

Luca Giordano, Palazzo Medici Riccardi, Florence, Hall of Mirrors (1682–1685), ceiling fresco Apotheosis of the Medici family.

Giulio Quaglio the Younger, Ljubljana Cathedral (St. Nicholas' Cathedral), Ljubljana (1703–1706), ceiling frescoes depicting the life of St. Nicholas.

Andrea Pozzo, Jesuit Church (Universitätskirche), Vienna (1703), ceiling fresco St. Ignatius Loyola received into heaven.

Giulio Quaglio the Younger, Church of Santa Maria del Corlo, Lonato del Garda (early 18th century), ceiling fresco ecoration.

Giovanni Battista Tiepolo, Würzburg Residence, Germany (1750–1753), ceiling fresco Allegory of the Planets and Continents.

[585] Notable examples in Poland:

Jan Jerzy Knoll and Johann Michael Rottmayr von Rosenbrunn, University Church, Wrocław (1704–1706), architectural and painted decoration.

Christoph Tausch (architecture), Johann Christoph Handke (frescoes), Aula Leopoldina, Wrocław (early 18th century), architectural and fresco decoration.

Antoni Jentsch, Georg Wilhelm Neunhertz, Ignatius Albert Provisore, Sanctuary Church, Krzeszów (1733–1735), architectural and fresco decoration.

Kilian Ignaz Dientzenhofer (architecture), Cosmas Damian Asam (frescoes), Benedictine Church, Legnickie Pole (1733), frescoes Glory of St Benedict and architectural decoration.

Michael Klein (attributed, architecture), Felix Anton and Christoph Thomas Scheffler (frescoes), Church of the Holy Sepulchre, Nysa (1731), ceiling frescoes and interior decoration.

Joseph Frisch (architecture), Johann Kuben (frescoes), Jesuit Church, Brzeg (1740–1746), illusionistic ceiling frescoes.

Giovanni Maria Bernardoni and Giuseppe Brizio (architecture), Józef Mayer (frescoes), Cathedral of St John the Baptist, Lublin (1757–1759), fresco cycle on the life of St John the Baptist.

[586] Bogna Ludwig, *"Zastosowanie iluzji perspektywicznej w monumentalnych dekoracjach wnętrz śląskich świątyń w okresie późnego baroku," Architectus* 2, no. 16 (2004): 3–27.

[587] Andrea Pozzo, *Perspectiva pictorum et architectorum. Pars prima* (Rome: Joannem Jacobum Komarek, 1693), 198.

Exterior illusory decoration

Beyond its use in interiors, architectural illusionistic painting was also applied to building exteriors, where façades were decorated with vivid colours and ornamental schemes. Artists painted architectural elements such as windows, portals, pilasters, and in some cases entire façades, directly onto flat wall surfaces to create the impression of fully articulated structures when viewed from a distance. The technique was employed in diverse contexts, serving both aesthetic and practical purposes: it allowed modest buildings to be visually enriched, enhanced the appearance of urban spaces, and provided architectural illusions that substituted for costly masonry or sculptural work. Painted façades often transcended purely decorative aims by incorporating heraldic emblems, religious imagery, or allegorical programmes that conveyed civic identity and political messages. In this way, patrons and artists achieved designs that were at once visually striking, symbolically meaningful, and economically efficient.

Precedents can be traced as far back as the Gothic period, where blind windows (*fenestrae clausae*), often decorated with blind tracery painted or modelled in plaster, were used to maintain the symmetry of façades without serving a functional purpose. In the Renaissance, exterior walls were frequently ornamented with sgraffito work in plaster, employing geometric and figurative motifs to create architectural illusions that likewise compensated for limited material resources.

Fig. 87. Painted architectural decorations. Left: the gatehouse of the *Certosa di Pavia*. Right: interior of the *Palazzo Spada* with painted windows creating a symmetrical composition. Source: author, 2025.

Although constant exposure to weather rendered painted façades highly vulnerable to deterioration, limiting their preservation and long-term artistic status, they nonetheless played a significant role in shaping the visual character of European cities. While they have not generally been accorded the same recognition as monumental fresco cycles or sculptural decoration, their cultural and urban impact was considerable. In the Bavarian and Tyrolean Baroque tradition, illusionistic exterior decorations known as *Lüftlmalerei* became a defining feature of civic architecture, reflecting both the ingenuity of artistic solutions and the adaptability of Italian models. Their widespread use is most strongly associated with the Baroque period, though firmly rooted in Renaissance traditions[588].

[588] Paula Kiessling and Waldemar Kiessling, *Lüftmalerei* (München: Verlag Bruckmann, 1959).

Fig. 88. Illusionistic Tyrolean façades. Left: Mannerist sgraffito decoration, late 16th century, courtyard of *Schloss Ambras*, Innsbruck, Austria. Right: late Baroque *Lüftlmalerei* decoration of the *Ansitz Liebenegg*, Innsbruck, Austria. Source: author, 2024.

Fig. 89. Rococo hall adjoining the Bamberg Town Hall with its illusionistic façade, including the detail of a sculpted putto's leg. Source: author, 2024.

An instructive example of an illusionistic exterior façade is the Rococo extension of the Bamberg Town Hall, constructed on an artificial island in the Regnitz River. Its painted decoration, executed by Johann Anwander in the mid-18th century, employs fresco technique to simulate architectural articulation. Columns, niches, cornices, and pilasters are rendered in perspective and combined with allegorical figures and ornamental motifs typical of the Rococo style. The integration of these elements produces

the effect of a three-dimensional sculpted façade, while also serving a civic representational function within the urban landscape.[589]

Forced perspective in baroque

Illusion in architecture was not confined to painting. As demonstrated in the Church of *San Satiro* and in the *Laurentian Library Vestibule*, forced perspective could be employed to alter spatial perception. A further example is the "Borromini Corridor," designed by Francesco Borromini in 1635 at the *Palazzo Spada* in Rome[590]. Built within the limitations of the palace's restricted site, and conceptually related to San Satiro, the corridor illustrates Borromini's precise application of perspective techniques. Although its actual length is only about 9 metres, the systematic diminution of architectural elements creates the impression that it extends to approximately 37 metres. Columns, floor tiles, and the sculpture at the far end were designed to decrease progressively in scale, establishing a coherent illusion of depth[591]. Partially preserved, painted Tuscan columns framing the passage reinforced the sense of recession[592]. The corridor thus demonstrates how architectural design in the Baroque period employed forced perspective and optical principles to manipulate space and guide visual experience[593].

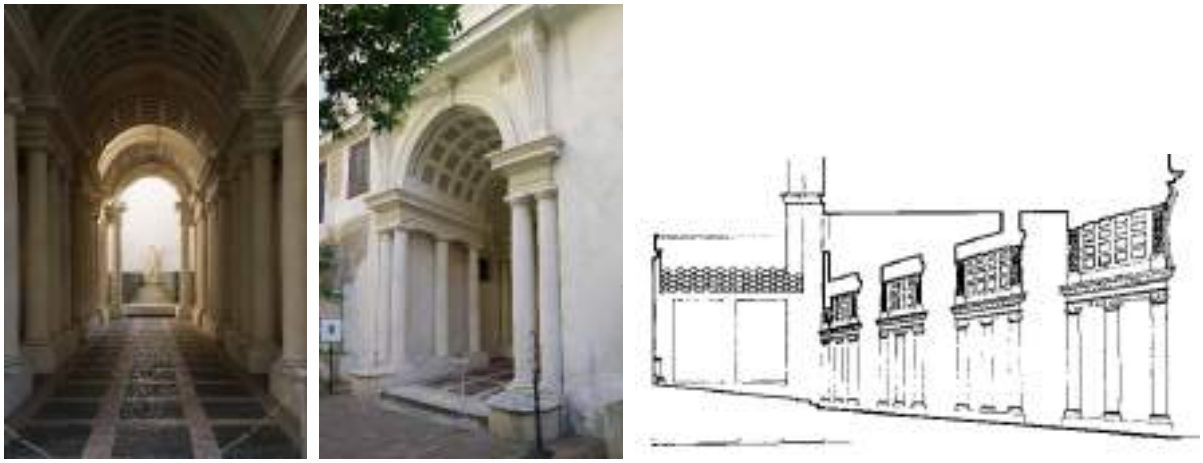


Fig. 90. *Borromini Corridor* in the *Palazzo Spada*, Rome, Italy, source: author, 2025. Cross-section diagram, (source: adapted from the information panel in the Palazzo Spada, based on photo by author, 2025).

A comparable use of forced perspective can be observed in Gian Lorenzo Bernini's *Scala Regia*[594] at the Vatican, completed in 1666. Commissioned by the pope, Bernini was tasked with converting an existing cramped and irregular passage into a monumental ceremonial staircase appropriate for the papal residence. The Scala Regia connects the Vatican Palace to St Peter's Basilica, leading directly to the Apostolic Palace. To overcome the spatial limitations, Bernini employed perspective manipulation similar to that used by Borromini in the corridor at the Palazzo Spada. The staircase gradually narrows

[589] Philipp Maria Halm, "The Town Hall in Bamberg and Its Fresco Decoration," *Die Denkmalpflege* 5, no. 3 (25 February 1903): 19–21.

[590] This Renaissance palace, built in the 16th century, now houses the Galleria Spada, which contains works by leading artists including Titian and Guido Reni.

[591] The statue was installed in the 19th century; previously, the termination of the corridor featured a painted garden scene in one-point *trompe-l'œil* perspective, which further accentuated the illusion of depth.

[592] Today, only fragments of the former illusionistic foreground survive, providing limited but valuable insight into how the corridor originally appeared in its full effect.

[593] Anthony Blunt, *Borromini* (Cambridge, MA: Belknap Press of Harvard University Press, 1990), 41–45.

[594] During my visit in Rome in November 2024 I was not able to come closer to the Scala Regia, due to the limited access for visitor, thus I was only able to capture high zoom photograph to document the object.

as it ascends, while the columns and ceiling diminish in scale, creating the illusion of greater depth and grandeur, in much greater scale than applied in *Palazzo Spada*. Through this calculated arrangement, Bernini transformed an otherwise constrained space into an imposing architectural approach, demonstrating the Baroque capacity to use optical devices to amplify ceremonial effect[595].

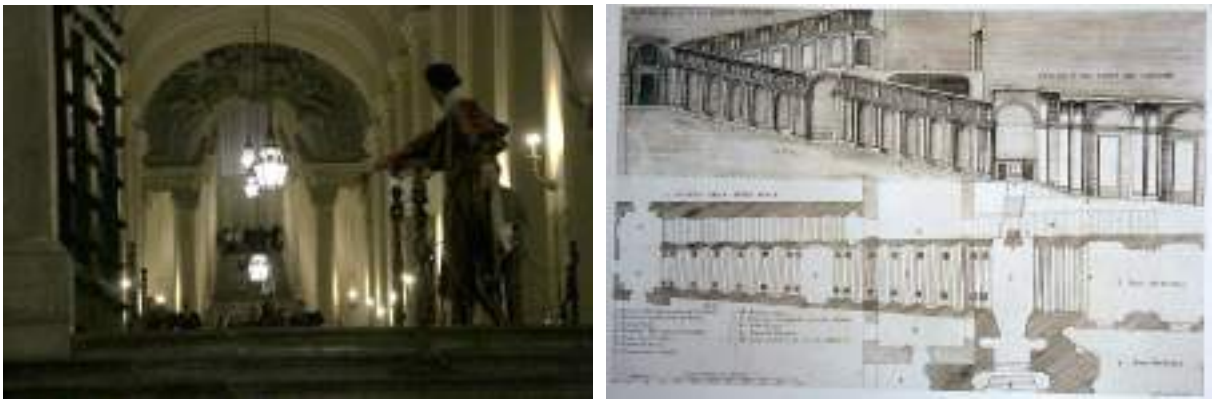


Fig. 91. Left: *Scala Regia* by Gian Lorenzo Bernini, source: author, 2023. Right: Plan and cross section of *Scala Regia* published in *Templum Vaticanum et ipsius origo* by Carlo Fontana in 1694, (source: Wikimedia Commons[596]).

While the previous examples focused on interiors, the principles of forced perspective and trapezoidal planning were also applied on an urban scale in the design of St Peter's Square, enhancing the grandeur of St Peter's Basilica in Vatican City. Conceived by Gian Lorenzo Bernini and completed in 1667, the square's colonnades recall the reversed perspectival strategies of the *Scala Regia* and Borromini's corridor at the *Palazzo Spada*, which can be seen as prototypes for this large-scale application. Their gradual narrowing directs the viewer's gaze towards the basilica's façade, making it appear closer and more imposing than it actually is.

Bernini divided the piazza into two distinct parts: a trapezoidal section adjoining the basilica and an elliptical section extending outward. This scheme required the demolition of a number of pre-existing buildings to achieve the desired spatial clarity. The colonnades consist of 284 Doric columns and 88 pilasters, surmounted by statues of saints, and were designed both to frame the square and to integrate pre-existing features such as the Egyptian obelisk, known as the "Witness,"[597] and Carlo Maderno's fountain. Bernini balanced the composition by adding a second fountain, thereby reinforcing the symmetry of the elliptical space. From the central point of the square, the rows of columns appear to align into a single row, creating an optical illusion of depth and reinforcing the perspectival focus towards the basilica. The combination of trapezoidal and elliptical forms amplifies the perception of spatial expansion, especially when viewed from the basilica's entrance[598]. Bernini's design demonstrates the Baroque use of geometry and optics on an urban scale, transforming the square into

[595] Howard Hibbard, *Bernini* (Harmondsworth, England: Penguin Books, 1965), 162–67; Anthony Blunt, *Borromini* (Cambridge, MA: Belknap Press of Harvard University Press, 1990), 30-32.

[596] Reproduction of plan of Scala Regia, engraving *from Templum Vaticanum et ipsius origo* (Rome, 1694), plate on p. 239; original source scanned via Wikimedia Commons, accessed August 28, 2025, https://commons.wikimedia.org/wiki/File:Scala_Regia.jpg

[597] It is believed that the obelisk was brought to Rome by Emperor Caligula in 37 AD. It originally stood in the Circus of Nero, where early Christians, including St. Peter, were martyred, thus the name "The Witness", and also the decision to locate the early Christian basilica. The obelisk was relocated to its current location in the square in 1586 by Pope Sixtus V, long before Bernini's design.

[598] Howard Hibbard, *Bernini* (Harmondsworth, England: Penguin Books, 1965), 162–67.

both a functional religious gathering place and a theatrical setting intended to inspire awe and spiritual reverence at the threshold of Christendom's most important church[599].

Fig. 92. Piazza San Pietro with its forced perspective, source: author, 2022. Right: Plan of Piazza San Pietro presented in Nolli's Plan of Rome (1748), (source: Interactive Nolli Map by Stanford University webpage[600])

3.1.5. Vedutive paintings

In contrast to the imaginary yet perfectly traced *quadratura*, vedute painting developed as an architectural landscape genre distinguished by accuracy and descriptive realism, gaining particular prominence during the era of Neo-Classicism[601]. Vedutists captured the cityscapes, frequently focusing on prominent buildings, monuments, and urban spaces. Like Renaissance artists, they employed linear perspective, by then a fully mastered technique, but often relied on the *camera obscura* to ensure precise proportions and correct recession of real space[602]. While this device guaranteed technical accuracy, artistic invention remained central, as painters selectively modified or idealised urban views to enhance composition and atmosphere. Functioning as proto-photographic records, vedute provided a pictorial equivalent of architectural documentation, enriched through calculated use of light, shadow, and colour. By positioning the viewer at an ideal vantage point, artists created compositions that

[599] The later history of the site further emphasises its representational role. In the Fascist era, Pope Pius XI and Benito Mussolini, as part of the Lateran Treaty of 1929 establishing Vatican City as an independent state, undertook the creation of a grand approach to the square. This involved the demolition of much of the Borgo neighbourhood to open the Via della Conciliazione, a monumental avenue linking Castel Sant'Angelo and the Tiber directly with St Peter's Basilica. The intervention reinforced the scenographic effect of Bernini's square, albeit in line with Fascist urban planning ideals of monumental axiality.

[600] Stanford University, Spatial History Project. *Interactive Nolli Map Website 2.0*. Accessed August 20, 2025. https://web.stanford.edu/group/spatialhistory/nolli/.

[601] The architectural theme of vedute was also explored in earlier epochs, particularly in seventeenth-century Flemish and Dutch Baroque art, especially during the Dutch Golden Age, with notable examples including View of Delft and The Little Street by Johannes Vermeer, as well as numerous cityscapes and church interiors by Pieter Saenredam.

[602] Camera Obscura portable device that projected external scenes through a lens and mirror onto paper. This allowed precise tracing of façades, canals, and streets, ensuring mathematical accuracy in perspective and proportions. Contemporary accounts confirm Canaletto's use of a portable version in Venice, which enabled him to record minute architectural details with exceptional fidelity.

See Museo Correr and Ca' Rezzonico – Museum of the 18th Century Venice, "Canaletto's Secret: How Canaletto's 'photographic' paintings are being used to fight the 'acqua alta' in Venice," *Google Arts & Culture*, accessed September 9, 2025, https://artsandculture.google.com/story/canaletto-s-secret-museo-correr/3QVhioQYNBkoJA?hl=en

encouraged an immersive engagement with the cityscape[603]. Commissioned largely by Grand Tour travellers, vedute served both as souvenirs and as expressions of civic identity, and their widespread reproduction in prints and engravings extended their documentary value far beyond their original patrons. In this sense, vedute painting stands at the intersection of art, science, and technology, foreshadowing photography and anticipating later visual media, including Virtual Reality.

One of the most renowned vedutists was the Italian painter Giovanni Antonio Canal, better known as *Canaletto*. He gained prominence for his highly detailed and accurate views of Venice, as well as for scenes of London, Greenwich, and the English countryside. His paintings vividly document urban landscape, canals, architecture, and aspects of daily life with precision. Canaletto's work became synonymous with eighteenth-century Venetian art, and through both his original paintings and widely circulated engravings, he helped establish an international market for vedute, securing their popularity among aristocratic patrons and collectors. His refined handling of light and shadow, combined with his ability to render expansive and atmospheric cityscapes, secured his enduring popularity. Today, Canaletto is regarded as one of the foremost painters of urban landscapes, celebrated in particular for his iconic views of Venice, which approach the descriptive accuracy of photography[604].

Fig. 93. Vedute di Venezia. Left: *St. Mark's Basin from the Puntana della Dogana*. Right: *View of the Grand Canal toward the Punta della Dogana from Campo Sant'Ivo*. Both in collection of *Pinacoteca di Brera*, Milan, Italy. Source: author, 2023.

Bernardo Bellotto, the nephew of Canaletto, continued his uncle's artistic style and occasionally even adopted his name, styling himself as Canaletto the Younger. Born in Venice, Bellotto trained in Canaletto's studio, where he mastered the techniques of perspective and precise architectural depiction that became the hallmarks of his own work. His early paintings were strongly influenced by his uncle, often depicting Venetian scenes. Around 1745, Bellotto left Venice and worked in various European courts, gradually broadening his subject matter. He was later invited to the court of Augustus III, Elector of Saxony and King of Poland, where he created some of his most celebrated works, including detailed cityscapes of Dresden and Pirna. He also painted views of Vienna and other Austrian cities for Empress Maria Theresa. From 1767 until his death in 1780, Bellotto served at the court of King Stanisław August Poniatowski in Warsaw, producing important vedutes of the city. These paintings acquired exceptional historical significance, as they later provided crucial reference material for the

[603] Stephen Farthing, *Historia sztuki* (Warszawa: Arkady, 2019), 256–61.

[604] Katharine Baetjer and Joseph Gluckstein Links, *Canaletto* (New York: The Metropolitan Museum of Art, 1989), 10–68.

post-war reconstruction of Warsaw after the Second World War. In this way, Bellotto's vedute exemplify the dual artistic and documentary role of the genre, uniting aesthetic ambition with urban memory[605].

Fig. 94. Bernardo Belloto (Canaletto the Younger) View of Warsaw from the Royal Castle (1773). National Museum, Warsaw. Source: author, 2024.

3.1.6. Panoramic painting

In the Age of Enlightenment, with rapid advancements in mathematics and its subfields such as logic and Gaspard Monge's descriptive geometry[606], a new form of illusory art emerged, building upon the tradition of vedute painting. Artists began extending the canvas to create seamless, immersive scenes capable of surrounding the viewer. This development, culminating in the invention of the 360-degree panorama[607], together with the adoption of non-collinear panoramic perspective, gave rise to panoramic art. Unlike traditional linear perspective, which generates depth on a flat surface from a single point of view, panoramic perspective encircles the observer through the use of multiple vanishing points, each corresponding to different sections of the panorama. Owing to the vast scale of the canvas and the human visual field of roughly 60 degrees, the presence of multiple vanishing points

[605] Stefan Kozakiewicz and Helena Kozakiewicz, *Bernardo Bellotto zwany Canaletto* (Warszawa: Arkady, 1980).

[606] Gaspard Monge, *Géométrie descriptive: leçons données aux écoles normales, l'an 3 de la République* (Paris: Bachelier, 1799).

[607] One of the earliest well-known examples of architectural panorama painting that anticipated the immersive 360-degree panoramas of the Enlightenment was Melchior Lorck's Panorama of Constantinople, created around 1559. This monumental work, measuring approximately 12 metres in length, presents a sweeping view of the Ottoman capital, Istanbul, in the 16th century. Whereas Enlightenment panoramas were generally constructed around a single projective centre corresponding to a hypothetical viewing position, Lorck employed multiple viewpoints, each relating to specific sections of the landscape. The result is an assemblage of different perspectives, combined into a continuous visual narrative. The panorama offers a detailed and intricate depiction of the city's architecture, topography, and maritime life, prominently featuring landmarks such as the Hagia Sophia, the Golden Horn, and the city's defensive walls. Although an artistic interpretation, the work possesses substantial documentary value, capturing the essence of 16th-century Constantinople and providing insights into its urban form and architectural character. In this sense, Lorck's panorama functions simultaneously as a work of art and a historical record, preserving a rare European perspective on one of the world's most significant cities.

See Nigel Westbrook, Kenneth Rainsbury Dark, and Rene van Meeuwen, "Constructing Melchior Lorichs's Panorama of Constantinople," *Journal of the Society of Architectural Historians* 69, no. 1 (2010): 62–87, https://doi.org/10.1525/jsah.2010.69.1.62; Nigel B. Westbrook and Rene van Meeuwen, "Reconstructing Sixteenth-Century Istanbul: The Use of Digital Modelling as an Heuristic Tool in Architectural History Research," *Architectural Theory Review* 18, no. 1 (2013): 62–82, https://doi.org/10.1080/13264826.2013.792852.

is not perceptible, since the viewer is positioned at the centre and cannot perceive the convergences simultaneously. Typically exhibited in purpose-built rotundas, panoramas marked a departure from the linear perspective of the Renaissance and the quadratura of the Baroque, while extending the principles of vedute painting to offer an immersive experience that enveloped the spectator within the scene. Panoramas were very much in tune with Enlightenment ideals: science, empiricism, education, and spectacle. Audiences were fascinated by them not only for entertainment, but also for their promise of accurate, encyclopaedic knowledge of cities, landscapes, and events.

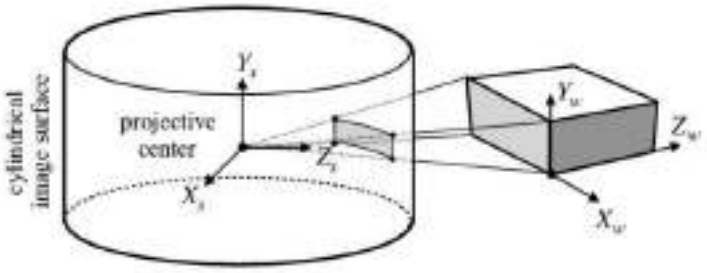


Fig. 95. Method of projecting objects onto a cylinder's surface using descriptive geometry, (source: Sharma, Nett, and Ventura, "Unsupervised Learning of Depth and Ego-Motion," [608]).

While the panorama as a pictorial representation of the city on a horizontal canvas had already been established during the Renaissance[609], most notably through the publication cycle of Georg Braun and Frans Hogenberg's *Civitates Orbis Terrarum*[610], which presented over 500 city views and panoramas from across Europe, Asia, Africa, and the Americas and now serves as a major documentary source on early modern urbanism, it was neither 360 degrees nor fully immersive.

The Irish painter Robert Barker was the pioneer of panoramic art[611], eventually securing a patent for it as a distinct artistic form[612]. He also coined the term "panorama," a portmanteau derived from the Greek words pano ("all") and horama ("view"). In 1787, Barker opened his first panoramic exhibition in Edinburgh, Scotland, featuring his watercolour masterpiece Edinburgh from Calton Hill, which presented a comprehensive 360-degree view of the city. His ambition was to immerse the spectator fully in the scene, dissolving the boundary between art and reality and pushing the perceptual limits of pictorial representation. This innovation reached its full impact a few years later, when in 1792–93 Barker opened a purpose-built rotunda in London's Leicester Square. The circular building, designed specifically for the display of 360-degree panoramas, transformed the panorama from a singular artistic

608 Alisha Sharma, Ryan Nett, and Jonathan Ventura. "Unsupervised Learning of Depth and Ego-Motion from Cylindrical Panoramic Video with Applications for Virtual Reality." *International Journal of Semantic Computing* 14, no. 3 (2020): 333–56.

609 An important precursor was the *Nuremberg Chronicle* (*Liber Chronicarum*, 1493), authored by Hartmann Schedel and illustrated in the workshop of Michael Wolgemut and Wilhelm Pleydenwurff. The volume contained numerous woodcut city views which, although often stylised or generic, established an early visual typology of the urban panorama later expanded in a more systematic and geographically accurate form by Braun and Hogenberg in the *Civitates Orbis Terrarum.*

610 Georg Braun and Frans Hogenberg, *Civitates Orbis Terrarum* (Cologne, 1575).

611 Although Robert Barker is widely credited with inventing the panorama, owing to his patent, he was preceded by Louis Le Masson's Panoramic View of Rome from the Terrace of San Pietro in Montorio (1779), a continuous city panorama that exemplifies a precise Neoclassical approach to architectural representation.

See Sylvie Blin, "The Panorama of Rome by Louis Le Masson," *La Gazette Drouot*, July 15, 2025, accessed September 9, 2025, https://www.gazette-drouot.com/en/article/the-panorama-of-rome-by-louis-le-masson/90233

612 Ralph Hyde, *Panoramania!: The Art and Entertainment of the "All-Embracing" View* (London: Trefoil, 1988); Angela L. Miller, "The Panorama, the Cinema, and the Emergence of the Spectacular," *Wide Angle* 18, no. 2 (1996): 34–69, https://doi.org/10.1353/wan.1996.0010; William Uricchio, "A 'Proper Point of View': The Panorama and Some of Its Early Media Iterations," *Early Popular Visual Culture* 9, no. 3 (2011): 225–38, https://doi.org/10.1080/17460654.2011.601165;

experiment into a repeatable cultural spectacle, attracting large audiences and establishing the medium as a new form of mass entertainment[613].

Fig. 96. Edinburgh from Calton Hill by Robert Barker, (source: National Library of Scotland [614]).

Another of Barker's works, London from the Roof of Albion Mills, offered an expansive and immersive 360-degree view of London, captured from the vantage point of the Albion Mills. This piece marked a further milestone in the development of panoramic art, exemplifying Barker's innovative contributions to the genre.

The immersive and realistic nature of Barker's panoramas quickly captured public imagination, establishing the panorama as a popular form of entertainment in the late 18th and 19th centuries, that many followed[615]. His works epitomised a synthesis of artistic invention and scientific precision, drawing upon advances in descriptive geometry. His pioneering approach not only integrated art and science seamlessly but also left an enduring legacy, with the panoramic format remaining a central feature of visual immersive culture in museums, exhibitions, and popular entertainment well into the 20th century[616]. His groundbreaking technique introduced a new way of experiencing the vastness and intricacy of the urban landscape, creating a lifelike, all-encompassing representation that gave viewers the sensation of physical presence within the scene, a precursor to what would later evolve into virtual reality.

An exemplary instance of panoramic representation combining both architectural and landscape elements is the work of the Dutch marine painter Hendrik Willem Mesdag, titled Panorama Mesdag[617]. This 360-degree painting depicts the seaside village of Scheveningen in the Netherlands, seen form the sand dune. It is displayed in a dedicated pavilion, where the effect of continuity is enhanced by placing the viewing platform above a layer of natural sand. This integration of real elements in the immediate foreground creates a seamless transition between the painted scene and the viewer[618].

---

[613] Denise Blake Oleksijczuk, *The First Panoramas: Visions of British Imperialism* (Minneapolis: University of Minnesota Press, 2011), 1–22.

[614] Robert Barker. *Panorama of Edinburgh from Calton Hill*. 1788. National Library of Scotland. Accessed August 20, 2025. https://maps.nls.uk/view/219387405.

[615] Other notable architectural panoramas include: Major James Taylor, A View of Sydney: The Taylor Panorama (c. 1821); Augustus Earle, Panoramic Views of Australia (1826 to 1827); Robert Burford, Panorama of Rio de Janeiro (1827); Jules Arsène Garnier, Panorama of Constantinople (c. 1882); Victor Meirelles and Henri Langerock, Panorama of Rio de Janeiro (painted 1888, exhibited 1891).

[616] Stephan Oettermann, *The Panorama: History of a Mass Medium*, trans. Deborah Lucas Schneider (New York: Zone Books, 1997), 104-110; Markman Ellis, "'Spectacles within doors': Panoramas of London in the 1790s," *Romanticism* 14, no. 2 (2008): 133–48, https://doi.org/10.3366/E1354991X0800024X; Denise Blake Oleksijczuk, *The First Panoramas: Visions of British Imperialism* (Minneapolis: University of Minnesota Press, 2011).

[617] The painting, completed in 1881, measures 14 metres in height and 120 metres in circumference. It represents the coastline, urban architecture of Scheveningen, and surrounding rural areas in a continuous circular composition.

[618] See Petra Halkes, "The Mesdag Panorama: Sheltering the All-Embracing View," *Art History* 22, no. 1 (1999): 83–98, https://doi.org/10.1111/1467-8365.00140; Museum Panorama Mesdag, "Home," *Panorama Mesdag*, accessed March 21, 2024, https://panorama-mesdag.nl/en/.

Fig. 97. Mesdag Panorama in Scheveningen, (source: Museum Panorama Mesdag [619]).

Military art panoramas form a distinct category in art history, notable for their depiction of decisive moments in battles, often emphasising charges or turning points in the conflict. Emerging as a popular form of public art in the nineteenth century, such works frequently served commemorative and patriotic purposes, celebrating national victories and educating viewers about historical events. The development of large-scale cycloramas, often exceeding one hundred metres in length, enabled audiences to immerse themselves in these scenes, creating the sensation of standing on the battlefield. Much like a commanding officer, the viewer could observe the unfolding events from a vantage point, gaining a strategic perspective. In this sense, nineteenth-century panoramas may be regarded as another precursors of virtual reality, employing spatial illusion, scale, and immersion to transport the observer into a reconstructed environment and to foster an embodied experience of history.

Leading practitioners included the Poles Jan Styka and Wojciech Kossak, as well as the Russian painter Franz Alekseevich Roubaud, renowned for the *Borodino Panorama*[620]. Other national traditions likewise produced notable works, including Paul Philippoteaux's *The Battle of Gettysburg Cyclorama*[621].

Given their immense size, painted panoramas required a dedicated architectural structure—the Panorama Pavilion. Typically designed as rotundas with cylindrical interiors, these buildings were purpose-built to accommodate and display panoramic art[622].

---

[619] Museum Panorama Mesdag. *Detail of Panorama Mesdag (Scheveningen)*. Photograph. Accessed August 20, 2025. https://panorama-mesdag.nl/media/images/Beeld_Panorama_Mesdag_slider.2e16d0ba.fill-1200x630.jpg.

[620] This painting depicts the pivotal Battle of Borodino, a decisive engagement during Napoleon's 1812 invasion of Russia, and forms part of Roubaud's series of panoramic battle compositions. Conceived to immerse viewers in the historical battlefield, it uses detailed, expansive depiction to convey the intensity and scale of the conflict. First exhibited in 1912 in a purpose-built rotunda in Moscow, it has since been rehoused in the Battle of Borodino Museum-Panorama on Kutuzovsky Prospect. Roubaud also produced the Siege of Sevastopol panorama (1904–1905), which portrays the Crimean War action and is displayed in a dedicated rotunda in Sevastopol.

See: Museum-Panorama "Battle of Borodino," *Музей-панорама «Бородинская битва»*, accessed March 21, 2024, https://1812panorama.ru/visitors/museum-panorama

[621] National Park Service, "Cyclorama Painting," *Gettysburg National Military Park*, accessed September 21, 2024, https://www.nps.gov/gett/learn/historyculture/cyclorama.htm.

[622] One noteworthy example is the Panorama Pavilion designed in 1801 by Robert Mitchell to display his panorama during the era of British Classicism. Another is the pavilion built to house the Battle of Gettysburg Cyclorama at the Alaska–Yukon–Pacific Exposition in 1909, characterised by a neo-Gothic design reminiscent of a medieval castle. A further instance is the Panorama of the Battle of Racławice Museum in Wrocław, constructed between 1961 and 1985 to the designs of Ewa

One of the most renowned examples is the *Panorama of Racławice*[623], a collaborative work by Polish painters Jan Styka[624] and Wojciech Kossak, supported by their assistants. Completed in 1894 after more than a year of continuous work, this monumental painting commemorated the centenary of the Kościuszko Uprising by depicting the Battle of Racławice of 1794. To enhance the work's authenticity, the surrounding landscape was based on sketches made by Styka on the actual fields of Racławice, which served as the model for the panoramic background. The mathematical challenge of rendering a continuous scene on a cylindrical canvas required careful planning, particularly in positioning the viewing platform to avoid distortion. This was achieved through the application of multipoint panoramic perspective, ensuring a coherent perception of the battle from the designated vantage point[625].

Upon entering the museum, visitors ascend to a central platform from which they can walk around the circular artwork. This spatial arrangement positions the viewer at the heart of the scene, creating the impression of being present on the battlefield[626]. Depicting a pivotal moment in the struggle for Polish independence, the Panorama of Racławice functions both as a monumental work of art and as a historical commemoration, its narrative unfolding as viewers move around the platform and encounter successive episodes of the battle. The illusion is reinforced through the combination of painted imagery and three-dimensional objects, including soil, plants, and weapons, arranged in front of the canvas. By merging pictorial and physical elements, the panorama blurs the boundary between artwork and viewer, intensifying the sense of immersion[627].

Dziekońska and Marek Dziekoński, which reflects the principles of socialist modernism while addressing the specific functional requirements of panoramic art.

See British Museum, "Object: *Section of the Rotunda, Leicester Square, in which is exhibited the Panorama*," Museum Number P. 1875-0710-4485, *British Museum Collection Online*, accessed September 28, 2024, https://www.britishmuseum.org/collection/object/P_1875-0710-4485; Muzeum Narodowe we Wrocławiu, "Wrocławska rotunda 'Panoramy Racławickiej,'" *Muzeum Narodowe we Wrocławiu*, accessed March 21, 2024, https://mnwr.pl/wroclawska-rotunda-panoramy-raclawickiej/.

[623] Measuring over 15 metres in height and approximately 120 metres in circumference, the *Panorama of Racławice* was first displayed between 1894 and 1944 in a specially designed rotunda in Lviv's Stryjewski Park. After the Second World War, the painting was relocated to Wrocław but remained without a dedicated pavilion for several decades. In 1956, an architectural competition for its new housing was won by Ewa Dziekońska and Marek Dziekoński; however, political tensions with the Soviet Union delayed the project, as the panorama depicted a Polish victory over Russian forces. The pavilion was not completed until 1985, when the panorama was finally made accessible to the public again. Today, the cylindrical structure, known as the *Panorama of the Battle of Racławice Museum*, is considered a significant example of the socialist modernist architectural period in Poland.

See Muzeum Narodowe we Wrocławiu, "Wrocławska rotunda 'Panoramy Racławickiej,'" *Muzeum Narodowe we Wrocławiu*, accessed March 21, 2024, https://mnwr.pl/wroclawska-rotunda-panoramy-raclawickiej/.

[624] The artist Jan Styka is renowned not only for the *Panorama of Racławice* but also for his historical and religious-themed works, including several panoramic paintings produced throughout his career. One notable example, completed in 1896, is *Golgota*, which depicts the Crucifixion of Christ on Calvary Hill before Jerusalem. In 1897, Styka created the *Panorama of Transylvania (Panorama Siedmiogrodzka),* although this work survives only in fragments and is partially lost today.

[625] Kazimierz Bartel, *Perspektywa malarska: Zasady, zarys historyczny, estetyka*, vol. 2 (Warszawa: Państwowe Wydawnictwo Naukowe, 1958), 196–202.

[626] At the centre of the composition, the Polish peasant forces (kosynierzy), armed with scythes and led by General Kościuszko on horseback, are depicted charging the Russian artillery, with Kościuszko raising his sword to rally the troops. To the left, Russian reinforcements appear, though they arrive too late to alter the outcome of the battle. On the opposite side of the cylindrical canvas, the Polish regular army advances against Russian positions, while cavalry units engage in a dramatic clash with the enemy. The panorama also incorporates smaller vignettes, including officers reporting to generals and scenes illustrating the human cost of war through the depiction of the wounded and dying. Symbolic motifs, such as a crucifix and a modest peasant hut, are integrated into the architectural landscape, reinforcing both religious and vernacular dimensions of the narrative.

[627] Franciszek Ziejka, *Panorama Racławicka* (Warszawa: Krajowa Agencja Wydawnicza, 1984); Romuald Nowak and Beata Stragierowicz, *Panorama Racławicka* (Wrocław: Muzeum Narodowe we Wrocławiu, 2021).

Fig. 98. *Panorma Racławicka* central part with Kosciuszko Charge (source: National Museum in Wrocław [628]).

Fig. 99. Interior of *Panorama Racławicka* Pavilion. Source: author.

A comparable example to the Panorama of Racławice is the *Tirol Panorama*, painted in 1896 by Franz Xaver Wagegg. It depicts the Tyrolean landscape with the town of Innsbruck and focuses on key historical events, particularly the Battle of Bergisel[629]. The painting is housed in a dedicated museum near Bergisel, designed by architect Hermann Kaufmann and opened in 2011. The display features a cylindrical interior and a central viewing platform, comparable to the Wrocław panorama. The building's siting aligns with the vantage point represented in the painting, allowing points in the contemporary view to correspond closely with the panorama. This alignment enables direct comparison between the present terrain and the historical scene, strengthening the didactic and commemorative purpose of the installation[630].

[628] National Museum in Wrocław. *Panorama of Racławice*. Photograph. Accessed August 20, 2025. https://mnwr.pl/wp-content/uploads/2018/08/RAC_panor_2-min.jpg.

[629] The Battles of Bergisel comprise four engagements fought in 1809 during the Tyrolean Rebellion against Bavarian rule, supported by Napoleonic France. Led chiefly by Andreas Hofer, the Tyrolean forces won the first and third battles and lost the second and fourth. The Tirol Panorama depicts the Third Battle of 13 August 1809 above Innsbruck. Following the final defeat, Hofer was captured and executed in 1810, and he later became a national symbol of Tyrolean resistance.

[630] Isabelle Brandauer, Stollwagner Architekten, and Philipp Josef Pamer, *Das Tirol Panorama: Der Bergisel und das Kaiserjägermuseum. Rund um den Mythos Tirol* (Innsbruck: Edition Alpina, 2011).

Fig. 100. *Tirol Panorama*. Source: author.

3.2 Emerging Of Virtual Reality In The Pre-Digital Era

Photography

The invention of photography is attributed to the French inventors and scientists Joseph Nicéphore Niépce and Louis-Jacques-Mandé Daguerre. Niépce's heliograph[631], View from the Window at Le Gras (c. 1826), is recognised as the first surviving photograph ever captured. This achievement marked a turning point in the visual documentation of reality, introducing a new medium that profoundly influenced art, science, and visual culture. By establishing a mechanical means of image capture, photography expanded the possibilities of representation, shaping both artistic practice and documentary recording. Niépce achieved his image by coating a pewter plate with a thin layer of a light-sensitive bitumen derivative, placing it in a camera obscura, and exposing it on a windowsill for several hours[632].

In 1839, Daguerre announced the invention of the daguerreotype, a photographic process that produced highly detailed and sharply defined images on silver-plated copper plates, thereby advancing Niépce's earlier experiments. Publicly revealed and rapidly adopted, the daguerreotype became the first widely practised form of photography[633]. Among Daguerre's most significant works is *Boulevard du Temple* (1838), notable as one of the earliest photographs to capture a human figure[634]. This image is of particular relevance to the present study, as it also records the architecture and urban landscape central to this thesis. This photograph marks a milestone in the history of photography, showcasing the

[631] Heliography involves the use of a photographic plate or surface that is exposed to sunlight to create an image.

[632] Robert Hirsch, *Seizing the Light: A Social & Aesthetic History of Photography*, 3rd ed. (New York: Routledge, 2017), 11–13.

[633] Ibid. 9-10.

[634] The image is notable as one of the earliest instances of photography to capture a human figure, despite the street itself appearing empty. The long exposure times required by early cameras meant that moving objects, such as pedestrians or carriages, did not register in the image. By chance, however, a man having his shoes shined by a bootblack remained still long enough to be recorded, making him the first person ever photographed in urban and architectural context.

potential of the medium to document and freeze moments in time. Daguerre's experiments and innovations, including this photograph, were instrumental in establishing photography both as an art form and as a means of visual expression[635].

Fig. 101. *View of the Boulevard du Temple*, Paris, by Louis-Jacques-Mandé Daguerre, 1838, (source: Wikimedia commons [636]).

Further advancement in photography came with the introduction of colour. The first colour photograph was produced in 1861 by Thomas Sutton, following a method devised by the physicist James Clerk Maxwell. In a paper published in 1855, Maxwell demonstrated that a colour image could be created by photographing a subject three times through red, green, and blue filters, applying the principles of the trichromatic Young–Helmholtz theory of colour vision, and then projecting the three images through corresponding filters[637]. For the demonstration, Sutton photographed a tartan ribbon, chosen for its distinct red, green, and blue bands. Although experimental and not yet practical for everyday use, this method laid the theoretical foundation for colour photography and established the basis of the RGB colour model[638].

[635] Ibid. 12-16; Encyclopaedia Britannica, s.v. "Daguerreotype," *Britannica.com*, last updated August 12, 2025, accessed June 24, 2024, https://www.britannica.com/technology/photography/Daguerreotype.

[636] Louis Daguerre. *Boulevard du Temple*. Daguerreotype photograph, 1838. Wikimedia Commons. Accessed [your access date]. https://commons.wikimedia.org/wiki/File:Boulevard_du_Temple_by_Daguerre.jpg.

[637] The trichromatic theory of colour vision, proposed by Young and Helmholtz, explains that humans perceive colour through three types of cone cells in the retina, each sensitive to red, green, or blue light. The brain combines signals from these cones to produce the full spectrum of colours we see.

[638] James Clerk Maxwell, "Experiments on Colour, as Perceived by the Eye, with Remarks on Colour-Blindness," *Transactions of the Royal Society of Edinburgh* 21, no. 2 (1855): 275–98; Beaumont Newhall, *The History of Photography: From 1839 to the Present*, 5th ed. (New York: Museum of Modern Art, 1984), 269–81; National Science and Media Museum, "A Short History of Colour Photography," *Objects and Stories* (blog), published July 7, 2020, accessed March 21, 2024, https://www.scienceandmediamuseum.org.uk/objects-and-stories/history-colour-photography.

Fig. 102. Left: The first colour photograph, produced using the three-colour method in 1861, depicting a coloured ribbon, (source: Wikipedia commons[639]). Right: Colour architectural landscape, *View of Agen, France*, showing St. Caprais Cathedral, 1877, created with the use of the *heliochrome* process, (source: Wikimedia commons[640]).

A major innovation in colour photography was introduced by the Lumière brothers with the invention of autochrome film in 1907. This process used a glass plate coated with microscopic grains of dyed potato starch in red, green, and blue, which acted as colour filters. As light passed through the plate, the grains produced colour images. Despite its technical limitations, autochrome marked a decisive step forward in photographic technology[641].

The next breakthrough came in 1935 with the introduction of Kodachrome film by Eastman Kodak. Its design incorporated multiple emulsion layers, each sensitive to a primary colour, which together created a full-colour image after exposure. The later Kodak C-41 process, a standardised method for developing colour negative film, consolidated colour photography as an industry standard. This made colour film widely accessible for both still photography and motion pictures, transforming visual culture and mass media[642].

The emergence of digital photography in the early 1990s represented another milestone, particularly with the release of the Sony Mavica digital camera[643]. Digital sensors replaced analogue film, allowing images to be stored as electronic files. Subsequent advances, including high-resolution sensors and sophisticated image-processing algorithms, firmly established digital colour photography as the dominant medium. These developments have been essential for transformation from pre-digital to fully digital era, and later creation of Virtual Reality experiences, discussed further in the following sections.

---

[639] James Clerk Maxwell. Tartan Ribbon (1861). Photograph. Wikimedia Commons. Accessed November 5, 2023. https://upload.wikimedia.org/wikipedia/commons/thumb/7/7f/Tartan_Ribbon.jpg/920px-Tartan_Ribbon.jpg.

[640] Louis Ducos du Hauron. Early color photograph of Agen, France (1877). Photograph. Wikimedia Commons. Accessed November 5, 2023. https://upload.wikimedia.org/wikipedia/commons/thumb/0/08/Duhauron1877.jpg/1920px-Duhauron1877.jpg.

[641] Beaumont Newhall, *The History of Photography: From 1839 to the Present*, 5th ed. (New York: Museum of Modern Art, 1984), 271.

[642] Ibid. 271-273.

[643] Digital Camera Museum, "Sony ProMavica MVC-2010 (1990)," accessed September 9, 2025, https://www.digitalkameramuseum.de/en/esvc/item/sony-promavica-mvc-2010

Stereoscopic images

Following the invention of photography, it became possible not only to capture individual moments but also to convey depth and the illusion of three-dimensional space. This principle of Stereopsis[644] was first described by Charles Wheatstone in 1838, in his explanation of stereopsis and binocular vision[645]. His research led to the creation of stereoscopic drawings and, ultimately, the invention of the stereoscope. The effect was achieved by capturing two slightly offset photographs of the same subject and presenting them side by side. When viewed through a stereoscope, which directed each image to the corresponding eye, the human brain fused the two perspectives to generate a sense of depth, replicating natural binocular vision[646]. This technique offered a more immersive and lifelike experience than conventional photography. From the 1850s onwards, stereography gained widespread popularity in both Europe and the United States. Among its notable practitioners was Francis Bedford, who specialised in architectural views and historical landscapes[647]. The medium remained fashionable until the early twentieth century and has been described as the first accessible form of virtual reality, often referred to as the "novelty period of 3D immersion"[648]. Stereographs covered a wide range of subjects, with landscapes, monuments, and staged narrative scenes proving especially popular. During the second half of the nineteenth century, stereography served not only as entertainment but also as an educational medium, profoundly influencing public knowledge and aesthetic sensibilities[649].

[644] (from Ancient Greek στερεός (stereós) 'solid' and ὄψις (ópsis) 'appearance, sight') is the component of depth perception retrieved through binocular vision.

[645] Charles Wheatstone, "Contributions to the Physiology of Vision.—Part the First. On Some Remarkable and Hitherto Unobserved Phenomena of Binocular Vision," *Proceedings of the Royal Society of London* 4 (1843): 76–77, https://doi.org/10.1098/rspl.1837.0035.

[646] Ray Zone, *Stereoscopic Cinema and the Origins of 3-D Film, 1838–1952* (Lexington: University Press of Kentucky, 2007), 1.

[647] Francis Bedford (1815–1894) devoted much of his work to documenting historical and cultural heritage, producing some of the earliest systematic photographic records of Gothic cathedrals, castles, and ruins in Britain. His reputation earned him royal patronage, and in 1862 he accompanied the Prince of Wales (later King Edward VII) on a tour of the Middle East, during which he created more than 200 images of sites in Egypt, Palestine, Syria, and Greece. Circulated widely through albums, prints, and stereographs, these photographs combined documentary and educational value with immersive visual appeal, exemplifying the dual role of nineteenth-century photography as both a medium of European heritage popularization and a form of mass visual consumption.

See The Image Centre, "Francis Bedford Research Collection," *The Image Centre* (formerly Ryerson Image Centre), accessed September 9, 2025, https://theimagecentre.ca/collection/francis-bedford-research-collection/; British Museum, "Object: *Section of the Rotunda, Leicester Square, in which is exhibited the Panorama*," Museum Number P. 1875-0710-4485, *British Museum Collection Online*, accessed September 28, 2024, https://www.britishmuseum.org/collection/object/P_1875-0710-4485

[648] Ray Zone, *Stereoscopic Cinema and the Origins of 3-D Film, 1838–1952* (Lexington: University Press of Kentucky, 2007.1-18.

[649] R. Duane King, "A Brief History of Stereoscopy," *Wiley Interdisciplinary Reviews: Computational Statistics* 5, no. 4 (2013): 334–40, https://doi.org/10.1002/wics.1264; Kevin R. Brooks, "Depth Perception and the History of Three-Dimensional Art: Who Produced the First Stereoscopic Images?" *i-Perception* 8, no. 1 (2017): 1–16, https://doi.org/10.1177/2041669516680114; The Royal Society, "Stereoscopy: the Birth of 3D Technology," *Google Arts & Culture*, accessed September 11, 2024, https://artsandculture.google.com/story/stereoscopy-the-birth-of-3d-technology-the-royal-society/pwWRTNS-hqDN5g?hl=en; *NOMA (New Orleans Museum of Art)*, "Stereoscopes: Nineteenth-Century Virtual Reality Devices," *Arts Quarterly*, October 19, 2017, accessed August 19, 2024, https://noma.org/stereoscopes-first-virtual-reality-devices/

Fig. 103. Stereoscopic photography (stereophotography) of the ruins of Valle Crucis Abbey in Llangollen by Francis Bedford, (source: Victoria and Albert Museum[650]).

An anaglyph is another technique for creating the impression of depth on a flat surface. It is a form of stereography that produces 3D images by combining two slightly offset views, usually in contrasting colours such as red and cyan. When viewed through glasses with matching coloured filters, with one lens red and the other cyan or blue, each eye receives a different image. The brain then fuses these images, creating the illusion of depth and a three-dimensional effect. Anaglyphs have been widely used in entertainment, print media, education, photography, virtual tours, and scientific visualisation, and played a particularly important role in the early development of 3D cinema. Although newer 3D technologies have since appeared, anaglyphs remain a practical and cost-effective way of achieving a convincing three-dimensional experience[651].

[650] Francis Bedford. *Llangollen – Valle Crucis Abbey, from Garden*. Albumen silver print, c. 1864-1865. Victoria and Albert Museum, item O1367922. Accessed August 20, 2025. https://collections.vam.ac.uk/item/O1367922/llangollen---valle-crucis-photograph-francis-bedford/.

[651] Eric Dubois, "A Projection Method to Generate Anaglyph Stereo Images," in *Proceedings of the IEEE International Conference on Acoustics, Speech, and Signal Processing* (Cat. No. 01CH37221), vol. 3 (Salt Lake City, UT: IEEE, 2001), 1661–64, https://doi.org/10.1109/ICASSP.2001.941256; Dorra Dhaou, Saoussen Ben Jabra, and Ezzeddine Zagrouba, "A Review on Anaglyph 3D Image and Video Watermarking," *3D Research* 10, no. 2 (2019): 1–12, https://doi.org/10.1007/s13319-019-0223-1; Andrew J. Woods and Chris R. Harris, "Comparing Levels of Crosstalk with Red/Cyan, Blue/Yellow, and Green/Magenta Anaglyph 3D Glasses," in *Proceedings of SPIE Stereoscopic Displays and Applications XXI*, vol. 7253 (2010), 0Q1–0Q12, doi:10.1117/12.840835.

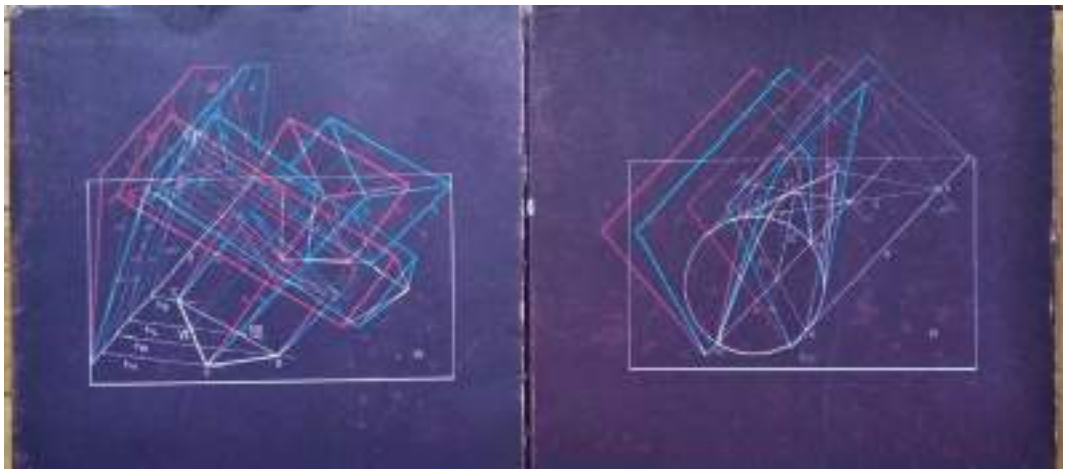


Fig. 104. *Zbiór zadań z geometrii wykreślnej* by Edward and Franciszek Otto[652]. Use of anaglyphs to create a depth effect and enhance students' understanding of descriptive geometry. Source: author.

Stereoscopy continues to find applications in various fields, particularly in entertainment through 3D cinema. Although experiments with stereoscopic films date back to the mid-twentieth century, the boom of the late 2000s and early 2010s marked a significant shift in the industry, driven by technological advances and the desire to enhance the cinematic experience, most notably with the success of Avatar in 2009. As the novelty faded, however, audiences became more critical of productions that relied on visual spectacle rather than strong storytelling, while issues such as the discomfort of 3D glasses and higher ticket prices further reduced its appeal. Nevertheless, the influence of this 3D wave remains evident: it expanded the possibilities of visual effects, accelerated the development of virtual and augmented reality, and contributed to the continuing evolution of immersive cinema technologies.

Movies

With the advent of photography, humanity gained the ability to capture and preserve life in still images. The next transformative step was to set these images into motion[653]. This pivotal advancement was achieved by the Lumière brothers with their invention of the *Cinématographe* in 1895[654]. The device advanced a roll of photographic film frame by frame, briefly pausing to expose each frame to light before the shutter closed and the film moved forward. The Cinématographe was not only a major technological breakthrough but also marked the birth of cinema and revolutionised the way reality could be perceived and documented.

The first public showcases of this invention included a series of short films directed and produced by Auguste and Louis Lumière. Among them, one work is especially crucial for the present discussion: *Arrival of a Train at La Ciotat (*fr. *L'Arrivée d'un train en gare de La Ciotat*), Lumière No. 653, presented in 1896. This 50-second, silent, black-and-white film, depicting a train pulling into the station at La Ciotat in southern France, stands as one of the earliest milestones in cinema. Its importance lies less in narrative content than in the strikingly realistic portrayal of a train advancing towards the camera. Contemporary accounts report that some viewers, unaccustomed to the immersive effect of projected

[652] Franciszek Otto, Edward Otto *Podręcznik geometrii wykreślnej* (Warszawa: Wydawnictwo Naukowe PWN, 1998).

[653] Theatre is intentionally omitted here because of its strong emphasis on narrative and its focus on human actors, rather than on architecture, which forms the central subject of this thesis. In theatrical productions, the built environment typically functions only as a thematic setting or backdrop for the performance.

[654] Louis Le Prince overtook in time the Lumière brothers with his film Roundhay Garden Scene recorded in 1888, being to this day the oldest film.

moving images, reacted with fear, believing the train was heading directly towards them. Though this anecdote may be partly apocryphal, it vividly illustrates the unprecedented psychological and perceptual impact of early cinema, laying the groundwork for immersion as a central element of the cinematic experience[655]. The influence of such experiments extended beyond cinema, foreshadowing later developments in virtual reality. By using perspective and motion to break through the static "canvas" of the screen, the Lumières' film introduced an illusion of spatial depth that anticipated the fully immersive environments of later technologies. Subsequent innovations, such as the introduction of colour and synchronised sound, further heightened the realism of cinema and its ability to simulate lived experience.

Fig. 105. Frames from *The Arrival of a Train at La Ciotat Station*, (source: Wikimedia commons [656]).

Sensorama 1956

As photography and film technology advanced, they remained primarily visual and auditory experiences, without engaging the other senses. A breakthrough came in 1957, when Morton Heilig created the Sensorama, and secured patent[657] for a pioneering cinematic device that expanded immersion beyond sight and sound. It combined a stereoscopic screen with speakers, fans, smell generators, and a vibrating chair, transforming the viewing experience into a multisensory event. Users would sit before the machine and peer into the display, experiencing short films such as a motorcycle ride through a city, enhanced by effects that engaged multiple senses[658]. Heilig also envisioned large-scale projects, including a "theatre for the masses," designed to stimulate multiple senses simultaneously[659].

Although the Sensorama was never widely commercialised, it is regarded as a precursor to modern virtual reality (VR). Heilig's invention demonstrated the potential of multisensory experiences in entertainment and remains an important milestone in the evolution of immersive media. Its legacy can

[655] Wheeler Winston Dixon and Gwendolyn Audrey Foster, *A Short History of Film*, 2nd ed. (New Brunswick, NJ: Rutgers University Press, 2013), 1–11.

[656]Lumière, Auguste and Louis. *L'Arrivée d'un train en gare de La Ciotat* (1896). Film. Wikimedia Commons. Accessed August 21, 2024.
https://upload.wikimedia.org/wikipedia/commons/6/6e/L%27Arriv%C3%A9e_d%27un_train_en_gare_de_La_Ciotat_%281897%29_par_les_fr%C3%A8res_Lumi%C3%A8re.webm.

[657] Morton L. Heilig, "Experience Theater," U.S. Patent 3,628,829, filed July 8, 1969; issued December 21, 1971, https://patents.google.com/patent/US3628829A/en

[658] Ray Zone, *Stereoscopic Cinema and the Origins of 3-D Film, 1838–1952* (Lexington, KY: University Press of Kentucky, 2007), 9.

[659] Howard Rheingold, *Virtual Reality: The Revolutionary Technology of Computer-Generated Artificial Worlds and How It Promises to Transform Society* (New York: Simon & Schuster, 1992), 49–53, 57–60; Alessandro Basso, "Advantages, Critics and Paradoxes of Virtual Reality Applied to Digital Systems of Architectural Prefiguration, the Phenomenon of Virtual Migration," *Proceedings* 1, no. 9 (2017): 915. https://doi.org/10.3390/proceedings1090915.

be traced in contemporary "7D cinemas," which continue to rely on the artificial stimulation of multiple senses to heighten the illusion of immersion[660].

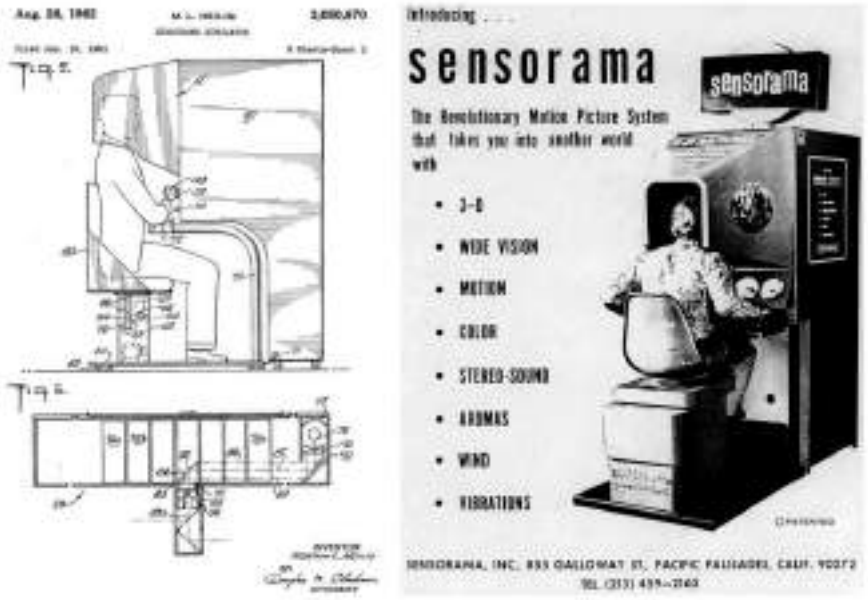


Fig. 106. *Sensorama*, the first virtual immersion system, the technical table and the pictures shown at the presentation of the experimental product, (source: U.S. Patent 3,050,870 [661]).

Ultimate Display 1965

In 1965, Ivan Sutherland[662], a computer scientist and at the time, associate professor of electrical engineering at Harvard University, presented a seminal paper titled The Ultimate Display[663]. In it, he envisioned a computer-generated virtual world indistinguishable from reality, where users could interact with simulated objects as if they were real. This environment, he argued, could be made so convincing that there would be no perceptible difference between the physical and the virtual. Sutherland's paper laid the foundations for the concept of virtual reality and is still regarded as a blueprint for modern VR[664]. He imagined a display capable of controlling the existence of matter itself, creating experiences so immersive that they would feel entirely real to the user, reaching an advanced level of human–computer interaction[665]. He also anticipated the need for navigation within such environments, a concept echoed today in devices like the Oculus Quest VR headsets.

---

[660] Morton L. Heilig, "Experience Theater," U.S. Patent 3,628,829, filed July 8, 1969; issued December 21, 1971, https://patents.google.com/patent/US3628829A/en.

"*The present invention, generally, relates to simulator apparatus and, more particularly, to apparatus to stimulate the senses of an individual to simulate an actual experience realistically.*"

[661] Morton L. Heilig. *Sensorama Simulator.* U.S. Patent 3,050,870, filed January 10, 1961, and issued August 28, 1962. Accessed August 21, 2024. https://patents.google.com/patent/US3050870A/en.

[662] It is worth noting that Sutherland also introduced and developed the concepts of object-oriented programming, graphical manipulation, and constraints in graphical design. His Sketchpad, presented in 1963, is considered the precursor to modern CAD (computer-aided design) systems, which architects extensively use throughout their professional careers today. The concept later evolved into so called wireframe 3D graphics, with application o perspective into digital drawings.

[663] Ivan E. Sutherland, "The Ultimate Display," in *Proceedings of the IFIP Congress*, vol. 2 (1965): 506–508.

[664] Johnathan Bown, Elisa White, and Akshya Boopalan, "Looking for the Ultimate Display," in *Boundaries of Self and Reality Online*, ed. Jayne Gackenbach and Johnathan Bown (San Diego: Elsevier, 2017), 239–59.

[665] Ivan E. Sutherland, "The Ultimate Display," in *Proceedings of the IFIP Congress*, vol. 2 (1965): 506–508.

"(…) A display connected to a digital computer gives us a chance to gain familiarity with concepts not realizable in the physical world. It is a looking glass into a mathematical wonderland. (…)

Although Sutherland's "ultimate display" remains only partially realised, it continues to raise profound philosophical questions about the nature of reality and perception. If a computer can generate an environment indistinguishable from the real world, it challenges conventional definitions of what constitutes reality. This concept was further advanced by Sutherland in 1968 with the invention of one of the first head-mounted display systems.

3.3 Digital Illusion and Virtual Reality

The Sword of Damocles 1968

As noted in the previous chapter, Ivan Sutherland was responsible for another major leap in the development of the virtual reality concept. In 1968, together with his students Bob Sproull, Quintin Foster, and Danny Cohen at the University of Utah, he developed the first head-mounted display (HMD) system, known as *The Sword of Damocles*[666]. This device was conceived as a direct follow-up to his earlier concept of The Ultimate Display[667].

Fig. 107. *The Sword of Damocles* by Ivan Sutherland, (source: Sutherland 1968 [668]).

(…) Knobs and joysticks of various kinds serve a useful function in adjusting parameters of some computation going on. For example, adjustment of the viewing angle of a perspective view is conveniently handled through a three-rotation joystick. Push buttons with lights are often useful. Syllable voice input should not be ignored. (…)

(…) The ultimate display would, of course, be a room within which the computer can control the existence of matter. A chair displayed in such a room would be good enough to sit in. Handcuffs displayed in such a room would be confining, and a bullet displayed in such a room would be fatal. With appropriate programming such a display could literally be the Wonderland into which Alice walked."

666 The name Sword of Damocles was inspired by the ancient Greek tale of Damocles, a courtier in Syracuse who envied the luxurious life of King Dionysius II and longed to experience his power. When allowed to sit on the throne for a day, he discovered a sword hanging above him, suspended by a single horsehair, symbolising the constant danger that accompanies authority. Overwhelmed by this realisation, Damocles pleaded to return to his ordinary life, recognising that the pursuit of power often ignores its hidden perils. Sutherland drew on this allegory to reflect the risks and challenges inherent in virtual reality: the bulky headset, suspended above the user by a mechanical arm, evoked the precariousness of the sword and served as a metaphor for the potential dangers of immersion in a digital world.

667 Ivan E. Sutherland, "A Head-Mounted Three Dimensional Display," in *Proceedings of the Fall Joint Computer Conference (AFIPS)* (1968), 757–64.

668 Ivan E. Sutherland, "A Head-Mounted Three-Dimensional Display," in *Seminal Graphics: Pioneering Efforts That Shaped the Field*, 1968.

Sutherland's Sword of Damocles is regarded as the first fully operational VR system and laid the foundation for modern virtual reality technologies[669]. It demonstrated the potential of immersive experiences through pioneering applications of computer graphics. The system featured a head-mounted display that presented simple wireframe, computer-generated images superimposed on the user's real-world view. The headset itself was rudimentary, resembling oversized goggles, and so heavy that it required suspension from a mechanical arm. The visual output consisted of basic three-dimensional wireframe models rendered in real time. Users could view geometric forms in 3D space, interact with the virtual environment, and experience a merging of physical and digital realities through a head-tracking system[670]. The device monitored the user's head movements, allowing them to look around within the virtual space. This interaction was groundbreaking, as it provided an early sense of presence and immersion in a computer-generated environment[671].

Wired Glove 1981-1982

Although Ivan Sutherland had already envisioned potential controllers for virtual environments in his Ultimate Display (1965), a true breakthrough in human–computer interaction came with the invention of the *wired glove*, also known as the *data glove* or *cyberglove*[672]. This device was fitted with a series of sensors, often fibre optic or resistive, that measured the position and movement of the fingers. By capturing the fine articulation of each finger joint, the glove enabled more natural interaction with digital environments. Beyond virtual reality, it could also be employed in general human–computer interaction tasks, allowing users to control virtual environments or software applications through gestures. The earliest versions of the glove were tethered by cables, which restricted mobility. However, with the development of wireless technology, users gained far greater freedom of movement, making the device more practical. One of its pioneering applications was within NASA, where the glove was integrated into early VR training simulations. In this context, it allowed astronauts to practise complex hand manipulations required for future space missions in a safe, controlled, virtual setting. This invention not only advanced VR interaction but also laid the foundation for modern input devices. The concept of natural gesture-based control influenced the evolution of hand-held controllers, eventually leading to joystick-like devices such as those used in Meta's Oculus Quest 2 system.

Videoplace 1983

Myron Krueger, an American computer artist, developed *Videoplace*, an "artificial reality"[673] laboratory that allowed users to interact with computer-generated environments. He began working on the concept in the mid-1970s and presented his invention in 1983. *Videoplace* was an interactive installation in which users engaged with virtual elements projected onto a large screen through image-processing techniques that interpreted their movements and translated them into actions within the virtual environment. Unlike many VR systems that required specialised equipment, *Videoplace* employed cameras to capture users' silhouettes, which were then integrated into the projected

[669] Much more accurate would be called it Augmented Reality (AR), due to the fact that uses is experiencing both worlds constantly, but most of the literature describe it as an Virtual Reality.

[670] Roy S. Kalawsky, *The Science of Virtual Reality and Virtual Environments: A Technical, Scientific, and Engineering Reference on Virtual Environments* (Wokingham, England ; Reading, MA: Addison-Wesley, 1993), 20–23.

[671] Rheingold, Howard. 1992. Virtual Reality : The Revolutionary Technology of Computer-Generated Artificial Worlds and How It Promises to Transform Society. New York: Simon & Schuster. Pp. 105-113

[672] Roy S. Kalawsky, *The Science of Virtual Reality and Virtual Environments: A Technical, Scientific, and Engineering Reference on Virtual Environments* (Wokingham, England ; Reading, MA: Addison-Wesley, 1993), 21.

[673] Krueger used new term "artificial reality" in his articles. He explains that Artificial Reality differs from Virtual Reality in that it encompasses any part of the Virtual Continuum except for reality itself. It includes everything from Augmented Reality to Virtual Reality.

environment. The system was pioneering in its emphasis on direct interaction and its development of body- and gesture-based tracking capabilities[674]. It also enabled multiple users to share the same virtual space, albeit in an early and experimental form, with a stronger orientation toward artistic installation than technological commercialisation. Nevertheless, *Videoplace* laid important foundations for later developments in interactive environments and the conceptual evolution of the metaverse. Its significance lies in exploring new modes of human interaction with virtual worlds, and an installation of Videoplace can still be experienced today at the University of Connecticut[675].

Fig. 108. Left: *Videoplace* and Krueger showing his avatar interacting in virtual environment. Right: Two silhouettes projected via *Videoplace* installation with drawing possibilities, (source: Kreuger 1985 [676]).

Nasa VIEW Simulator 1988

The inventions discussed earlier, including stereography, and it's advanced version[677], the wired glove, advances in human–computer interaction, head tracking, and early image projection in augmented reality, were crucial in shaping immersive environments and establishing the foundations of modern virtual reality[678]. The first system to bring these elements together in a coherent prototype was the *Virtual Interface Environmental Workstation* (VIEW), developed in 1988 at the NASA Ames Research Centre as a training tool for astronauts[679]. VIEW employed a basic three-dimensional environment composed of wireframe models and simple light-reflection calculations. Despite its technical limitations, it enabled real-time interaction with virtual objects and spaces through programmed responses, making it an important step in simulation-based training. The integration of a glove

[674] Myron W. Krueger, "VIDEOPLACE: A Report from the ARTIFICIAL REALITY Laboratory," *Leonardo* 18, no. 3 (1985): 145–51; Myron W. Krueger, Thomas Gionfriddo, and Katrin Hinrichsen, "VIDEOPLACE—An Artificial Reality," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '85)*, 35–40 (New York: Association for Computing Machinery, 1985), https://doi.org/10.1145/317456.317463.

[675] Howard Rheingold, *Virtual Reality: The Revolutionary Technology of Computer-Generated Artificial Worlds and How It Promises to Transform Society* (New York: Simon & Schuster, 1992), 122–28.

[676] Myron W. Krueger and Stephen Wilson, "VIDEOPLACE: A Report from the ARTIFICIAL REALITY Laboratory," *Leonardo* 18 (1985): 145–51.

[677] Advanced panoramic stereographic photography using the LEEP Panoramic Stereo Photography System. The LEEP (Large Expanse, Extra Perspective) system, developed by Eric Howlett in the late 20th century, was designed to capture immersive wide-angle images with enhanced depth and realism through stereo photography techniques.

[678] Many other inventions were necessary to create a fully operational system, but due to the complexity and varying influence of some tools, I have chosen to minimise the historiographic section of this thesis. While this background is not the core focus of the work, it serves as an essential introduction to today's systems.

[679] Howard Rheingold, *Virtual Reality: The Revolutionary Technology of Computer-Generated Artificial Worlds and How It Promises to Transform Society* (New York: Simon & Schuster, 1992), 110.

controller, which allowed users to manipulate virtual objects as if they were real, added an unprecedented level of interactivity.

Contemporary systems such as the Oculus Quest 2 represent a significant evolution of this early concept. Modern headsets provide vastly improved visual quality through high-resolution displays and function as standalone wireless devices, while retaining the option to connect to a computer for enhanced computational power. Yet despite these advances, the fundamental principles of immersion and interaction remain rooted in the foundations established by VIEW in the late 1980s.

Fig. 109. Left: Nasa's *VIEW* with Head Mounted Display and use of *wired glove* controller. Right: *VIEW* system graphic environment with virtual hand, based on wired glove controller, (source: Association for Computing Machinery[680]).

CAVE 1992[681]

While the development of virtual reality had largely focused on the individual user equipped with head-mounted goggles, which partially restricted awareness of the real world, there was little alternative until 1992, when the CAVE VR system (Cave Automatic Virtual Environment) was introduced[682]. Developed at the University of Illinois at Chicago's Electronic Visualization Laboratory (EVL) by Daniel J. Sandin, Thomas A. DeFanti, and Carolina Cruz-Neira, this innovative system offered a new way of experiencing digital environments, reminiscent of Ray Bradbury's vision of a virtual room in his short story The Veldt (1950[683]. The CAVE provided an immersive form of visualisation that enabled users to interact with three-dimensional data naturally and intuitively, without being "blindfolded" by a headset. Importantly, it also allowed multiple users to share the same immersive experience simultaneously.

The central concept of the CAVE was the use of multiple projection screens, typically four to six, forming the walls, floor, and sometimes ceiling of a room-sized enclosure. These screens, constructed from translucent materials such as Plexiglas, displayed stereoscopic computer-generated imagery using dual

680 "New Techniques: Find Missing Places." *CHI '90 Technical Video Program*. Association for Computing Machinery (ACM), 1990.

681 Since the author will employ this technology in future case studies, the technical aspects will be presented later, while this section focuses solely on the historical significance and development of CAVE VR.

682 Carolina Cruz-Neira, Daniel J. Sandin, Thomas A. DeFanti, Robert V. Kenyon, and John C. Hart, "The CAVE: Audio Visual Experience Automatic Virtual Environment," *Communications of the ACM* 35, no. 6 (1992): 64–72, https://doi.org/10.1145/129888.129892.

683 Ray Bradbury, "The Veldt," *The Saturday Evening Post*, September 23, 1950.

projectors to create a convincing 3D effect. To perceive depth, users wore lightweight stereoscopic glasses, often fitted with reflective markers or horns tracked by a camera-based motion system, which enabled the environment to respond dynamically to their movements. Some implementations also incorporated a rotating ball interface, allowing more complex navigational input such as walking or even running within the virtual space. Beyond its technical innovation, the CAVE marked a turning point in the history of virtual reality. It offered higher visual fidelity and reduced motion sickness compared with early head-mounted displays, and it shifted the paradigm from an isolated, individual experience to a shared, collaborative, room-scale environment. Throughout the 1990s, it was widely adopted in research and industry, particularly in scientific visualisation, medicine, and engineering.

Fig. 110. Virtual Reality Cave system. Faculty of Electronics Telecommunication and Informatics, Immersive 3D Visualization Laboratory, Gdansk University of Technology. Source: author, 2023.

360° digital projection 2013

Although photography has a long history, it was not initially possible to create fully spherical images due to the limitations of lens and camera construction. Early panoramic photography was achieved with specialised devices such as the Cirkut camera[684], or through analogue methods by manually assembling a series of photographs. The real breakthrough in capturing spherical images only came with the advent of digital photography[685].

Some early photographic attempts were made using omnidirectional cameras[686] or spherical lenses, and later digital cameras introduced the option of stitching together multiple photographs to produce panoramic or spherical images. A major milestone in the public use of such technology was the launch

[684] The Cirkut camera, introduced in the early 20th century, was a large-format panoramic camera capable of capturing 360-degree images on film. It used a rotating mechanism to slowly turn the camera while exposing a long strip of film, creating wide, continuous panoramic photographs. The Cirkut camera was popular for capturing landscapes, cityscapes, and large group photos, producing highly detailed and expansive images that were unmatched at the time.

[685] The idea of surrounding the viewer with an all-encompassing image, however, was not new, as mention in previous paragraphs the panoramic paintings, had already sought to create a fully immersive visual experience by enveloping the spectator in a continuous 360-degree scene. Similarly, spherical projection was well understood in descriptive geometry and was famously explored artistically by M. C. Escher Yet, due to technical constraints, it remained impossible to capture reality in this way with traditional photographic equipment.

[686] Omnidirectional cameras typically use a parabolic mirror, which varies in span, to disperse the rays projected onto the traditional camera image plane, allowing to capture semi-spherical images projected on the flat photographic film.

of Google Street View in 2007, which employed panoramic stitching to create navigable, immersive maps of cities and landscapes[687].

A decisive step forward came in 2013 with the release of the Ricoh Theta, the first commercially successful consumer camera designed to capture full spherical images using two wide-angle lenses[688]. Other companies, including GoPro and Samsung, soon followed with their own models, such as the GoPro Fusion and Samsung Gear 360, which further popularised 360-degree photography and video. Unlike earlier bulky multi-camera rigs, these compact devices made spherical content far more accessible to the general public. Their impact was reinforced by the rise of social media and streaming platforms, with YouTube and Facebook beginning to support 360° video in 2015 and bringing immersive media into everyday digital culture.

The growing accessibility of spherical photography and video also created a natural link to virtual reality platforms. 360° content quickly became one of the first widely available immersive formats for consumer VR headsets. In this way, spherical imagery not only transformed digital photography but also extended the long tradition of panoramas, from painted rotundas to digital spheres, playing an important role in bridging traditional visual culture with fully immersive virtual reality environments.

Oculus VR googles 2016[689]

Even though the concept of virtual reality had been developed much earlier, commercially viable and home-accessible VR solutions were not possible for many years due to the high cost of equipment. Experiments in the entertainment industry during the 1990s sought to bring VR to a wider audience. Notable examples include the Virtuality arcade systems (1991)[690], Sega VR (1993) [691], and the Nintendo Virtual Boy (1995)[692]. These products focused primarily on gaming and attempted to offer more than simple visual and audio stimulation, yet technical limitations prevented them from achieving true immersion and long-term success. In the early 2000s, VR entered a period of dormancy and stagnation, largely because computing power remained insufficient, display resolution and refresh rates were inadequate, and motion-tracking systems were either inaccurate or prohibitively expensive. While small-scale experiments continued in academic and military contexts, the technology had not yet reached the level required to fulfil the long-standing vision of immersive VR[693].

---

[687] Paul Moakley, "Street View and Beyond: Google's Influence on Photography," *TIME*, October 24, 2012, accessed September 11, 2024, https://time.com/55683/street-view-and-beyond-googles-influence-on-photography/.

[688] *RICOH360 Blog*, "Looking Back over the Last 10 Years — Interviews Commemorating RICOH THETA's 10th Anniversary," *RICOH360 Blog*, March 14, 2024, accessed September 13, 2024, https://blog.ricoh360.com/en/interviews-commemorating-the-10th-anniversary

[689] Similar to CAVE VR, this technology will be employed by the author in future case studies. Accordingly, the technical aspects will be presented later, while this section focuses solely on the historical significance and development of VR goggles.

[690] The first mass-produced VR entertainment system, Virtuality, was introduced in arcade halls. It featured an HMD with stereoscopic 3D visuals and head-tracking, and real-time rendering. The system offered several games but was expensive and inaccessible to home users.

[691] Sega attempted to bring VR to the home market with the Sega VR headset, designed for the Sega Genesis console. Despite the commercial interest, it never reached the market due to technical limitations and concerns about motion sickness.

[692] The Virtual Boy was a portable console that offered 3D depth using a red monochromatic stereographic display. However, it was a commercial failure due to its limited software and game library, discomfort, and poor visuals.

[693] The primary issue was the inadequate graphics card technology and computational power, which were not capable of calculating and rendering large environments. In the case of VR, this was particularly challenging as the graphics had to be rendered twice, once for each lens of the HMD.

A significant breakthrough and the first major commercial success came with Palmer Luckey's Oculus Rift. Initially launched as a Kickstarter project in 2012, the Rift quickly attracted widespread attention and was acquired by Facebook in 2014. The consumer version, released in 2016, marked the beginning of modern VR. It introduced improved head tracking, stereoscopic 3D visuals, and a more comfortable design, while incorporating the accumulated technological advances of previous decades. Nevertheless, the Rift still required a PC connection and functioned essentially as a display system with two hand-operated controllers. The resurgence of VR in the 2010s was made possible by advances in consumer electronics, particularly the miniaturisation of high-resolution displays and motion sensors developed for smartphones. Alongside Oculus, devices such as the HTC Vive and Sony PlayStation VR in 2016 broadened the ecosystem and established VR as a mainstream technology[694]. With the launch of these platforms, the VR market changed fundamentally, praised for balancing performance with affordability and offering cost-effective solutions that reached a mass audience.

Beyond gaming, these developments also supported professional applications. In fields such as architecture, engineering, and real estate, VR headsets have been adopted as tools for design visualisation, collaborative review, and client presentations, integrating immersive simulations into established creative and technical workflows. Within architectural practice, in particular, VR has been employed to present projects in an interactive and spatially coherent manner, enabling clients to examine proposed spaces in a more direct and experiential way.

Fig. 111. Oculus Quest 2. Source: author, 2025.

Microsoft HoloLens 2016

The next step in technological development was the Microsoft HoloLens, first released in 2016 and followed by a second edition in 2019, which advanced the concept of virtual reality into what is now termed mixed reality. Similar in principle to Sutherland's Sword of Damocles, the HoloLens projects digital images onto transparent glass lenses, enabling users to view digital content while still perceiving the real world. Unlike the rudimentary technology of the late 1960s, it integrates advanced optics, sensors, and processing systems that allow digital elements to be overlaid onto the physical environment in real time. This blending of physical and digital domains distinguishes it from traditional virtual reality headsets, which fully immerse the user in a simulated space. The introduction of the

[694] Other popular devices: HTC Vive (2016), PlayStation VR (2016), Valve Index (2019): Oculus Quest (2019): Meta Quest 2 (2020), Meta Quest 3 (2023), Apple Vison (2023). Recently the development rapidly advanced as the current technology allows for much more complicated solutions integrating Augmented Reality into HMD.

HoloLens represented the first commercially viable mixed-reality system. Its applications have been concentrated in professional and industrial contexts, including healthcare, manufacturing, education, and design, where it is used for tasks such as training, visualisation, and remote collaboration. These uses illustrate how mixed-reality devices have expanded the scope of immersive technologies beyond entertainment, integrating them into practical and technical workflows.[695].

Fig. 112. Microsoft HoloLens attached to the hardhat of construction worker, (source: Microsoft webpage [696]).

Future

Based on current research and observations of ongoing developments in VR and computer technology, it is clear that new tools will continue to emerge, extending the limits of what is technically possible. Future advancements are expected in hardware, including lighter and more comfortable headsets, higher-resolution displays, and more seamless forms of immersion. Eye-tracking and artificial intelligence are also likely to enhance the realism and interactivity of virtual environments. At the same time, the continuing miniaturisation of technology, combined with potential breakthroughs in quantum computing, may profoundly influence everyday digital interactions.

Virtual reality has evolved significantly from its early conceptual stages to the sophisticated systems available today. What began as a vision of immersive simulation has become a practical reality with applications across numerous industries. The release of the Apple Vision Pro in 2024, alongside comparable devices from Oculus and HTC, signals a possible transformation in the role of the personal computer. Some commentators suggest that the conventional workstation may eventually be displaced by mixed-reality systems, shifting many aspects of digital interaction into immersive environments. This development would have direct implications for professional practice, including architecture, where the workstation itself may be reconceptualised as a space for simulation-driven design.

[695] Microsoft Learn, "What Is Mixed Reality?" *Microsoft Learn*, January 25, 2023, accessed September 13, 2024, https://learn.microsoft.com/en-us/windows/mixed-reality/discover/mixed-reality; Lauren Goode, "Microsoft's HoloLens 2 Puts a Full-Fledged Computer on Your Face," *WIRED*, February 24, 2019, accessed September 13, 2025, https://www.wired.com/story/microsoft-hololens-2-headset/

[696] Microsoft. *Trimble XR10 with HoloLens 2*. Microsoft Docs. Published October 13, 2022. Accessed August 21, 2024. https://learn.microsoft.com/en-us/hololens/hololens2-options-trimble-xr10-edition.

Fig. 113. *Apple Vision Pro,* presented in 2024, as an example of a mixed-reality device positioned as a potential successor to traditional personal computers, (source: YouTube[697]).

Another crucial development shaping the future of immersive technologies is the rapid progress of artificial intelligence, particularly in the field of image and video generation. Tools such as OpenAI's DALL·E and Sora, alongside comparable generative models, are capable of producing highly realistic visual and animated content from text prompts. When combined with VR and mixed reality, such systems may enable the on-demand creation of dynamic environments, architectural scenarios, or cultural reconstructions without the need for manual 3D modelling. This convergence of AI and VR could significantly accelerate design processes and democratise access to immersive content, while also raising critical questions about authorship, authenticity, and creative control. In the workplace, VR and mixed reality are also expected to reshape modes of remote collaboration. Immersive environments, referred to as "metaverses", may allow distributed teams to meet in shared virtual spaces that replicate some aspects of a physical office. Within such spaces, colleagues could be represented by avatars, work with 3D models, and participate in virtual meetings or conferences. These developments hold the potential to make remote work more interactive and engaging, although their actual impact will depend on technological maturity and user adoption.

Nevertheless, several challenges remain. The cost of devices continues to limit widespread accessibility, and the creation of high-quality, contextually relevant content remains resource-intensive. Concerns over privacy, data security, and the psychological effects of prolonged immersion also need to be addressed as these technologies become more embedded in everyday life. This trajectory raises fundamental questions about the extent to which society will embrace parallel, computer-simulated environments. For example, in the field of heritage, these technologies can facilitate remote visits to historic monuments, reconstruct their former states, or provide immersive interpretation without the need for physical reconstruction. In this respect, immersive media can contribute to the preservation, study, and dissemination of cultural heritage while expanding opportunities for public engagement.

[697] Apple. "Apple Vision Pro". YouTube video, 1:17. Posted June 5, 2023. Accessed August 20, 2025. https://www.youtube.com/watch?v=Btf4mN37OsU

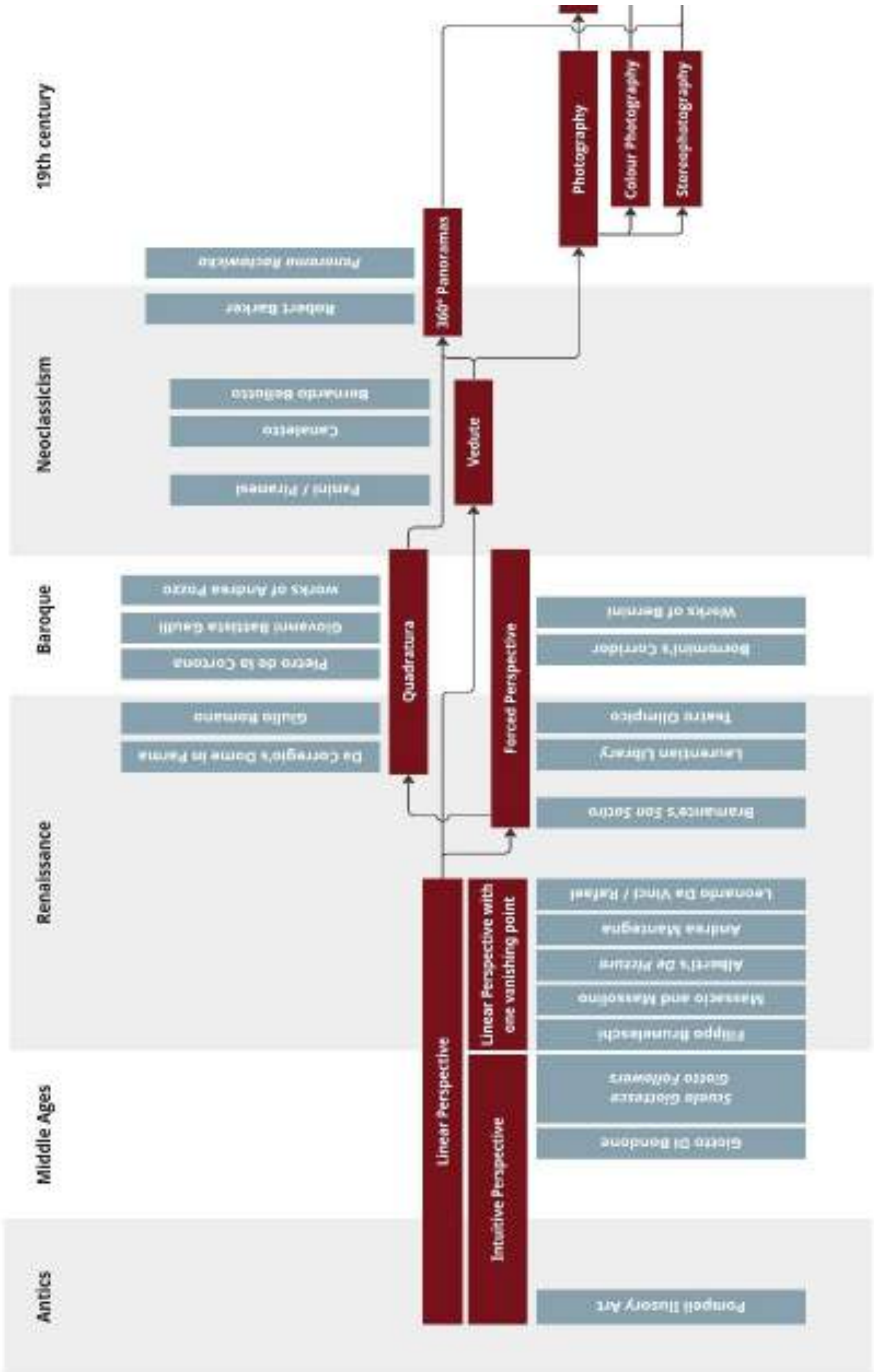
3.4 Summary Of The Chapter

The history of immersive practices reveals a continuous human aspiration to transcend the pictorial frame and dissolve the boundary between image and viewer. From antiquity onwards, artists developed techniques of illusion, perspective, and spatial manipulation that anticipated many of the perceptual strategies later adopted by digital media.

Roman frescoes, such as those at the Villas of Livia and Fannius Synistor, transformed walls into enveloping landscapes and fictive architectures. Medieval painters, exemplified by Giotto, explored empirical systems of depth, while the Renaissance codified linear perspective through Brunelleschi and Masaccio, later perfected in large-scale mural programmes. The Baroque brought illusionism to its height, as Cortona, Pozzo, and Bernini fused painting, sculpture, and architecture into dramatic, all-encompassing environments. From the seventeenth century onwards, vedute combined documentary precision with immersive city views, anticipating Robert Barker's panorama of the late eighteenth century. Panoramic art flourished in the nineteenth century, while photography introduced a new mode of realism, from Niépce and Daguerre's experiments to Bedford's Middle Eastern surveys and Maxwell's colour innovations. With the Lumière brothers' films, immersion expanded into time and movement, marking the transition from static to dynamic media. The twentieth century produced the first prototypes of virtual reality: Heilig's Sensorama, Sutherland's head-mounted display, and later interactive systems such as the data glove, Videoplace, and the CAVE environment. These experiments laid the foundation for today's consumer VR technologies, exemplified by the Oculus Rift. Across these diverse practices, the underlying ambition has remained constant: to extend pictorial space into lived experience and to engage the viewer as an active participant.

Yet the leap from optical illusion to virtual simulation also marks a fundamental shift. Earlier traditions relied on fixed vantage points and passive spectatorship, whereas VR creates interactive and responsive environments in which the user's movements actively shape perception. Unlike painted or cinematic illusions, which are irreversible once executed, digital reconstructions are modifiable and reversible, allowing for dynamic reconfigurations and multiple hypotheses. VR also extends immersion beyond the visual by incorporating spatial audio, haptics, and embodied interaction, transforming it into a multisensory experience.

This chapter has shown that VR both inherits and transforms the lineage of immersive art. While it extends centuries of experimentation with illusion and perspective, the shift from static images to interactive, multisensory environments marks a true paradigm change. Whereas earlier forms confined viewers to fixed vantage points, VR liberates them into interactive space. Immersion is no longer a one-directional projection imposed by the artist but a dynamic experience co-created by creator and participant. In this respect, VR not only continues the history of immersive practices but also redefines them, opening new possibilities for architectural heritage interpretation and conservation that transcend the material limits of earlier traditions, and marking a decisive transformation in how immersion itself is conceived.


Antics
Middle Ages
Renaissance
Baroque
Neoclassicism
19th century
Linear Perspective
Intuitive Perspective
Linear Perspective with one vanishing point
Forced Perspective
Quadratura
Veduta
360° Panoramas
Photography
Colour Photography
Stereophotography
Pompeii Illusory Art
Giotto Di Bondone
Scuola Giottesca
Giotto Followers
Filippo Brunelleschi
Massacio and Massolino
Alberti's De Pictura
Andrea Mantegna
Leonardo Da Vinci / Rafael
Bramante's San Satiro
Laurentian Library
Teatro Olimpico
Borromini's Corridor
Works of Bernini
Da Corregio's Dome in Parma
Giulio Romano
Pietro da la Cortona
Giovanni Battista Gaulli
works of Andrea Pozzo
Panini / Piranesi
Canaletto
Bernardo Bellotto
Robert Barker
Panorama Raclawicka

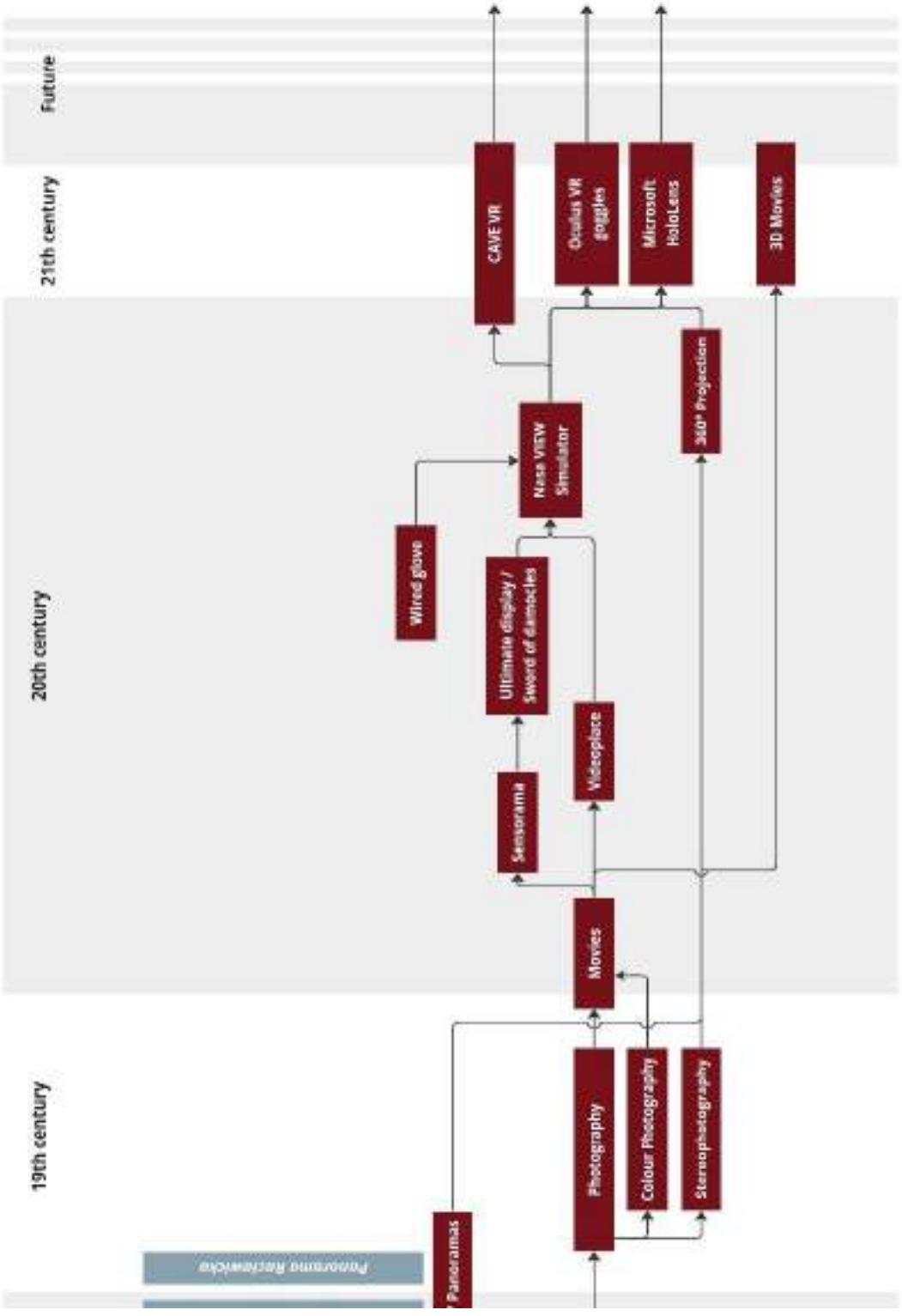


Fig. 114. Graphical synthesis of historical development of immersive virtual reality. Source: author.

CHAPTER 4

APPLICATIONS AND TECHNOLOGICAL ASPECTS OF IMMERSIVE SCAN BASED DIGITAL RECONSTRUCTION

VIRTUAL REALITY TECHNOLOGY IN ARCHITECTURAL HERITAGE AND ITS IMPACT ON CONSERVATION

4. Applications and technological aspects of immersive scan based digital reconstruction

Introduction

While virtual reconstructions have traditionally been understood as digital models displayed on screens in the form of static renders or informative animations, recent developments in virtual reality have transformed these models into immersive simulations. Such environments do not merely present reconstructions; they situate the viewer within them, engaging multiple senses and fostering an embodied experience of architectural space. This shift reflects a broader trend in heritage visualisation: moving from the production of descriptive representations to the creation of experiential environments.

Immersive simulations are characterised by their capacity to generate a sense of presence within reconstructed settings. This effect is achieved through technologies such as stereoscopic display, real-time rendering, head and body tracking, and augmented or mixed reality interfaces. Systems including head-mounted displays, CAVE environments, and a growing range of AR applications enable users to navigate and interact with historical reconstructions as if physically inhabiting them. Unlike traditional virtual reconstructions, which remain externalised objects of observation, immersive simulations blur the boundary between observer and environment, continuing a long cultural aspiration to dissolve the pictorial frame.

A significant step in enabling such immersive experiences has been the development of scan-based solutions, which allow the direct digitalisation of architectural structures and sites. By employing ground-based and aerial photogrammetry or laser scanning, heritage sites can be recorded with accurate geometrical and material data that serve as the foundation for immersive simulations. This scan-derived fidelity ensures that reconstructions are not solely interpretive but anchored in measurable evidence, thereby enhancing their reliability. When integrated into immersive environments, these datasets provide users with the opportunity not only to view reconstructions but also to virtually inhabit the digitally recorded fabric of heritage sites.

4.1. Applications of Virtual Reality in Heritage Conservation

4.1.1 Before virtual reconstruction

Hand-drawn reconstructions

Traditionally, the synthesis and presentation of research findings in archaeology and architectural history relied heavily on hand-drawn reconstructions. These included detailed plans, elevations, sections, and perspective sketches, typically created by architects, historians, or artists drawing from archaeological evidence, historical texts, and comparative analysis. Such drawings were often based on measured inventories and surveys or historic records and followed standardized graphic conventions, particularly linear drawing, to ensure clarity and comparability across different sites and projects.

To visualize ancient sites and structures, practitioners employed perspective and axonometric sketches as well as watercolour paintings, all designed to bring lost or ruined buildings back to life without physically altering the preserved remains. Frequently, these hand-drawn reconstructions included hypothetical elements, especially when parts of a structure were missing. In such cases, artists used

comparative analysis with better-preserved sites to guide their depictions, indicating conjectural or less-certain features with dashed lines, lighter colours, or explanatory annotations. Supplementary notes, legends, or graphic overlays helped distinguish between well-documented, hypothetical, and speculative aspects of the reconstruction, visually communicating the degree of certainty or supporting evidence for each part.

Hand-drawn reconstructions also served important pedagogical purposes, acting as teaching tools in academic contexts and fostering critical thinking about sources, interpretation, and uncertainty. Moreover, they played a key role in public engagement, making the past more accessible and imaginable through visually rich illustrations, frequently published in books, magazines, and museum displays, that brought historical research to a broader audience.

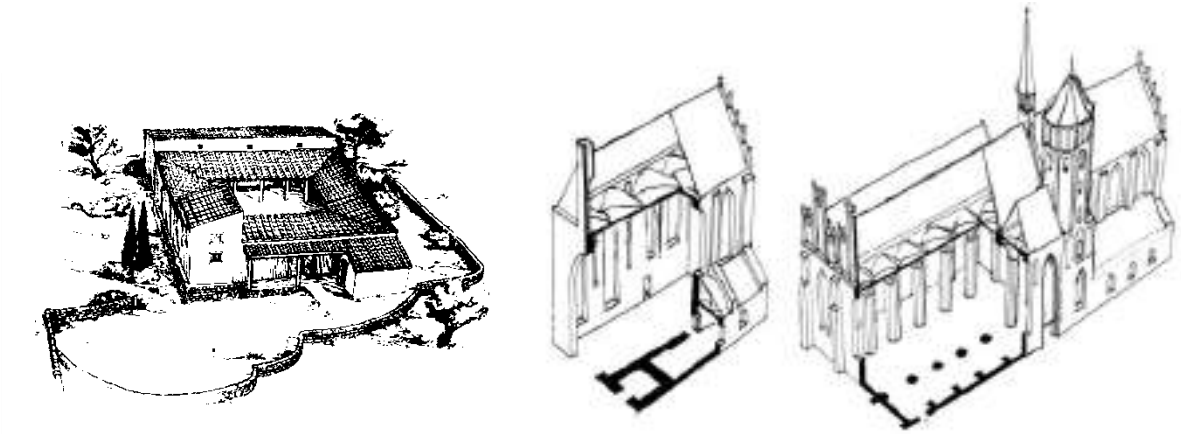


Fig. 115. Left: Drawn Domus Romanus House of Vari, Panels in British Museum, source: author. Right: Drawn reconstruction of Dominican monastery in Gdańsk, by Piotr Samól, (source: Samól 2022[698]).

Fig. 116. Survey and reconstruction of Lago Traiano, *Galleria delle Carte Geografiche* in the Vatican Museums, painted between 1580 and 1585 by Ignazio Danti. Source: author, 2022.

[698] Piotr Samól, *Architektura Kościołów Dominikańskich w Średniowiecznych Prusach* (Gdańsk: Wydawnictwo Słowo/Obraz Terytoria, 2022).

Fig. 117. Colour reconstruction of Gdańsk in late middle ages, 1937 by Otto Kloeppel, (source: Kloeppel 1937[699]).

Physical models

Beyond two-dimensional representations, physical scale models have been essential tools for visualizing and communicating research in architecture and archaeology. Unlike drawings, which are limited to a single viewpoint, three-dimensional models allow viewers to examine reconstructed objects from any angle, greatly enhancing spatial understanding and engagement. These models can represent a wide range of structures including temples, churches, fortifications, and entire urban areas, and are frequently employed to support both academic scholarship and public education.

Constructed from materials such as wood, plaster, resin, metal such as bronze castings, or more recently, 3D-printed plastics, physical models serve multiple purposes. They help visualize and test hypotheses about missing architectural elements or overall site layouts, allowing researchers to update or modify models as new discoveries are made. Physical models are valuable analytical tools for studying proportions, relationships, construction methods, and even the effects of lighting and sight lines in both interiors and exteriors.

Widely displayed in museums, exhibitions, and educational settings, scale models make complex spatial and architectural information accessible to diverse audiences. They are especially helpful for visualizing sites that are ruined, incomplete, or lost, bridging the gap between abstract descriptions and tangible reality. With modern approach those models can be even further explored with form of mapping of visuals onto the model, showing elements, presenting history, and other narratives. Notable examples include the “Plastico di Roma Antica” at the Museum of Roman Civilization[700], which reconstructs the ancient city of Rome at scale, and models of historical churches or archaeological sites used in university teaching.

[699] Otto Kloeppel, Das Stadtbild von Danzig in drei Jahrhunderten seiner großen Geschichte (Danzig: A. W. Kafemann, 1937), plan IV.

[700] Museo della Civiltà Romana, “Plastico di Roma Imperiale,” *Museo della Civiltà Romana*, accessed July 2, 2025, https://www.museociviltaromana.it/it/percorso/plastico-di-roma-imperiale.

In academic programs of architecture, archaeology, and art history, physical models are valuable pedagogical tools, as author with the team researched and presented in scientific paper[701]. They encourage hands-on learning, enhance spatial reasoning, and engage students and visitors through tactile, interactive exploration. Used alongside drawings, photographs, and maps, physical models offer a crucial three-dimensional complement to traditional documentation, fostering both scholarly analysis and public appreciation of historical environments.

Fig. 118. Left: Plastico di Roma imperiale, (source: Plastico Roma Blog[702]). Right: 3D printed Reconstruction of Chorin Kloster. Source: author, 2022.

Fig. 119. Bronze casted model of reconstruction of Malmo and its fortifications in 18th century. Source: author, 2022.

[701] Szymon Kowalski, Piotr Samól, and Jakub Szczepański, "Physical Models in the Education of Architectural History," *World Transactions on Engineering and Technology Education* 20, no. 4 (2022): 251–57.

[702] *Il Plastico di Roma Antica* (detail view). Photograph. Accessed August 20, 2025. https://blogger.googleusercontent.com/img/b/R29vZ2xl/AVvXsEhEwhA-OkhtRhvh4X-1MOz5OyLYz8Zz1Zd8dL3keaTk_aQ5_V02UrXuf9mmc8Dyi-PBum-kEQ_8ciJ6gtu1fs4Kb69fgLduD3TmopS2-AFy0MUQOcx6GgdmByUpcrR5T4v3SSILtCcz6DU/s1140/plastico+roma+rerum1.png.

Fig. 120. Reconstruction models of castle-fortress Hohensalzburg. Left: Wooden model showing state around 17th century. Middle: Digital mapping on physical model. Right: Plaster Reconstruction of Colosseum. Source: author, 2023.

Transparent panels

Photomontages and overlays, especially with the advent of photography, allowed researchers to combine images of current ruins with artistic interpretations of their original appearance. Descriptive texts and literary reconstructions further enriched the public's understanding, offering narrative explanations and hypothetical scenarios where visual evidence was lacking.

Fig. 121. See thru panels in Carnuntum, Austria of Heidenthor, (source: Wikimedia commons[703]).

Other solutions

Based on the author's experience, the supplementation of a translocated ancient Roman mosaic at the archaeological museum in Padova using a video projector presents an interesting example of digital reconstruction, effectively blending physical and digital elements while ensuring that the digital aspects remain clearly distinguishable. Another noteworthy approach to supplementing historical models, rather than constructing full reconstructions, can be seen in the work of Eduardo Tresoldi[704], who uses steel mesh to convey the volume and shape of lost architectural forms over authentic ruins[705]. This technique provides visitors with valuable structural information while clearly indicating that the reconstruction is contemporary. The result is a sculptural work of art that, as the artist describes, represents "absent matter," emphasizing the spiritual presence of architecture without resorting to imitation.

[703] Wikimedia Commons. *Heidentor (Carnuntum)*. Photograph. Accessed August 20, 2025. https://commons.wikimedia.org/wiki/File:Carnuntum_Heidentor2.jpg.

[704] Edoardo Tresoldi, *Official Website*, accessed July 3, 2025, https://www.edoardotresoldi.com/.

[705] Niall Patrick Walsh, "Edoardo Tresoldi's Basilica di Siponto Awarded the Gold Medal for Italian Architecture," *ArchDaily*, October 16, 2018, accessed July 3, 2025, https://www.archdaily.com/903999/edoardo-tresoldis-basilica-di-siponto-awarded-the-gold-medal-for-italian-architecture

Fig. 122. Left: Complementing an antique mosaic using a video projector. Source: author. Right: Eduardo Tresoldi's mesh reconstruction of Basilica di Siponto, (source: Edoardo Tresoldi[706]).

4.1.2. Virtual reconstruction

Virtual Reconstruction as presented in both London Charter[707] and Seville Charter[708] is a method used to visualize historical and architectural research. The following examples will not demonstrate immersive virtuality, but rather present 3D model representations[709]. Virtual reconstruction functions as a critical synthesis tool by integrating architectural, archaeological, and historical research into unified 3D models. These platforms facilitate cross-disciplinary collaboration, enable the testing of competing hypotheses, and provide transparent visualization of uncertainties in heritage studies.

Rome Reborn

Rome Reborn is widely recognized as a pioneering project in the field of digital heritage, demonstrating how digital reconstruction can effectively synthesize diverse strands of research and enhance the visualization of cultural heritage[710]. Initiated in 1996 by Bernard Frischer at UCLA's Cultural Virtual Reality Laboratory, with team, the project's goal was to create a comprehensive 3D model of ancient Rome at its height around 320 CE.

The first fully realized version, Rome Reborn 1.0[711], was unveiled to the public in 2007, following the intensive 3D laser scanning of the "Plastico di Roma Antica," a detailed scale model housed at the

[706] Roberto Conte, *Basilica di Siponto* by Edoardo Tresoldi. Photograph. Accessed August 20, 2025. https://images.adsttc.com/media/images/5bc5/c071/f197/cc17/1200/053c/slideshow/Edoardo_Tresoldi_Basilica_di_Siponto_%C2%A9_Roberto_Conte_4.jpg?1539686502.

[707] *The London Charter for the Computer-based Visualisation of Cultural Heritage*, accessed March 22, 2022, http://www.londoncharter.org.

[708] *The Seville Principles: International Principles of Virtual Archaeology*, adopted at the XVI International Congress of Classical Archaeology, Seville, 2011, https://icomos.es/wp-content/uploads/2020/06/Seville-Principles-IN-ES-FR.pdf

[709] Owing to the technical capabilities of computer graphics, any 3D model can be adapted for immersive virtual visualization.

[710] For this thesis, Rome Reborn is significant because it demonstrates how virtual reconstruction can integrate complex, multidisciplinary knowledge into a coherent and accessible digital form. The project sets a methodological benchmark for digital heritage, validating the approach taken here and highlighting the broader potential of research-driven visualization for both academic inquiry and public interpretation of architectural heritage.

[711] Bernard D. Frischer, Dean Abernathy, Gabriele Guidi, Joel Myers, Cassie Thibodeau, Antonio Salvemini, Pascal Müller, H. Peter Hofstee, and Barry Minor, "Rome Reborn," in *ACM SIGGRAPH 2008 New Tech Demos* (New York: ACM, 2008), https://doi.org/10.1145/1401615.1401649.

Museum of Roman Civilization[712]. This achievement laid the groundwork for further development, with subsequent releases of version 2.0 in 2008[713], version 3.0 in 2018, and most recently, version 4.0 in November 2023, produced in partnership with Flyover Zone and released as "Flight Over Ancient Rome." The project also covered Hadrian's Villa in Tivoli.

Throughout its evolution, Rome Reborn has brought together archaeological, architectural, and historical research into a unified virtual environment encompassing the entire urban landscape of Imperial Rome. Utilizing advanced computer graphics and 3D modelling techniques, the project serves as both an engaging resource for public audiences and a powerful platform for academic research. The virtual city enables scholars to test hypotheses related to urban development, architectural change, and historical context within an interactive setting. For example, Frischer's case studies of the Rostra in the Roman Forum demonstrate how 3D urban models can lead to new discoveries and foster collaborative, interdisciplinary research[714].

Fig. 123. Rome Reborn, (source: Yorescape[715]). Left: Current state. Right: Reconstruction.

Visualizing Venice

The Visualizing Venice initiative explores the use of advanced digital tools to map and model the evolution of Venice across centuries, placing particular emphasis on time as a critical factor and the so-called fourth dimension in heritage visualization. Huffman, Giordano, and Bruzelius[716] document how the project integrates GIS, photogrammetry, archival research, and 3D modelling to create temporal, layered reconstructions that make visible the city's architectural and urban changes over time. While the project is notable for its interdisciplinary collaboration and for demonstrating how the fourth dimension can be visualized, it also highlights the persistent challenges facing digital heritage work. The reliability and interpretive depth of these time-based reconstructions are inevitably constrained by uneven, fragmentary, or ambiguous historical data, which can affect the accuracy of certain

[712] Gabriele Guidi, Bernard Frischer, Michele Russo, Alessandro Spinetti, Luca Carosso, and Laura Loredana Micoli, "Three-Dimensional Acquisition of Large and Detailed Cultural Heritage Objects," *Machine Vision and Applications* 17, no. 6 (2006): 349–360, https://doi.org/10.1007/s00138-006-0029-z.

[713] Karl Dylla, Bernard Frischer, Pascal Müller, Andreas Ulmer, and Simon Haegler, "Rome Reborn 2.0: A Case Study of Virtual City Reconstruction Using Procedural Modeling Techniques," in *Making History Interactive. Computer Applications and Quantitative Methods in Archaeology (CAA)*, Proceedings of the 37th International Conference, Williamsburg, Virginia, March 22–26, 2009, ed. Bernard Frischer, Jane Webb Crawford, and David Koller, BAR International Series S2079 (Oxford: Archaeopress, 2010), 62–66.

[714] Bernard Frischer and David Massey, "3D Urban Models as Tools for Research and Discovery: Two Case Studies of the Rostra in the Roman Forum Utilizing Rome Reborn," in *Critical Archaeology in the Digital Age*, ed. Kevin Garstki (Los Angeles: Cotsen Institute of Archaeology Press, 2022), 23–48.

[715] Flyover Zone. *Yorescape*. Streaming platform for virtual tours of historical ruins. Accessed July 1, 2025. https://yorescape.com.

[716] Kristin L. Huffman, Andrea Giordano, and Caroline Bruzelius, *Visualizing Venice: Mapping and Modeling Time and Change in a City* (London & New York: Routledge, 2017), https://doi.org/10.4324/9781315100685.

modelled periods. Moreover, as Huffman and Giordano[717] point out, there is a critical need to consider how dynamic visualizations of time and change might inadvertently oversimplify complex urban narratives or reinforce selective historical perspectives, especially as such models are increasingly used in public outreach and education. Thus, Visualizing Venice serves both as a leading example of digital humanities in action and as a reminder of the epistemological and ethical complexities that come with visualizing the fourth dimension in urban heritage at scale[718].

Fig. 124. Visualizing Venice, (source: Visualizing Venice[719]). Left: Basilica dei Santi Giovanni e Paolo. Right: Mapping technique.

Digital Karnak

Digital Karnak is a project aimed at creating an interactive 3D reconstruction of the ancient temple complex at Karnak in Luxor, Egypt. As described by Sullivan and Snyder[720], the project combines archaeological findings, historical research, architectural analysis, and GIS data to produce a digital model that represents the temple's development over different historical periods. One of the main objectives is to make the spatial and chronological complexity of the site accessible for both scholarly analysis and educational use. The model enables users to examine the architectural evolution and urban context of Karnak through a temporal interface, making time a central component of the visualization. The project also addresses issues of digital publication and peer review, offering a platform where interpretations, evidence, and uncertainties can be critically evaluated. Sullivan and Snyder discuss the challenges related to integrating incomplete or contradictory sources and highlight the need for transparency regarding the basis and limits of digital reconstructions. Digital Karnak illustrates the potential for 3D models to support research and teaching while also underscoring the ongoing methodological and interpretive challenges in digital heritage projects.

[717] Kristin L. Huffman and Andrea Giordano, "Visualizing Venice to Visualizing Cities – Advanced Technologies for Historical Cities Visualization," in *Communications in Computer and Information Science* (Cham: Springer International Publishing, 2021), 171–87, https://doi.org/10.1007/978-3-030-93186-5_8.

[718] "Visualizing Venice: Projects," Venice International University, accessed July 1, 2025, https://www.univiu.org/vecchio-sito/103-summer-schools/1265-visualizing-venice-projects.

[719] Visualizing Venice. "La potenza di Venezia si è edificata sul mare…" Photograph. Facebook. Accessed July 1, 2025. https://www.facebook.com/307591582656900/photos/pb.100054277190999.-2207520000/307598709322854?type=3.

[720] Elaine A. Sullivan and Lisa M. Snyder, "Digital Karnak: An Experiment in Publication and Peer Review of Interactive, Three-Dimensional Content," *Journal of the Society of Architectural Historians* 76, no. 4 (2017): 464–482, https://doi.org/10.1525/jsah.2017.76.4.464.

Fig. 125. Digital Karnak with current state photographs, (source: Digital Karnak[721]).

4.1.3 Gaming with virtual reconstruction aspect

The entertainment industry, particularly gaming, has long been a major driver of technological innovation[722] due to its global market value. History-inspired titles frequently depict diverse periods and conflicts, with the Second World War[723] being the most prominent theme[724]. Game development studios often recreate aspects of the past by drawing on historical places and events[725], while embedding them in fictionalised narratives that combine authenticity with immersive storytelling[726]. Beyond their entertainment value, games have become powerful tools for historical storytelling and education in both history and architecture. Many museum applications adopt mechanics originally pioneered in the gaming industry, and research on gamification demonstrates that incorporating game-based elements into learning environments can significantly increase engagement and effectiveness[727].

A key distinction between historical simulation games and traditional films lies in the nature of audience engagement. While films can vividly depict historical events, they ultimately offer viewers a passive role limited to observation. In contrast, video games designed to simulate past events invite players to interact with their environment, make decisions, and often assume the roles of historical figures or ordinary participants[728]. This interactivity can foster a more nuanced understanding of historical complexities. When further enhanced with virtual reality (VR) technology, these games provide an even greater sense of presence, enabling users to feel immersed in reconstructed historical

[721] Digital Karnak. University of California, Santa Cruz. Accessed July 1, 2025. https://digitalkarnak.ucsc.edu.

[722] Presented in chapter 3.4 Digital Illusion and Virtual Reality

[723] As an author, I will focus on this period due to my strong scientific interest and the extensive research I have conducted on the architecture and the problem of reconstruction and museology exposition of the former battle site of the Westerplatte in Gdańsk, which will be described in the following chapters.

[724] Given the aim of this work, the study will focus exclusively on games that blend architecture with entertainment while providing significant historical simulations and architectural value.

[725] Many games attempt to recreate key events from the conflict, with Operation Overlord being particularly popular, largely due to the influence of Steven Spielberg's film Saving Private Ryan, and the realistic portrayal of landing on the beaches in Normandy.

[726] Immersion in computer games is not strictly about engaging all the senses but refers to the deep involvement players experience when fully absorbed in a game's world. It is achieved through high-quality graphics, sound design, gameplay mechanics, and a captivating narrative. By fostering a sense of presence and emotional connection, immersion makes games more engaging and memorable, even without the use of VR headsets.

[727] Andrew Martin Wainwright, "Teaching Historical Theory through Video Games," *The History Teacher* 47, no. 4 (2014): 579–612, https://www.jstor.org/stable/43264296.

[728] As commercial, high-budget productions, these types of games are primarily profit-driven. Consequently, they often exaggerate action and excitement, much like action films, in order to enhance entertainment value and boost sales.

settings. This combination of agency and immersion positions games as a unique and potentially powerful medium for historical education and interpretation.

The Normandy beaches provide a striking example of how historical sites are represented in games. Today, the area is preserved as a landscape of remembrance, with museums, memorials, and battlefields such as Pointe du Hoc[729]. *In Call of Duty 2*[730], developers recreated the assault on Pointe du Hoc, offering a dramatized but location-based simulation of the historic event. Although framed primarily for entertainment, this digital depiction allows players to experience preserved sites as a form of interactive "time travel," blending real locations with gameplay[731]. More recent adaptations have presented the Normandy landings in VR, making them one of the few war-themed titles to offer a fully immersive experience[732].

Fig. 126. Pointe du Hoc. Right: Frame from the game Call of Duty 2, (source: Call of Duty 2). Right: Today's view, (source: Google Street View[733]).

One of the most influential examples of architecture-driven historical gaming is Ubisoft's *Assassin's Creed* series. While the overarching narrative is fictional, each title is set in a carefully reconstructed historical context: from the Medieval Crusades and the Italian Renaissance to the American Revolution, Ancient Egypt, and Ancient Greece[734]. The developers strive to integrate their stories into historically informed urban and architectural environments, digitally recreating not only landmarks but entire cities[735]. This approach enables players to explore immersive simulations of past urban life, such as Renaissance Florence with its churches of Santa Maria del Fiore and Santa Maria Novella[736].

[729] Described in chapter 2.

[730] Infinity Ward, Call of Duty 2, PC version (Santa Monica, CA: Activision, 2005), video game.

[731] At sites like Pointe du Hoc, where the impact of war is still visibly present, immersive and action-oriented portrayals risk overshadowing the gravity of conflict and loss. This can diminish both the memorial and educational significance of these locations, leading to the banalization of death and sacrifice when such sites are presented primarily for entertainment.

[732] Medal of Honor: Above and Beyond (2020), See *Medal of Honor: Above and Beyond*, Meta Quest, accessed July 1, 2025, https://www.meta.com/pl-pl/experiences/medal-of-honor-above-and-beyond/3647259232032222

[733] Google Maps. *Street View – Pointe du Hoc*. Latitude 49.3966, Longitude −0.9882. Accessed July 1, 2025. https://goo.gl/maps/mxzNmL3vM3m3o1fA9.

[734] Examples of settings: *Assassin's Creed II* – Florence and Venice during the Renaissance, *Assassin's Creed Origins* – Ancient Egypt during the Ptolemaic period. *Assassin's Creed Unity* – Paris during the French Revolution, *Assassin's Creed Shadows* - *S*engoku Jidai period Japan

[735] The cities depicted in the Assassin's Creed series are based on real locations from the corresponding historical periods; however, they are reduced in scale to facilitate smooth graphics processing and computer calculations. These cities often feature a series of similar buildings, such as tenement houses, which serve as assets to optimise overall game performance.

[736] Lai Ma, *"Video Game as an Immersive Interactive Virtual Interpretation of Historic Heritages, Taking Assassin's Creed as an Example,"* master's thesis, Columbia University, 2021, https://doi.org/10.7916/D8-4VNQ-D355.

Fig. 127. Recreation of churches of Santa Maria del Fiori and Santa Maria Novella in Florence in the game Assassin's Creed II, (source: Assassins Creed fandom webpage[737]).

The Czech production *Kingdom Come: Deliverance*[738] represents a different approach, distinguished by its commitment to authenticity. Set in Bohemia during 1403, at the time of the conflict between King Wenceslas IV and his brother Sigismund, the game reconstructs the architecture, clothing, weaponry, and customs of medieval life. Its environment encompasses castles, monasteries, villages, and towns, all modelled on meticulous research into the landscape and built environment of the period. By drawing directly from the region between Sázava and Rattay, the game produces historically grounded simulations of 15th-century Bohemia, offering players an unusually detailed and reality-based reconstruction of the medieval world.

Fig. 128. Sasau Monastery comparison. Left: photograph real state in 2018. Right: in-game footage depicting the medieval state during the construction of the monastery, (source: steam community[739]).

[737] Assassin's Creed Wiki. *"Assassin's Creed Wiki main page."* Fandom. Accessed July 1, 2025. https://assassinscreed.fandom.com.

[738] *Kingdom Come: Deliverance* (official site), accessed July 1, 2025, https://kcd1.kingdomcomerpg.com/.

[739] SimVU. *Sasau Monastery* (graphic work). Steam Community Workshop. Accessed July 1, 2025. https://steamcommunity.com/sharedfiles/filedetails/?id=1306613309.

Fig. 129. Reconstruction of medieval Kutna Hora, In-game footage, (source: Kingdome Come II webpage[740]).

By contrast, the *Tomb Raider* series demonstrates how games may be inspired by historic architecture without striving for exact reconstruction. Centred on the fictional archaeologist Lara Croft, the franchise situates players in diverse locations such as Angkor Wat, the Egyptian pyramids, Incan cities, etc. These environments blend archaeological motifs with fantasy storytelling, puzzle-solving, and action-adventure mechanics. While not intended as precise reconstructions, the settings nonetheless spark public interest in archaeology and ancient architecture, illustrating how games can act as gateways to cultural heritage even when their narratives are fictional[741].

These examples illustrate how digital games range from highly accurate reconstructions to loosely inspired fictional settings. Their capacity for immersion and interactivity distinguishes them from traditional media, positioning them as a valuable, though sometimes problematic, tool for heritage interpretation. While they can educate and inspire, the dramatization and fictionalisation inherent in gaming also raise questions of historical accuracy and authenticity that must be critically considered in both scholarship and heritage practice.

Another important aspect is their technological impact on immersive visualisation methods, many of which are derived from game-based solutions. Engines such as Unity and Unreal were originally developed for entertainment purposes, but they have been readily adapted for applications in digital heritage, virtual museums, and architectural reconstruction. Their flexibility in rendering, interactivity, and real-time simulation makes them a central foundation for digital heritage visualisation.

4.1.4. Immersive virtual reconstructions

Immersive virtual reality guides are increasingly being adopted in museums and heritage sites to enhance visitor engagement and interpretation. As highlighted by Styliani et al.[742], these technologies enable visitors to interactively explore and learn about cultural heritage within three-dimensional,

[740] Kingdom Come: Deliverance. Official website. Accessed July 19, 2024. https://www.kingdomcomerpg.com.

[741] Tim Winter, "Angkor Meets Tomb Raider: Setting the Scene," *International Journal of Heritage Studies* 8, no. 4 (2002): 323–336, https://doi.org/10.1080/1352725022000037218.

[742] Styliani Sylaiou, Fotis Liarokapis, Kostas Kotsakis, and Petros Patias, "Virtual Museums, a Survey and Some Issues for Consideration," *Journal of Cultural Heritage* 10, no. 4 (2009): 520–528, https://doi.org/10.1016/j.culher.2009.03.003.

immersive environments. Economou[743] their value as interpretive tools, offering interactive experiences that extend beyond conventional modes of presentation

Unlike non-immersive digital reconstructions presented through static images or animations, immersive virtual reality guides present heritage sites in a more engaging and comprehensive way by employing advanced 3D modelling techniques. These technologies can propose reconstructions of missing architectural elements, thereby offering a fuller view of a site and deepening the understanding of its historical and spatial context. By overlaying digital reconstructions onto surviving structures, immersive VR supports more nuanced interpretations of architectural development and cultural significance.

Such applications demonstrate the capacity of immersive VR to deliver dynamic and educational experiences, making complex historical narratives accessible to a wider audience. Given the breadth of existing initiatives, this dissertation will focus on examples in which the author has had direct involvement, as well as those that represent particularly innovative technological solutions.

Palmyra VR

The Palmyra VR project[744] presents a case of immersive virtual reconstruction focused on the ancient Syrian city of Palmyra, a World Heritage Site that suffered extensive damage and destruction during recent conflicts. In this monograph, Silver, Fangi, and Denker document how the project integrates digital photogrammetry, panoramic photography, and historical sources to produce three-dimensional models of Palmyra's monuments, which are then adapted to a virtual reality environment. The project exemplifies a virtual restitution of Palmyra's pre-destruction state, enabling audiences to experience its former architectural and cultural richness. At the same time, it highlights broader debates around authenticity and representation in digital heritage, illustrating both the potential and the challenges of reconstructing sites that have been irreparably damaged.

Fig. 130. Palmyra VR Reconstruction, (source: Staatliche Museen zu Berlin – Museums-Website[745]).

Cluny Abbey

The Benedictine Cluny Abbey, located in Cluny, Burgundy, France, became one of the most influential monastic institutions in medieval Europe[746]. During its most prosperous period, Cluny Abbey was

[743] Maria Economou and Laia Pujol-Tost, "Educational Tool or Expensive Toy? Evaluating VR Evaluation and Its Relevance for Virtual Heritage," in *New Heritage: New Media and Cultural Heritage*, ed. Yehuda E. Kalay, Thomas Kvan, and Janice Affleck (London: Routledge, 2007), 242–260.

[744] Minna Silver, Gabriele Fangi, and Ahmet Denker, *Reviving Palmyra in Multiple Dimensions: Images, Ruins and Cultural Memory* (Caithness, UK: Whittles Publishing, 2018)

[745] "Experience Ancient Palmyra in 360° and in 3D." Staatliche Museen zu Berlin – Museums-Website. Accessed July 1, 2025. https://www.smb.museum/en/whats-new/detail/experience-ancient-palmyra-in-360-and-in-3d/.

[746] Founded in 910 by William I, Duke of Aquitaine

famous for its vast wealth and significant influence on Romanesque architecture[747]. The abbey church, celebrated for its extensive artistic program, was once the largest church building in Christendom[748]. Unfortunately, much of the abbey was destroyed during the French Revolution, with its stones repurposed for local construction. Today, only a small fraction of the original structure survives, including parts of the southern transepts, the lower sections of the front towers, foundations of the main nave, and portions of the exterior walls [749].

Based on the existing remains of Cluny Abbey, researchers from Arts et Métiers at ParisTech launched the project "Digital Rebirth of the Greatest Church of Cluny." By compiling a series of digital inventories, they created a detailed 3D model of the church's current state, which then served as the foundation for a full digital reconstruction of the entire abbey. To make this model accessible to the public, interesting solution with rotatable screens were installed in the surviving section of the church's transept. These interactive screens allow visitors to explore digital visualizations of the missing sections of the church, enabling them to understand the original interior proportions, sculptural decorations, and overall scale of the abbey, all without impacting the authentic remains[750].

Fig. 131. Rotatable Screen with digital reconstruction of the Cluny Abbey before its destruction, (source: Strabic. Cluny-III en 3D[751]).

Chorin Monastery

Since the history and conservation of Chorin Cloister have already been described in the previous chapter, this section will focus solely on the case of virtual reconstruction. To address the challenges posed by the church's partial incompleteness and to enhance the visitor experience, a dedicated

[747] Throughout its history, the abbey saw the construction of three successive churches, with the third and final basilica initiated by Abbot Hugh of Semur and constructed by architect Hézelon de Liège, beginning in 1088. The grand church featured a five-aisled nave, double transepts, and a choir with an ambulatory and radiating chapels. It was noted for its remarkable height and length, barrel vaults, and elaborate sculptural decoration. The richly adorned design of Cluny set a precedent for later Gothic cathedrals and influenced church architecture across Europe.

[748] Retaining this distinction until the rebuilding of St. Peter's Basilica in Rome in the 16th century.

[749] Janet T. Marquardt, *From Martyr to Monument: The Abbey of Cluny as Cultural Patrimony* (Newcastle upon Tyne, UK: Cambridge Scholars Publishing, 2007)

[750] Jérôme Landrieu, Christian Père, Jacques Rollier, Stéphane Castandet, and Grégory Schotte, "Digital Rebirth of the Greatest Church of Cluny Maior Ecclesia: From Optronic Surveys to Real Time Use of the Digital Model," *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XXXVIII-5/W16 (2012): 31–37, https://doi.org/10.5194/isprsarchives-XXXVIII-5-W16-31-2011.

[751] Strabic. *Cluny-III en 3D*. Immersive 3D projection with augmented reality installations at the entrance of the Cluny site. Accessed July 1, 2025. https://strabic.fr/Cluny-III-en-3D.

application guide has been developed[752]. This guide is designed to answer key questions about the monastery complex as a historical monument. Presented as an interactive tool for exploration and time travel, the application is freely available for download from both the Apple and Google app stores.

To fully immerse visitors in the cultural history of the site and provide an experience similar to virtual reality[753], the app offers a virtual tour featuring 360° VR impressions[754]. This feature enables users to explore carefully selected locations within the monastery, transporting them into the past and allowing for vivid comparisons to the period when the Cistercians inhabited the complex, all while navigating today's authentic and preserved architectural environment. In addition to the captivating virtual journey, the application also provides supplementary written information, including detailed descriptions of various architectural elements and historical images, with specific pins on the map. Together, these features enrich visitors' understanding and appreciation of the monastery's rich heritage.

Fig. 132. Comparison of the existing state of Chorin Cloister and its digital reconstruction view via the dedicated smartphone application, with the correction. Source: author.

The case of Chorin also highlights the important issue of presenting unintended errors in 3D reconstructed models, and the responsibility of publication of such. The 3D virtual reconstruction application displays a very unusual interpretation of the vaults in the main nave, as shown in the figures below. The model depicts a form of ribbed vault with lunettes, or perhaps a highly distorted sexpartite vault, which is an extremely complex and atypical solution for Cistercian architecture and particularly unusual for late 13th-century Cistercian Gothic. Furthermore, the side naves are still preserved with

[752] *Kloster Chorin 3D: Monastery Chorin 3D – at the time of the Cistercians*, developed by Menno Egbert Mennenga, for Android (Google Play Store), accessed July 1, 2025, https://play.google.com/store/apps/details?id=com.reunion.klosterchorin.

[753] It is not virtual reality per se; rather, it is closer to augmented reality, although it lacks both the ability to blend the digital and physical worlds and the immersive aspect typical of virtual reality.

[754] *Kloster Chorin*, virtual tour presented by Museum Virtuell GmbH, accessed July 1, 2025, https://visit.museum-virtuell.com/de/tour/chorin.

the characteristic ribbed cross vaults, and plans published in the literature also indicate ribbed cross vaults[755], which are typical of Cistercian architecture.

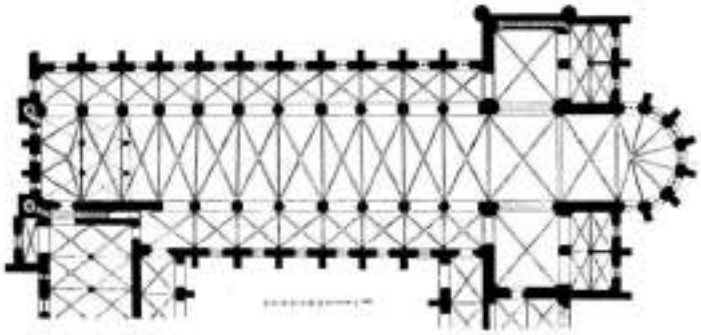


Fig. 133. Chorin Abbey by Georg Dehio and Gustav von Bezold 1901, (source: Dehio and von Bezold[756]).

Ancient Olimpia, Greece

Today the archaeological site of Olympia[757] offers invaluable insights into ancient Greek culture, architecture, and the origins of the Olympic tradition, which has been designated as a UNESCO World Heritage Site[758]. Today's site contains numerous archaeological remains and structures of many culturally important objects such as the Temple of Zeus, which once housed the renowned statue of Zeus sculptured by Phidias. Other reminiscent objects are the Temple of Hera, the Stadium where the Ancient Olympic Games took place, Gymnasion, Palaestra, and many other architectural remains. Olympia is also particularly notable as the birthplace of the ancient Olympic Games, which were first held in 776 BC.

The Project 'Olimpia in Virtual Reality'[759] is centred on the immersive visualization of various architectural structures, such as temples, as they existed thousands of years ago. The self-guided tour accompanied by an audio guide provides engaging and animated narratives about these ancient sites, the project's primary impact stems from its ability to recreate and present these structures in their original location at Ancient Olympia. This augmentation significantly enhances the visitor's experience when exploring the archaeological ruins. Furthermore, it addresses the common limitation of tourists having limited architectural knowledge, typically obtained during their middle to high school education, which often necessitates the use of imagination to fill in the gaps when viewing historical structures, such as the ancient Temple of Zeus in Olympia, thus the use of entertaining techniques such as VR headsets finds its best application[760].

---

[755] Georg Dehio and Gustav Theodor Friedrich von Bezold, *Die Kirchliche Baukunst des Abendlandes* (Stuttgart: Cotta'sche Buchhandlung, 1901), plate 456.

[756] Dehio, Georg, and Gustav von Bezold. *Klosterkirche*. From *Die kirchliche Baukunst des Abendlandes*, plate 455. Stuttgart: Verlag der Cotta'schen Buchhandlung, 1887-1901, *Figure 456 Chorin / Kloster Chorin*

[757] The ancient archaeological site of Olympia, located in the Peloponnese Peninsula in Greece, is a historically very significant site of the Antiquity era. The architectural objects of the Sanctuary of Olympia dates back to multiple Cultural periods such as Archaic, Classical and Hellenistic Grece and Rome, to its final abandonment in 7th century A.D. and rediscover in year 1766.

[758] "Archaeological Site of Olympia," UNESCO World Heritage Centre, accessed July 1, 2025, https://whc.unesco.org/en/list/517/.

[759] Olympia Back In Time. "Self-guided Virtual Reality & Audio Tour at the Archaeological Site of Olympia." Accessed July 1, 2025. https://www.olympiabackintime.com.

[760] Based on the multiple reviews on the TripAdvisor webpage and the simply statistical analysis it is possible to draw conclusions that its very good approach towards and new way of sightseeing of a ruins. 250/266 reviews rated the

Fig. 134. Digital reconstruction of Nymphaion, (source: Olimia Back in Time webpage [761]).

Fig. 135. Left: Remains of Doric Temple of Temple of Zeus at Olympia, source: author. Right : Concept of Virtual Reconstruction Zeus's Temple, (source: Olimia Back in Time webpage [762]).

Fig. 136. Tourist sightseeing the Ancient Olympia with the Virtual Reality goggles. Source: author.

experience as a "excellent", 12/266 rate is "very good", 2/266 as an average, 1/266 as a poor and finally 1/266 rated it as a "terrible".

Most commonly, reviews indicate that people appreciate the project's capability to revive the historical context of athletes and visualize human-scale proportions and reconstructed architecture. Several reviews also highlight the ability to vividly position the statue of Olympian Zeus, one of the ancient Seven Wonders, within its original temple setting, allowing visitors to truly grasp the scale of both the temple and the statue.

[761] Olympia Back In Time. "Self-guided Virtual Reality & Audio Tour at the Archaeological Site of Olympia." Accessed July 1, 2025. https://www.olympiabackintime.com.

[762]Olympia Back In Time. "Self-guided Virtual Reality & Audio Tour at the Archaeological Site of Olympia." Accessed July 1, 2025. https://www.olympiabackintime.com.

4.2. Technological Foundations For Scan Based VR Applications

4.2.1. Survey and inventory methods

Introduction

In heritage documentation and conservation practice, the terms survey and inventory are often used interchangeably. For the purpose of this thesis, however, it is important to distinguish between them for the sake of clarity, according to the Cambridge English Dictionary. To simply in following paragraphs survey will be address as an action while inventory as a deliverable.

Survey refers to the process of collecting and recording data about a built or cultural resource. It may involve field measurements, historical research, and condition assessment, usually undertaken within a defined timeframe[763].

Inventory denotes a structured and ongoing repository or document. It is composed of standardized forms, drawings, reports, and photographs, and serves to archive, manage, and compare heritage resources over time[764].

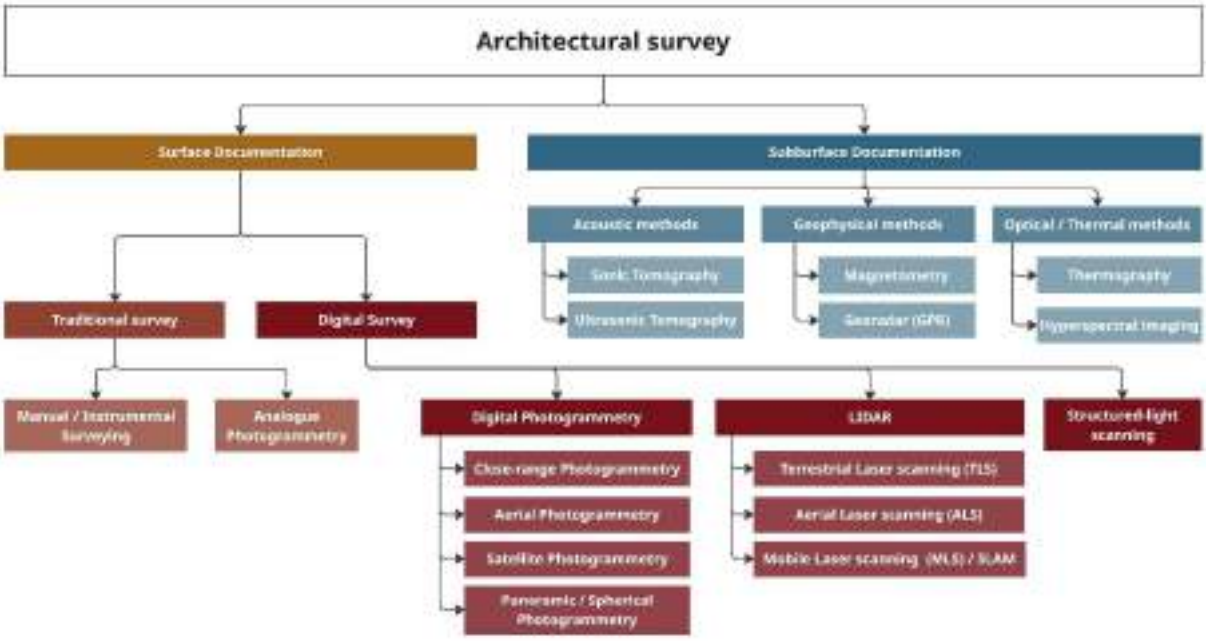


Fig. 137. General typology of architectural survey methods. Source: author.

Architectural survey may be broadly categorised into surface documentation and subsurface documentation, reflecting the dual need to record both visible and concealed aspects of the built fabric[765]. Majority of architectural survey focus on the surface documentation, which seeks to represent the existing state and geometry of a structure. By contrast, subsurface documentation methods are more specialised and are not typically undertaken in every project. They require additional expertise,

[763] "Survey," Cambridge English Dictionary, accessed July 1, 2025, https://dictionary.cambridge.org/us/dictionary/english/survey.

[764] "Inventory," *Cambridge English Dictionary*, accessed July 1, 2025, https://dictionary.cambridge.org/us/dictionary/english/inventory.

[765] In this thesis, not every survey method is applied. Rather, the case studies emphasise the diverse utilisation of inventory databases across different applications, broadening the concept of survey through their direct role in research and by presenting the varied deliverables that emerge from these processes.

equipment, and interpretation, and are usually applied only when structural analysis, archaeological investigation, or material diagnosis is necessary for future architectural or conservation interventions. These methods include acoustic techniques such as sonic or ultrasonic tomography[766], geophysical approaches such as magnetometry and ground-penetrating radar (GPR)[767], as well as optical and thermal tools including thermography and hyperspectral imaging[768]. While subsurface surveys provide highly valuable and complementary insights, revealing hidden structures, stratigraphy, or other information, they are selective rather than routine in the general architectural survey practice.

This form of surface survey underpins most conservation and restoration projects, as it provides measurable records of dimensions, proportions, and spatial configurations essential for both inventory and design work. This form of survey forms the basis for most architectural, conservation or any other project which involves redesign or adaptation of existing structures, as it provides measurable data on dimensions, proportions and spatial configurations, which are essential for both inventory and design work. Surface methods encompass traditional manual and instrumental surveying, later expanded through analogue photogrammetry, and today dominated by digital techniques such as close-range and aerial photogrammetry[769] which produce textured mesh models, terrestrial and mobile LiDAR[770], which produce point clouds or integration of methods[771] in where different datasets can be integrated

[766] Sofía Aparicio Secanellas, Juan Carlos Liébana Gallego, Guillermo Anaya Catalán, Rodrigo Martín Navarro, Javier Ortega Heras, Miguel Ángel García Izquierdo, Margarita González Hernández, and José Javier Anaya Velayos, "An Ultrasonic Tomography System for the Inspection of Columns in Architectural Heritage," *Sensors* 22, no. 17 (2022): article 6646, https://doi.org/10.3390/s22176646; Monika Zielińska and Magdalena Rucka, "Assessment of Wooden Beams from Historical Buildings Using Ultrasonic Transmission Tomography," *International Journal of Architectural Heritage: Conservation, Analysis, and Restoration* 17, no. 1 (2023): 249–261.

[767] Marilena Cozzolino, Elisa Di Giovanni, Paolo Mauriello, Salvatore Piro, and Daniela Zamuner, "Geophysical Methods for Cultural Heritage," in *Geophysical Methods for Cultural Heritage Management* (Cham: Springer International Publishing, 2018), 9–66, https://doi.org/10.1007/978-3-319-74790-3_3.

[768] Antonio Costanzo, Mario Minasi, Giuseppe Casula, Massimo Musacchio, and Maria Fabrizia Buongiorno, "Combined Use of Terrestrial Laser Scanning and IR Thermography Applied to a Historical Building," *Sensors* 15, no. 1 (2015): 194–213, https://doi.org/10.3390/s150100194.

[769] Hüseyin Murat Yilmaz, Mustafa Yakar, S. Ali Güleç, and Orhan Nuri Dülgerler, "Importance of Digital Close-Range Photogrammetry in Documentation of Cultural Heritage," *Journal of Cultural Heritage* 8, no. 4 (2007): 428–433, https://doi.org/10.1016/j.culher.2007.07.004; Paolo Salonia, Serena Scolastico, Andrea Pozzi, Andrea Marcolongo, and Tommaso Leti Messina, "Multi-Scale Cultural Heritage Survey: Quick Digital Photogrammetric Systems," *Journal of Cultural Heritage* 10, Supplement 1 (2009): e59–e64, https://doi.org/10.1016/j.culher.2009.09.004; Kaitlyn Kingsland, "Comparative Analysis of Digital Photogrammetry Software for Cultural Heritage," *Digital Applications in Archaeology and Cultural Heritage* 18 (2020): e00157, https://doi.org/10.1016/j.daach.2020.e00157.

[770] Nicola Lercari, "Terrestrial Laser Scanning in the Age of Sensing," in *Digital Methods and Remote Sensing in Archaeology*, ed. Maurizio Forte and Stefano Campana (Cham: Springer International Publishing, 2016), 3–33; Douglas Pritchard, Joerg Sperner, Sophie Hoepner, and Ruth Tenschert, "Terrestrial Laser Scanning for Heritage Conservation: The Cologne Cathedral Documentation Project," *ISPRS Annals of Photogrammetry, Remote Sensing and Spatial Information Sciences* IV-2/W2 (2017): 213–220, https://doi.org/10.5194/isprs-annals-IV-2-W2-213-2017; Nicola Lercari, "Monitoring Earthen Archaeological Heritage Using Multi-Temporal Terrestrial Laser Scanning and Surface Change Detection," *Journal of Cultural Heritage* 39 (2019): 152–165, https://doi.org/10.1016/j.culher.2019.04.005; Luis Mateus, José Fernández, Vasco Ferreira, Clara Oliveira, João Aguiar, Ana S. Gago, Pedro Pacheco, and José Pernão, "Terrestrial Laser Scanning and Digital Photogrammetry for Heritage Conservation: Case Study of the Historical Walls of Lagos, Portugal," *ISPRS International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XLII-2/W11 (2019): 843–847, https://doi.org/10.5194/isprs-archives-XLII-2-W11-843-2019; Junshan Liu, Salman Azhar, Danielle Willkens, and Botao Li, "Static Terrestrial Laser Scanning (TLS) for Heritage Building Information Modeling (HBIM): A Systematic Review," *Virtual Worlds* 2, no. 2 (2023): 90–114, https://doi.org/10.3390/virtualworlds2020006; Junshan Liu, Danielle Willkens, and Russell Gentry, "Developing a Practice-Based Guide to Terrestrial Laser Scanning (TLS) for Heritage Documentation," *Heritage* 8, no. 8 (2025): 313, https://doi.org/10.3390/heritage8080313.

[771]Alberto Guarnieri, Nicola Milan, and Antonio Vettore, "Monitoring of Complex Structure for Structural Control Using Terrestrial Laser Scanning (TLS) and Photogrammetry," *International Journal of Architectural Heritage* 7, no. 1 (2013): 54–67; Yahya Alshawabkeh, Mohammad El-Khalili, Eyad Almasri, Fadi Bala'awi, and Amaal Al-Massarweh, "Heritage Documentation Using Laser Scanner and Photogrammetry: The Case Study of Qasr Al-Abidit, Jordan," *Digital Applications in Archaeology and Cultural Heritage* 16 (2020): e00133, https://doi.org/10.1016/j.daach.2019.e00133; Elisabetta Doria, Silvia La Placa, and

for better outcome. These approaches enable highly precise measurement and three-dimensional modelling of architectural structures, ensuring both accuracy and reproducibility.

The workflow of heritage documentation does not end with the production of an form of inventory, but extends it into the multiple ways in which these datasets can be utilized. Inventories increasingly function not as static archives but as dynamic frameworks for analysis, interpretation, and application. In conservation projects, inventories in form of drawing representing the current state provide the foundation for condition assessment, damage mapping, ongoing monitoring, and the planning of architectural interventions, ensuring that decision-making is based on measurable and reproducible basis. In academic research, inventories serve as comparative datasets that enable the study of architectural typologies, structural transformations, and material histories across time, while also facilitating historical changes analyses of urban fabric[772].

At the same time, inventories have become central to digital workflows. Data derived from surveys can be transformed into CAD drawings, various types of 3D models[773], or integrated into Building Information Models (BIM) and Heritage Building Information Models (HBIM). In these environments, spatial, descriptive, and historical information is consolidated, allowing for the management of complex datasets and their connection to semantic and archival sources. HBIM in particular has emerged as a powerful tool for conservation, enabling the integration of diagnostic data, structural analysis, and material studies within a single parametric framework that supports both conservation and future management strategies[774].

Jolanta Sroczynska, "Digital Methodologies for Architectural Heritage Preservation: Integrating Photogrammetry, Mobile Laser Scanning, and Immersive Technologies," *Rivista Tema* 11, no. 2 (2025);

[772] Stefano Campana and Fabio Remondino, eds., *3D Recording and Modelling in Archaeology and Cultural Heritage: Theory and Best Practices*, BAR International Series S2598 (Oxford: BAR Publishing, 2016), 7–26.

[773] David Koller, Bernard Frischer, and Greg Humphreys, "Research Challenges for Digital Archives of 3D Cultural Heritage Models," *Journal on Computing and Cultural Heritage* 2, no. 3 (2009): 1–17, https://doi.org/10.1145/1658346.1658347.

[774] Maurice Murphy, Eugene McGovern, and Sara Pavia, "Historic Building Information Modelling (HBIM)," *Structural Survey* 27, no. 4 (2009): 311–327, https://doi.org/10.1108/02630800910985108; Conor Dore, Maurice Murphy, Serena McCarthy, Fiona Brechin, Clare Casidy, and Evelien Dirix, "Structural Simulations and Conservation Analysis – Historic Building Information Model (HBIM)," *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XL-5/W4 (2015): 351–357, https://doi.org/10.5194/isprsarchives-XL-5-W4-351-2015; Nazarena Bruno and Riccardo Roncella, "HBIM for Conservation: A New Proposal for Information Modeling," *Remote Sensing* 11, no. 15 (2019): 1751, https://doi.org/10.3390/rs11151751; Xiucheng Yang, Pierre Grussenmeyer, Mathieu Koehl, Hélène Macher, Arnadi Murtiyoso, and Tania Landes, "Review of Built Heritage Modelling: Integration of HBIM and Other Information Techniques," *Journal of Cultural Heritage* 46 (2020): 350–360, https://doi.org/10.1016/j.culher.2020.05.008; Andrea Lumini, "The Integrated Digital Survey of the Florence Air Warfare School. HBIM-Based Protocols for Documentation and Information Management," *DISEGNARECON* 16, no. 30 (2023): 1–15, https://doi.org/10.20365/disegnarecon.30.2023.11.

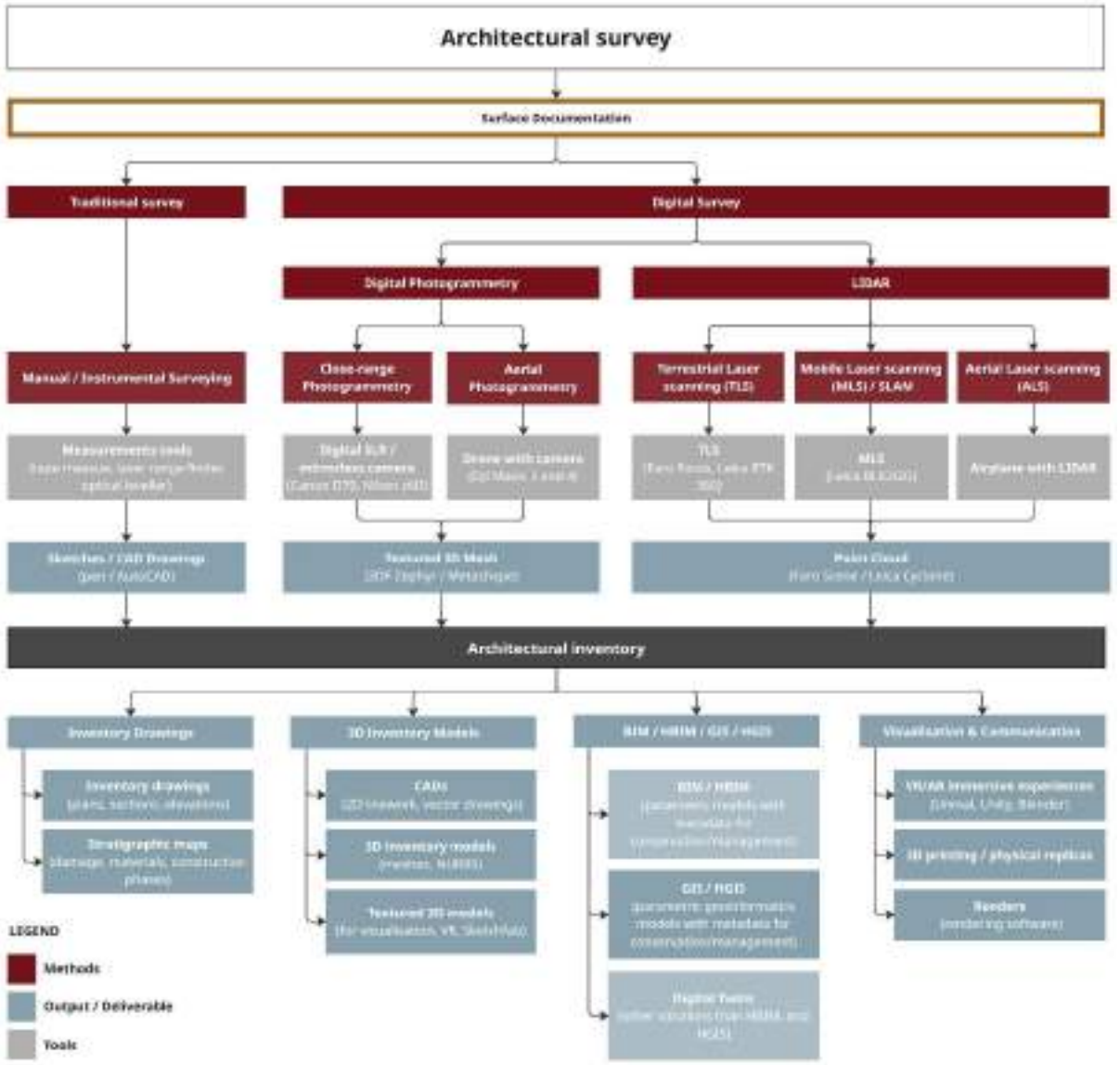


Fig. 138. Practical methods and tools for surface documentation in architectural heritage. Source: author.

Within this thesis, attention is therefore directed to three methods that are most commonly employed in the survey of the researched objects: traditional inventory, photogrammetry, and LiDAR scanning. These approaches are presented in detail, as they remain the standard means of generating reliable and versatile inventories, whether in analogue or digital form, and serve as the essential basis for subsequent applications in research, conservation, and digital reconstruction.

Traditional inventory

The methodology of traditional architectural inventory, deeply rooted in geodesy, descriptive geometry, and drawing techniques, and relying on conventional measuring methods, was for a long time the fundamental approach to producing architectural survey drawings. It was applied to objects in various conditions, from heritage ruins to post-construction inventories, with the aim of documenting the structure. This work relied on tools such as tape measures, optical levellers, and theodolites, later complemented by digital devices including laser range finders, laser levels, and other surveying equipment, to accurately record dimensions, layouts, and architectural elements.

Traditional inventories also followed established conventions of architectural and building drawing, including standardised scales, notations, and line work, which ensured clarity and comparability across surveys[775], particularly in the heritage field[776]. While labour-intensive and time-consuming, the process of manual measurement and drawing fostered close observation and interpretive engagement with the building, producing records that were not only descriptive but also analytical.

For centuries, the act of drawing by hand was inseparable from the practice of inventory. Beyond its technical function, manual drawing required acute observation, analytical judgment, and interpretive skill. Surveyors and architects translated measured data into plans, sections, and elevations, applying conventions of line weight, shading, and symbolic notation to convey both technical precision and architectural character. As a result, hand drawings carried a cognitive and interpretive value that extended beyond measurement, serving simultaneously as record and analysis of architectural heritage.

The late twentieth century introduced a decisive transformation with the adoption of computer-aided design (CAD). Initially developed for engineering and industrial purposes[777], CAD systems quickly became indispensable in architectural documentation, reduced the manual labour of redrawing and facilitated the management of complex projects, offering precision, speed, and the ability to easily edit or reproduce drawings with unprecedented efficiency, translating direct observation into a digital environment.

Today, both approaches coexist. Hand drawing remains essential in the early stages of fieldwork, especially for sketching and annotating observations on site, while CAD provides the platform for producing standardised, reproducible, and sharable digital survey drawings. The interplay between hand methods and CAD reflects the broader shift in architectural documentation, where traditional observational skills are preserved as a foundation even as digital technologies expand the possibilities of representation and analysis.

Within the framework of traditional inventory, high-quality photographic documentation plays a crucial role. Photographs[778] provide a visual record of a structure from multiple perspectives, capturing architectural details that may not be fully conveyed through measured drawings and preserving aspects of materiality, texture, and setting that are essential to a building's character. They also function as comparative evidence, enabling the assessment of condition over time and supporting the detection of deterioration, damage, or alterations. Beyond their immediate technical utility, photographs possess historical value: they fix a particular moment in the life of a monument, offering future researchers insight into its physical state and cultural context. In combination with precise measurements, photographic records contribute to a comprehensive and trustworthy inventory, forming an indispensable foundation for the documentation and conservation of architectural heritage. At the same time, it must be acknowledged that photographic evidence is not entirely objective, as choices

[775] Elżbieta Miśniakiewicz and Wojciech Skowroński, *Rysunek techniczny budowlany* (Warsaw: Arkady, 2013).

[776]Brykowska, Maria. 2003. Metody pomiarów i badań zabytków architektury. Warszawa: Oficyna Wydawnicza Politechniki Warszawskiej; Maciej Prarat and Ulrich Schaaf, "Inwentaryzacja Pomiarowo-Rysunkowa Zabytków Architektury Drewnianej w Procesie Konserwatorskim – Problemy i Propozycja Standaryzacji," *Budownictwo i Architektura* 14, no. 4 (2015): 99–110.

[777] As noted in the previous chapter, Ivan Sutherland was instrumental in introducing and developing the principles of object-oriented programming, graphical manipulation, and the use of constraints in digital design. His 1963 program Sketchpad is widely regarded as the precursor to modern computer-aided design (CAD) systems, which remain fundamental tools in contemporary architectural practice. Building on this innovation, the concept evolved into the development of wireframe three-dimensional graphics, enabling the integration of perspective into digital drawings and laying the groundwork for subsequent advances in computer graphics and architectural visualization.

[778] Both historical analog and digital.

of framing, lighting, and perspective can influence interpretation; this underlines the importance of integrating photographs with other survey methods to achieve a balanced and reliable record[779].

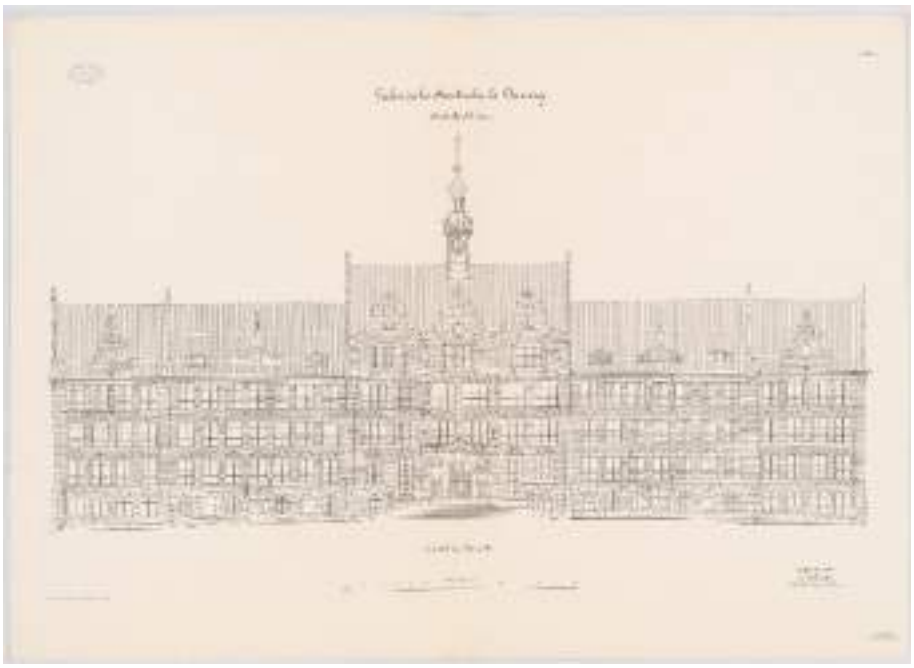


Fig. 139. Post-construction inventory drawing of Main Building of Gdańsk University of technology 1904 Author: Albert Carsten with the team, (source: Architekturmuseum der Technischen Universität Berlin[780]).

While contemporary technologies such as photogrammetry and laser scanning, discussed in the following sections, have greatly expanded the possibilities of capturing complex geometries and large-scale sites, traditional inventory remains an essential skill. It provides a fundamental benchmark for architectural practice and a reference against which digital surveys are calibrated, even as these newer methods build upon its foundations to deliver more precise and versatile digital inventories.

Photogrammetry

Photogrammetry is a method of deriving metric information from overlapping photographs, originally developed as an analogue technique but today almost entirely digital. By applying principles of projective geometry, it reconstructs three-dimensional geometry from two-dimensional image correspondences, enabling the creation of highly detailed 3D models from standard photographs.

Photogrammetry is widely applied in cultural heritage, where it supports condition assessment, damage mapping, and monitoring. It is equally valuable for producing inventories of small artefacts, documenting complex architectural elements, or modelling entire urban districts. Its versatility, relatively low cost, and high level of detail have made it one of the most popular methods in contemporary survey practice, complementing and often integrated with both traditional inventories and LiDAR scanning.

[779] Even when advanced software such as AutoCAD, BIM, or HBIM is employed, the underlying measurement methodology remains unchanged; what differs is the final product, whether a hand drawing, a CAD printout, or a digital model.

[780] Architekturmuseum der Technischen Universität Berlin. *Sammlungssuche: Kontakt POS=74*. Accessed July 1, 2025. https://architekturmuseum.ub.tu-berlin.de/index.php?p=79&POS=74.

Fig. 140. Digital Camera, Nikon Z6II + Nikon Nikkor Z 24-200 mm f/4-6.3, used in the photogrammetry process. Source: author.

Fig. 141. Drones (DJI Mavic 3, DJI Mavic Mini 3, DJI Phantom 4) in use for aerial photogrammetry. Source: author.

Traditional photogrammetry relied on aerial and ground-level photographs to measure the dimensions, contours, and spatial coordinates of objects, particularly in disciplines such as geodetic surveying. As a geometric reconstruction technique, it applies the principles of projective geometry to determine three-dimensional positions from two-dimensional image correspondences.[781]. With the development of specialised software[782], photogrammetry has evolved into a fully digital process that automatically transforms sets of photographs into 3D models. This evolution has been reinforced by technological advances such as drones and high-resolution cameras, which have expanded its scope and made it more accessible across a wide range of applications, including heritage.

[781] A key feature of traditional photogrammetry was stereoscopy, in which paired images taken from different viewpoints were viewed through stereoscopes or mirrors to create a three-dimensional effect. The associated phenomenon of parallax, where objects appear displaced between the two images according to their distance, provided the basis for calculating depth and spatial coordinates.

[782] The most widely used photogrammetry software for architectural applications includes Metashape, 3DF Zephyr, and RealityCapture.

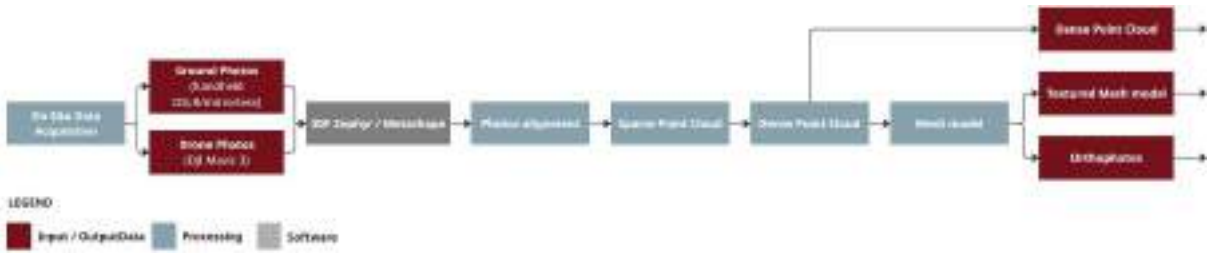


Fig. 142. Photogrammetry methodological workflow. Source: author.

The photogrammetric workflow begins with on-site data acquisition, typically using ground photographs taken with a handheld DSLR or mirrorless camera. When available, these can be complemented by aerial imagery captured by a drone equipped with a camera, although this is not a requirement. The collected datasets are imported into photogrammetry software such as 3DF Zephyr, where the images are processed through a sequence of steps. To achieve accurate 3D reconstruction from 2D images, photogrammetry software requires knowledge of internal camera parameters such as focal length, lens distortion, and the principal point. This calibration is typically performed using reference images or known patterns and ensures that 2D image points can be reliably converted into 3D coordinates. Many modern cameras, however, automatically embed calibration data in the metadata of captured photographs. First, photo alignment establishes camera positions and orientations, producing a sparse point cloud. Feature detection facilitates the establishment of correspondences between the images, enabling the software to discern the relationships between the objects depicted in each image. This process generates an extensive network of key points and their interconnections. This is then densified to generate a dense point cloud, which represents the geometry of the surveyed object in detail. From this stage, a mesh model can be created by triangulating[783] the point cloud into vertices, edges, and faces, representing the continuous surface of the object. The mesh can be subsequently enhanced by texture mapping, where cut-outs from the original photographs are projected onto the geometry to create a photorealistic surface, producing a textured mesh model. Optionally, orthophotos can be generated through orthographic projection, for example, building elevations, providing outputs for precise documentation[784].

Because photogrammetry does not inherently include real-world scale[785], reference measurements or scale bars are required to establish a 1:1 relationship, making it necessary to incorporate some traditional inventory methods for distance control. Once scaled, the model can be further refined through post-processing, including decimation, hole filling, smoothing, and other filtering procedures. The resulting outputs vary according to project needs and can be exported in standard formats for use in CAD, NURBS, BIM/HBIM environments, as well as in 3D modelling, 3D printing, virtual and augmented reality, or immersive visualisations.

[783] Triangulation is the process of joining points into small triangular surfaces. These connected surfaces create a continuous 3D model that represents the shape of the object. There are different methods of creation of mesh surfaces but the most popular is Delaunay triangulation.

[784] Through orthographic projection, orthophotos are generated without perspective distortion, enabling precise two-dimensional representations of elevations or façades to be derived from the 3D model. Based on the textured mesh model, it is possible to create high-resolution elevation views which, in the author's experience, can capture details as fine as the mortar joints between individual bricks.

[785] Drones and certain cameras are equipped with built-in GPS modules that embed spatial information into the metadata of each photograph, enabling the geodetic position of every image to be referenced. While this data can approximate a 1:1 scale, it should always be verified with critical measurements to ensure precise documentation.

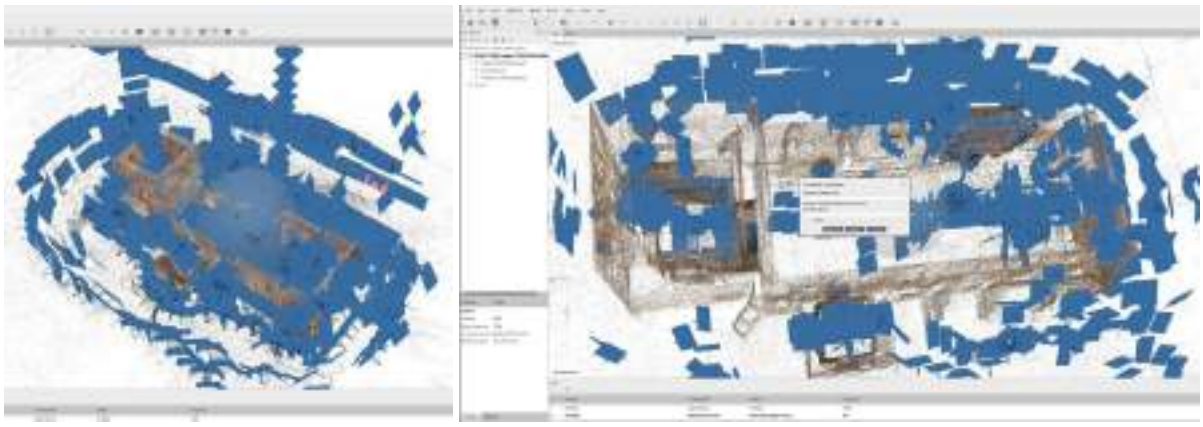


Fig. 143. Architectural scale photogrammetry: combined ground and aerial photogrammetry of the church in Steblewo processed in Metashape software. Source: author[786].

Fig. 144. Architectural scale photogrammetry: textured 3D mesh model of the church ruins in Steblewo. Source: author[787].

Photogrammetry has become one of the most widely used methods in heritage documentation, valued above all for its versatility, accessibility, and ability to produce detailed three-dimensional models from standard photographic imagery. Modern digital workflows enable the reconstruction of highly accurate geometry when sufficient image overlap, resolution, and calibration data are provided, making photogrammetry suitable for applications ranging from small artefacts to architectural complexes and even entire urban areas captured by drones. This scalability, combined with relatively low equipment and software costs, makes photogrammetry an indispensable tool for conservation practice. In heritage contexts, it is particularly valuable for producing inventories, condition assessments, and visual records, while also generating datasets that can support monitoring and analysis over time.

In terms of accuracy, photogrammetry can achieve results ranging from centimetre- to millimetre-level precision under optimal conditions. Its main strength lies in scalability: the same principles can be applied to document objects at vastly different scales, from small artefacts to entire cities with the aid of drones. However, this flexibility also makes photogrammetry more dependent on environmental conditions such as lighting, texture, and vegetation coverage, which can limit completeness and consistency of the data.

[786] In Corporation with: Katarzyna Kierszejna, Barbara Niedziela, Dominika Ochocińska.

[787] DALABPG *Ruiny kościoła w Steblewie (Church ruins)*. 3D model, by Szymon Kowalski; Barbara Niedziela; Dominika Ochoćińska and Katarzyna Kiersztejna. Sketchfab. Accessed June 12 2024, https://sketchfab.com/3d-models/ruiny-koscioa-w-steblewie-church-ruins-7c141e3e8faa46509ec4767a1550aaa6

Despite its advantages, photogrammetry has inherent limitations. Unlike laser scanning, it does not directly measure geometry but reconstructs it through projective analysis. Surfaces that are reflective, transparent, or lacking in texture are difficult to capture reliably, and scaling always requires external control points or reference measurements. Urban-scale projects can also be computationally demanding, often requiring the processing of thousands of images. Nevertheless, one of the greatest strengths of photogrammetry remains its ability to combine geometric reconstruction with photorealistic texture, producing datasets that are both metrically useful and visually compelling. This makes it one of the most effective methods for integrated heritage surveys, often used in combination with TLS to balance precision with visual richness.

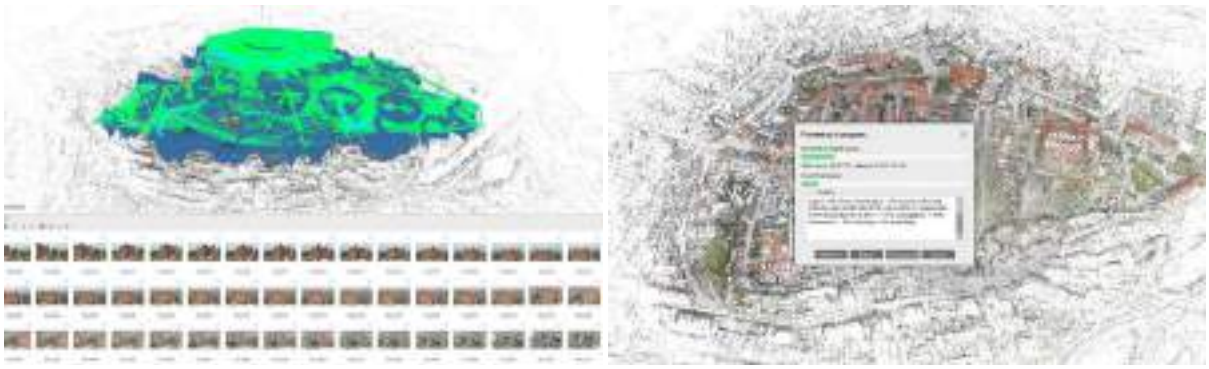


Fig. 145. Urban scale photogrammetry: processing of the historical city centre of Gniew using aerial imagery in Metashape software. Author: Source: author in cooperation with Paulina Bone.

Fig. 146. Urban scale photogrammetry: Comparison of untextured mesh with textured mesh of historical city centre of Gniew in Metashape software. Source: author in cooperation with Paulina Bone[788].

Laser scanning

Laser scanning is a method of three-dimensional data acquisition that directly measures spatial geometry by recording distances between the scanner and surrounding objects. Unlike photogrammetry, which reconstructs geometry from overlapping images, laser scanning captures it directly by emitting laser pulses that strike surfaces and reflect back to the device. By calculating the

[788] DALABPG, *Medieval city of Gniew, Poland*, 3D model, by Szymon Kowalski and Paulina Bone, Sketchfab, published March 9, 2024; accessed June 12 2024, https://sketchfab.com/3d-models/medieval-city-of-gniew-poland-4051ac2b603144009091db18d66a41fe

travel time of each pulse, the scanner determines the exact distance to the object. Repeated millions of times, this process produces a dense set of measurements that together form a 3D point cloud, in which each point corresponds to a position on the surface of the scanned object. Many modern scanners are also equipped with integrated cameras to capture panoramic imagery, which can later be mapped onto the point cloud to add realistic colour information.

Fig. 147. Terrestrial laser scanners: Leica RTC 360 and Faro Focus 70. Source: author.

Fig. 148. Mobile laser scanners. Source: author.

Laser scanning has become a widely used technique across multiple disciplines, including geodesy, architecture, heritage preservation, civil engineering, archaeology, and industrial applications. Depending on the device, the method can be implemented in several forms: terrestrial laser scanning (TLS) with tripod-mounted scanners, mobile or SLAM-based scanning (MLS) for walk-through data acquisition, and aerial laser scanning (ALS) mounted on drones or aircraft for large-scale topographic mapping. Its main output is a point cloud dataset of exceptionally high precision, offering a reliable representation of complex structures, landscapes, or entire urban areas. The method is particularly

valuable in documenting irregular or inaccessible sites such as historical ruins, dense vegetation, mountainous terrain, or dense urban fabric, where traditional methods may be impractical.

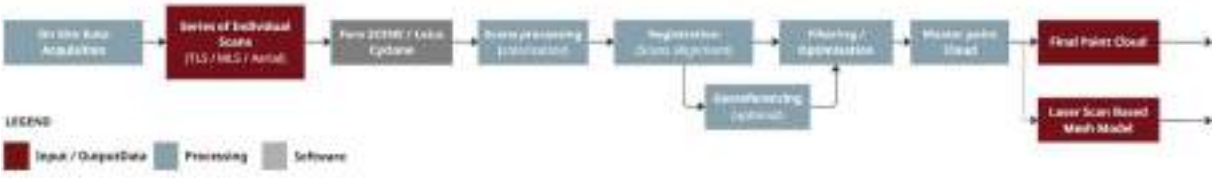


Fig. 149. Terrestrial and mobile laser scanning methodological workflow. Source: author.

The laser scanning process begins with on-site data acquisition, during which the scanner captures a series of individual scans from different positions. These scans are imported into specialised software such as Faro Scene or Leica Cyclone[789], where they are recalculated and processed. At this stage, panoramic images recorded by the scanner's integrated cameras are applied to the initially monochrome point clouds to provide realistic colour, a step known as scan colorisation.

The next phase is registration, where the individual scans are aligned by identifying overlapping areas and shared reference points. Registration may be carried out automatically when sufficient overlap is present, manually by selecting planes or points, or visually by interactively aligning scans within the software. Once aligned, the scans are merged into a master point cloud, which is then refined through filtering and optimisation to remove noise, correct measurement errors, and improve accuracy. If required, the dataset can also be georeferenced, linking the project to a global coordinate system. From this stage, two primary deliverables can be produced: a final point cloud, representing the surveyed object or site with high precision, and a laser-scan-based mesh model, generated by triangulating the point data into continuous surfaces.

Fig. 150. Registration of clusters. Source: author.

Laser scanning, particularly TLS, has become a standard tool in heritage documentation, valued above all for its exceptional accuracy and reliability in recording highly complex geometries. Modern scanners are capable of millimetre-level precision across ranges of tens to hundreds of metres, depending on the model, which makes TLS indispensable for condition assessment, structural monitoring, and the creation of detailed conservation records. This accuracy ensures that even subtle deformations or surface irregularities can be detected, making TLS one of the most trusted methods for generating baseline datasets in conservation practice. With regard to scale, TLS is most effective for documenting individual buildings or sites. When a large number of scans are acquired and carefully registered,

[789] Usually dependant on the manufacturer of the Scanner.

however, the method can also be extended to cover entire urban areas. Increasingly, TLS data is integrated with mobile laser scanning (MLS) or aerial LiDAR, enabling more comprehensive documentation that combines high-precision detail with broader spatial context.

Fig. 151. *The Golden Gate* in Gdańsk. Left: laser scan orthophoto; centre: laser scan orthophoto with adjusted opacity; right: synthesised inventory drawing derived from the digital survey. Source: author, drawing by Zofia Piwońska.

At the same time, the method has practical limitations: scanners and software are costly, datasets are extremely large and require powerful hardware, and the registration process can be time-consuming when many scans are involved. TLS is also subject to occlusion, as it records only what is directly visible from each station, which necessitates multiple setups to ensure complete coverage of complex geometries. The effective distance of laser scanning is dependent on the specific model of scanner, which influences its suitability for documenting either small-scale architectural details or larger structures. Scanning reflective, translucent, or very dark surfaces may result in incomplete data, and large-scale projects generate datasets of considerable size that require careful management. The method is also relatively time-intensive compared to photogrammetry, particularly when multiple stations are required. Nevertheless, one of its greatest strengths remains the reproducibility of highly accurate TLS datasets, which makes them invaluable for long-term monitoring of changes such as deformations, erosion, or structural cracks.

TLS outputs are increasingly integrated into HBIM environments, where precise point clouds form the geometric foundation for heritage models. In practice, laser scanning is often combined with photogrammetry, uniting geometric accuracy with the visual realism of image-based modelling. This approach reflects the principle of the integrated survey, in which different documentation methods are strategically applied to complement one another. Compared to photogrammetry, TLS delivers higher automation and precision, though at greater cost, and is therefore regarded as an essential complementary method in the survey of heritage architecture. This integrated survey approach, increasingly promoted in international conservation practice, can be applied across scales from single artefacts to urban landscapes, and also underpins the methodology of the case studies presented in this thesis.

Fig. 152. Urban-scale laser scan of the Dominican Quarter in Tallinn. Source: author.

4.2.2. Immersive visualization methods.

Immersive visualization methods represent the technological spectrum through which digital reconstructions can be experienced. They range from simple, low-cost systems that democratise access, through consumer-level devices offering detailed interaction, to advanced laboratory installations enabling collaborative immersion[790]. This continuum reflects both the diversity of available technologies and their varied applications, spanning public outreach, levels of immersion, and modes of perception.

Google Cardboard

Google Cardboard, introduced by Google in 2014, exemplifies the entry-level approach to virtual reality. It is constructed from cardboard cutouts and plastic spherical lenses, reflecting a minimalist design and a clear DIY ethos. The device can be assembled by the user, often with simple Velcro straps to secure it to the head. Its core functionality relies on personal smartphones, which serve as both the display and processing unit, thereby significantly reducing costs. By optimising existing smartphone capabilities, Google Cardboard minimises the need for specialised and expensive hardware while still enabling immersive experiences.

Through dedicated applications or plugins, the smartphone display is split into two stereoscopic fields. Combined with built-in gyroscopes and accelerometers, this configuration allows the view to respond dynamically to the user's head movements. As a result, Google Cardboard generates the illusion of depth and tracks head orientation in real time, producing an interactive though simplified immersive experience. Although its fidelity and level of interaction are limited, its affordability makes it a valuable

[790] Beyond Cardboard, HMDs, CAVEs, and emulation methods, immersive visualization also includes other approaches. Panoramic and 360° viewers provide non-interactive immersion through static or video-based environments, often used in exhibitions or online dissemination. Augmented and mixed reality headsets such as Microsoft HoloLens or Magic Leap extend the experience into physical space, while projection-based installations including domes and panoramic screens are increasingly employed in museums and cultural venues. These methods, however, fall outside the scope of this thesis.

tool for public dissemination and an accessible entry point to virtual reconstructions for wide audiences.

Fig. 153. VR phone holder with spherical lenses, made of plywood and based on the original Google Cardboard design. Designed by Szymon Kowalski and cut on a CNC machine[791]. Source: author.

VR Goggle (HMD)

At the next level, head-mounted displays (HMDs)[792], or virtual reality (VR) goggles such as Oculus Quest, HTC Vive, or Sony PlayStation VR, provide a significantly higher degree of immersion. These devices are designed to replace the perception of physical reality with a fully computer-generated environment, employing stereoscopic optics, high-resolution displays, and integrated motion-tracking sensors. Each unit is equipped with a pair of spherical lenses, one for each eye, which project stereoscopic images and create a convincing three-dimensional depth effect. In addition, most devices incorporate an array of sensors including gyroscopes, accelerometers, and often cameras for positional tracking, enabling the system to monitor head movement and orientation in real time. Many also feature spatial audio, further enhancing realism. Hand controllers extend interaction by translating gestures into virtual actions, providing a more tactile and intuitive means of engagement within the simulated space. HMDs are available both as tethered models, connected to a powerful computer, and as standalone units with built-in processing capacity. By combining these features, HMDs produce a strong sense of presence and embodied navigation, though their use can be limited by cost, physical discomfort, or simulator sickness. For heritage applications, however, they represent a versatile balance between accessibility and precision, allowing visualization to be explored with high fidelity and interactivity.

[791] I would like to express my sincere gratitude to Dominik Sędzicki for direct help with topic and cutting out the elements on CNC mill machine.
[792] With historical context described in chapter 3.

Fig. 154. Virtual Reality Goggles (Head Mounted Display) model Oculus Quest 2 by Meta. Source: author.

Cave

The Cave Automatic Virtual Environment (CAVE), first developed at the University of Illinois in 1992[793] and conceptually linked to Plato's allegory of the cave, represents the most advanced form of immersive visualization. Unlike head-mounted displays or smartphone-based systems, the CAVE projects stereoscopic images directly onto the walls, floor, and ceiling of a dedicated room, allowing multiple participants to share the same virtual environment simultaneously. This collective dimension makes it especially valuable for collaborative analysis, interdisciplinary research, and conservation discussions.

The Immersive 3D Visualization Laboratory at Gdańsk University of Technology[794], directed by Professor Jacek Lebiedź at the Faculty of Electronics, Telecommunications and Informatics, provides a unique case study as the only facility in Poland and among the few in Europe to host CAVE installations at three different scales. The Mini CAVE employs rimless computer monitors arranged around the user's head to simulate an enclosed field of view for individual exploration. The Midi CAVE, approximately two by one by one metres, accommodates one active user or several observers, supported by motion-tracking

[793] With historical context described in chapter 3.

[794] "Immersive 3D Visualization Lab," *Faculty of Electronics, Telecommunications and Informatics, Gdańsk University of Technology*, accessed July 1, 2025, https://eti.pg.edu.pl/lzwp/o-laboratorium.

systems. The Big CAVE, by contrast, is a full-scale installation of about three by three by three metres, capable of hosting multiple users simultaneously. Here, synchronised high-resolution projectors illuminate translucent walls, floors, and ceilings, delivering a shared and deeply immersive experience, though one that requires substantial computational resources and infrastructure.

Fig. 155. Big cave. Source: author.

The immersive effect of the Big CAVE is achieved through high-performance computing with multi-core processors and advanced graphics cards, which collectively drive twelve projectors (two per wall). Participants wear stereoscopic 3D glasses to ensure proper image alignment, while specialised tracking glasses equipped with markers allow the system's cameras to monitor head movements in real time. A sixth wall on a rail system can be closed to fully enclose the users within the virtual space. The environments themselves are generated through advanced software, with game engines such as Unity and Unreal Engine enabling the integration of 3D models, visual effects, and audio to create convincing reconstructions.

Miniaturised versions of the CAVE concept also exist, replicating its key principles on a smaller scale. These use stereoscopic displays and 3D glasses to create a depth effect within compact enclosures, ranging from systems that surround the whole body to more focused head-level configurations. Their adaptability demonstrates the flexibility of the CAVE principle across different technical and spatial constraints.

Fig. 156. Left: Mini CAVE. Right: Midi CAVE. Source: author.

Taken together, the CAVE systems at Gdańsk highlight the adaptability and scientific value of this technology, spanning applications from engineering and medical simulation to cultural heritage research. Compared to head-mounted displays and smartphone-based systems, CAVEs offer the

distinct advantage of enabling group immersion, fostering shared interpretation and collaborative evaluation. In the context of heritage conservation, this makes them particularly powerful as platforms where experts, stakeholders, and the public can collectively experience and discuss digital reconstructions.

Immersive emulation workflow

Regardless of the device employed, the pathway from a 3D model to an immersive environment follows a broadly similar structure (see Fig. X). First, a digital model is generated through methods such as CAD design, BIM workflows, photogrammetry, or laser scanning. These datasets form the Digital Inventory and are represented in the chart as Photogrammetry Mesh Models, Point Clouds, and 3D Models. They are then prepared for real-time use, which typically involves optimising geometry, textures, and lighting to ensure smooth performance and adapting the level of detail to the target platform's computing capacity. In the case of large point clouds or highly detailed scans, this often requires decimation or data reduction to balance file size and visual fidelity. The optimised model is exported in standard formats such as FBX, glTF, or OBJ and subsequently imported into a rendering platform capable of interactive output.

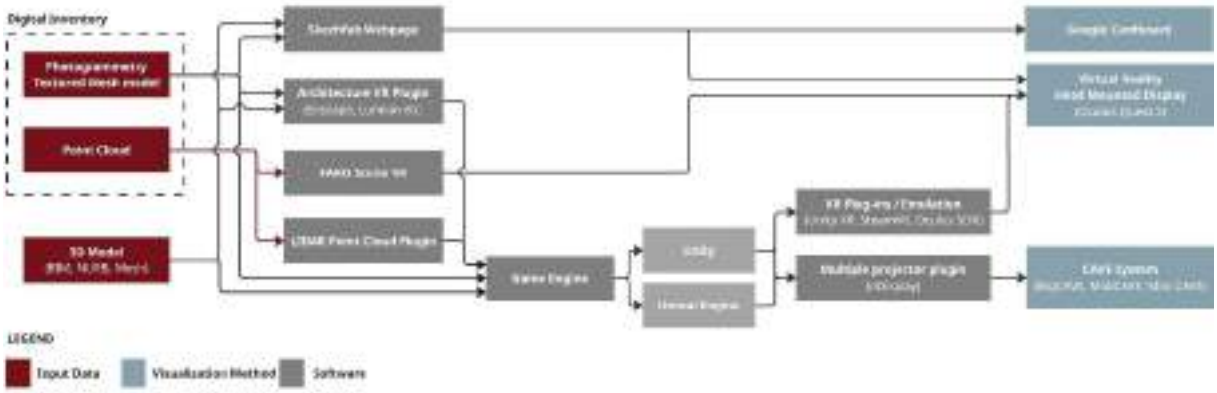


Fig. 157. Visualization Workflow: Transforming 3D Models into Immersive Environments. Source: author.

Depending on the application, this step may be carried out in game engines such as Unity or Unreal, in architectural plugins like Enscape or Lumion, or in online viewers such as Sketchfab. In the diagram, these are grouped under Game Engine or VR Plugins/Platforms. Once in these environments, the model can be enriched with materials, lighting effects, and interactive elements, balancing graphical realism with the real-time rendering demands of the target system.

From here, the pipeline diverges according to the output device. For smartphone-based viewers such as Google Cardboard, the platform generates a stereoscopic split-screen image that synchronises with the phone's built-in sensors. For head-mounted displays (Oculus Quest 2), dedicated GPUs render stereoscopic images at high frame rates, often enhanced with ray tracing and spatial audio, while controllers extend embodied interaction. For CAVE systems (BigCAVE, MidiCAVE, MiniCAVE), the rendering software distributes synchronised images across multiple projectors, which, in combination with head-tracking glasses, create a shared immersive environment supported by multi-core processors and GPU clusters.

Thus, while the input data may originate from the same survey or modelling workflow, the processing and rendering pipeline must be adapted to the technical requirements and limitations of each immersive system. Crucially, these adaptations must also preserve the integrity and authenticity of the underlying dataset, ensuring that optimisation does not distort essential historical or architectural

information. This demonstrates that immersive visualization is not a single technology but a chain of transformations, where the same 3D model can be translated into multiple modes of experience depending on both the audience and the required level of fidelity.

4.3. Summary Of The Chapter

Both digital reconstructions and virtual reality applications in heritage are not mere technological curiosities but methodological instruments that open new possibilities for interpretation. They allow the presentation of former states or specific moments in time, while applications such as hypothetical reconstructions, immersive guides, and heritage-oriented gaming demonstrate how virtual reconstructions can engage diverse audiences, offer alternative narratives, and simulate architectural transformations without altering the physical remains. Such uses address conservation dilemmas by providing non-invasive and reversible reconstructions that preserve the authenticity of surviving fragments while leaving space for multiple hypotheses.

The reliability of these visualizations depends on the quality of the underlying inventory, strengthened by new digital survey methods including photogrammetry and laser scanning. Immersive visualization platforms, from low-cost headsets to advanced CAVE systems, provide the means of experiencing reconstructions, though their effectiveness varies with fidelity, accessibility, and audience. Taken together, these approaches confirm that digital reconstruction is not an autonomous act but one that must be grounded in historical research, architectural analysis, survey, and critical reflection to maintain scholarly credibility and conservation value.

At the same time, the potential of VR must be weighed against its limitations. Hardware and software evolve rapidly, raising concerns about sustainability and long-term access, while digital inventories with complex datasets still lack stable archival standards. Yet despite these challenges, VR offers distinct advantages over material reconstruction: it is non-invasive and reversible, supports the coexistence of multiple hypotheses, and enhances transparency by making uncertainties and intermediate states visible. Above all, it fosters embodied understanding of architectural space and should be understood as a critical complement to conservation practice, an immaterial reconstruction medium that respects authenticity while expanding interpretive possibilities. The following chapter demonstrates how these principles can be applied in practice through case studies at the interior, object, and urban scale.

CHAPTER 5

IMMERSIVE VIRTUAL RECONSTRUCTIONS IN ARCHITECTURAL HERITAGE: CASE STUDIES AND APPLICATIONS

VIRTUAL REALITY TECHNOLOGY IN ARCHITECTURAL HERITAGE AND ITS IMPACT ON CONSERVATION

5. Immersive Virtual Reconstructions in Architectural Heritage: Case Studies and Applications

5.1. Introduction

This chapter constitutes the central part of the dissertation, presenting case studies that demonstrate the application of immersive virtual reconstructions to architectural heritage. Building on the methodological framework outlined in previous chapters—including traditional survey techniques, digital documentation, and the principles codified in the London Charter (2009) and Seville Principles (2011)—this section translates theory into practice. Each case study shows how advanced recording methods such as laser scanning, photogrammetry, and drone-based surveys, when combined with immersive visualisation platforms, enable reconstructions that are rigorous, transparent, and accessible.

The focus extends beyond the production of accurate three-dimensional models to explore their evolution into interactive environments capable of simulating lost architectural states, testing hypotheses, and engaging diverse audiences. Situated within historical and conservation contexts, the reconstructions address key debates on authenticity, reversibility, and the role of digital media in heritage practice. To this end, the chapter introduces the author's methodological solutions, which combine digital inventory with historical and architectural research to support the creation of valid immersive reconstructions.

To fully address the research objectives, a virtual reality application was developed for each case study, employing a range of tools and display methods to visualise architectural change over time. Each case study is presented according to a consistent structure: introduction, review of state of knowledge and historical background, historical research findings, methods of digitalisation, 3D modelling processes, and finally the implementation of virtual reality for simulation. This structure, refined over the course of the research, ensures that each component cumulatively contributes to the final immersive reconstruction. The following subsections apply this framework to three distinct scales of intervention: the architectural interior, the individual structure, and the urban context.

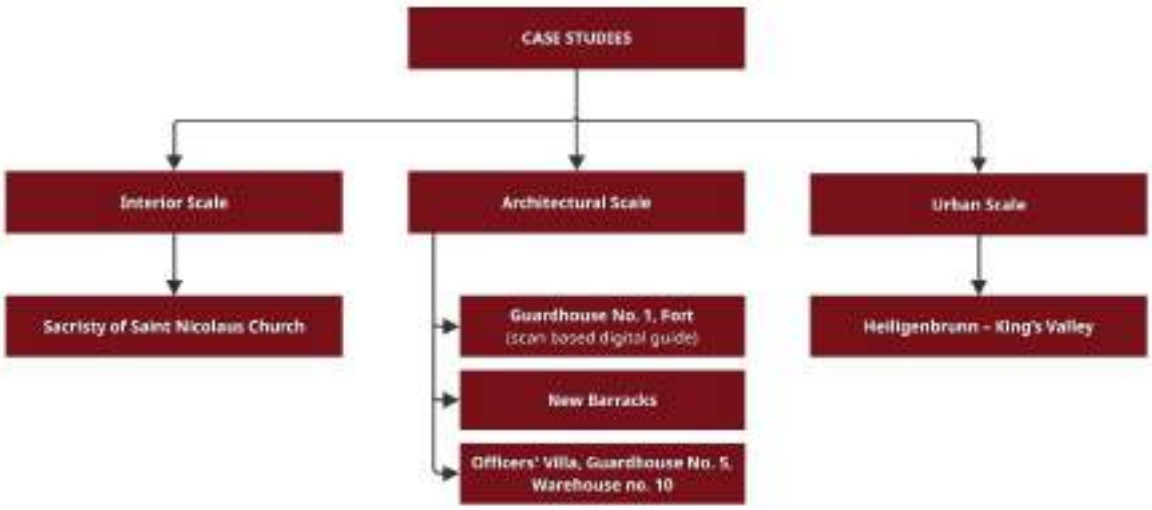


Fig. 158. Overview of Case Studies. Source: author.

Methodological Framework

The research also aims to present the author's methodological solutions that combine digital inventory and historical research to support the creation of valid immersive virtual reconstructions. All research objects have been digitised using a variety of techniques described in Chapter IV. The chosen methods were selected and applied according to the complexity and scale of each object, with the intention of demonstrating adaptable and replicable workflows for future applications.

Simultaneously, each object has been analysed from architectural, historical, and conservation perspectives to identify patterns of transformation. This multi-layered approach facilitates conclusions regarding the use of virtual reality in heritage contexts. In particular, the thesis aims to demonstrate the potential of virtual reality as an immaterial tool for immersive simulation of architectural reconstructions of historic buildings, especially in cases where no clear heritage protection policy exists. In such instances, virtual reconstructions may offer a possible mediation solution for engaging with contested or incomplete heritage. These findings are intended to contribute both to the broader academic discourse and to practical strategies for heritage interpretation and virtual reconstruction. It also demonstrates that immersive reconstruction is not an isolated act of modelling but a critical methodology that bridges documentation, interpretation, and simulation.

The methodological approach employed in the following case studies is structured around the integration of digital survey techniques, historical and architectural analysis, and immersive visualisation technologies. The workflow proceeds from data acquisition, through modelling and simulation, to immersive reconstruction, with iterative feedback loops at each stage.

Fig. 159. General methodological scheme. Source: author.

Digital Inventory: The objects of study were documented using terrestrial laser scanning or photogrammetry or and drone-based surveys. These methods, described in detail in Chapter IV, were selected according to the complexity and scale of each site.

Historical and Architectural Research: Architectural Investigations, Archival studies, iconographic materials, and earlier scholarly investigations provided the interpretive framework for reconstruction.

3D Modelling: The collected datasets were synthesised into geometric models that integrated both empirical measurement and interpretive hypotheses.

Immersive Simulation: Models were implemented in virtual reality environments, employing both head-mounted displays (HMDs) and CAVE systems, in order to provide interactive, embodied experiences.

Virtual Reconstruction: The final stage combined empirical data and interpretive modelling into immersive reconstructions that visualise architectural change over time and enable comparative hypotheses to be tested.

Relation to Previous Research

The methodology presented here builds upon earlier projects and publications undertaken by the author within the framework of international collaborations[795]. These works provided the critical groundwork for the systematic approach developed in this dissertation and yielded valuable methodological insights, particularly concerning the integration of survey data with immersive platforms. Some of these insights have already been tested and partially published, while others laid the foundations for the systematic framework further advanced and applied in the case studies presented here.

	Year	Bibliographic Note	Focus
1	**2020**	Szymon Kowalski, Piotr Samól, Jakub Szczepański, and Witold Dłubakowski, "Teaching Architectural History through Virtual Reality," World Transactions on Engineering and Technology Education 18, no. 2 (2020): 297–302.	Use of virtual models in didactics
2	**2020**	Szymon Kowalski, Piotr Samól, and Jakub Szczepański, "Virtual Reality Tools in Teaching the Conservation and History of Polish Architecture," World Transactions on Engineering and Technology Education 18, no. 4 (2020): 393–398.	Use of virtual models in didactics
3	**2022**	Szymon Kowalski, Piotr Samól, and Jakub Szczepański, "Physical Models in the Education of Architectural History," World Transactions on Engineering and Technology Education 20, no. 4 (2022): 251–257.	Role of physical models in architectural history education, as a basic research to confront findings with the digital approach.
4	**2023**	Wojciech Samól, Szymon Kowalski, Arkadiusz Woźniakowski, and Piotr Samól, "Where the Second World War in Europe Broke Out: The Landscape History of Westerplatte, Gdańsk/Danzig," Land 12, no. 3 (2023): 596.	Landscape history evolution of Westerplatte, cartographical and historical research.
5	**2023**	Szymon Kowalski, Silvia La Placa, and Alberto Pettineo, "From Archives Sources to Virtual 3D Reconstruction of Military Heritage – The Case Study of Port Battery, Gdańsk," The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences XLVIII-M-2-2023 (2023): 885–893.	Implementation of integrated digital survey and immersive virtual reconstruction
6	**2024**	Szymon Kowalski, Jacek Lebiedź, Sandro Parrinello, and Francesca Picchio, "New Skills for Architects: 3D Scanning for an Immersive Experience in Architectural Education," Global Journal of Engineering Education 26, no. 2 (2024): 115–121.	Extension of skills dedicated for the architects in digital era

[795] Szymon Kowalski, Piotr Samól, Jakub Szczepański, and Witold Dłubakowski, "Teaching Architectural History through Virtual Reality," *World Transactions on Engineering and Technology Education* 18, no. 2 (2020): 297–302.

Szymon Kowalski, Piotr Samól, and Robert Hirsch, "Virtual Reality Tools in Teaching the Conservation and History of Polish Architecture," *World Transactions on Engineering and Technology Education* 18, no. 4 (2020): 399–404.

Szymon Kowalski, Piotr Samól, and Jakub Szczepański, "Physical Models in the Education of Architectural History," *World Transactions on Engineering and Technology Education* 20, no. 4 (2022): 251–57.

Wojciech Samól, Szymon Kowalski, Arkadiusz Woźniakowski, and Piotr Samól, "Where the Second World War in Europe Broke Out: The Landscape History of Westerplatte, Gdańsk/Danzig," *Land* 12, no. 3 (2023): 596, https://doi.org/10.3390/land12030596.

Szymon Kowalski, Silvia La Placa, and Alberto Pettineo, "From Archives Sources to Virtual 3D Reconstruction of Military Heritage – The Case Study of Port Battery, Gdańsk," *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XLVIII-M-2-2023 (2023): 885–893, https://doi.org/10.5194/isprs-archives-XLVIII-M-2-2023-885-2023.

Szymon Kowalski, Jacek Lebiedź, Sandro Parrinello, and Francesca Picchio, "New Skills for Architects: 3D Scanning for an Immersive Experience in Architectural Education," *Global Journal of Engineering Education* 26, no. 2 (2024): 115–121.

Szymon Kowalski and Wojciech Samól, "Architektura oraz historia tzw. nowych koszar na Westerplatte w latach 1933–2023," *Przegląd Historyczno-Wojskowy* 25, no. 2 (2024): 92–138, https://doi.org/10.32089/WBH.PHW.

7	**2024**	Szymon Kowalski and Wojciech Samól, “Architektura oraz historia tzw. nowych koszar na Westerplatte w latach 1933–2023,” Przegląd Historyczno-Wojskowy 25, no. 2 (2024): 92–138.	Architectural investigations and historical research.
8	**(forthcoming)**	Silvia La Placa, Andrea Bongini, Szymon Kowalski, and Jakub Szczepański, *The Canal System, Stone Sluice, Locks and Defence: Gdańsk Urban Fortifications. Report of Achieved Research Experiences for the Development of the H2020 Prometheus Project* (Pavia: Pavia University Press, forthcoming).	Implementation of integrated digital survey and immersive virtual reconstruction
9	**(forthcoming)**	Szymon Kowalski Silvia La Placa, Elisabetta Doria, Jacek Lebiedź and Piotr Samól, *Immersive Virtual Reconstruction of Sacristy …*	Implementation of integrated digital survey and diachronic immersive virtual reconstruction

Fig. 160. Summary table on publications related to the research. Source: author.

One such important study was the article “From Archive Sources to Virtual 3D Reconstruction of Military Heritage: The Case Study of Port Battery, Gdańsk”[796], which drew upon the architectural findings of Robert Hirsch and Arkadiusz Woźniakowski. In this project, the author contributed by transforming archival and survey data into scan-based immersive virtual reconstruction. Conducted as part of the international research grant PROMETHEUS Protocols for Information Model Libraries Tested on Upper Kama Heritage[797], the study demonstrated the feasibility of simulating ruined military architecture without physical reconstruction, offering a non-invasive alternative for heritage engagement.

Fig. 161. Virtual reconstruction in immersive environment. Source: author.

Another significant project, also conducted under the PROMETHEUS grant, resulted in the publication “The Canal System, Stone Sluice, Locks and Defence”[798]. This study explored the application of virtual reality in the context of architectural adaptation proposals. Using laser scanning and BIM-oriented software, the research developed potential design scenarios for the adaptive reuse of a ruined watermill. The integration of BIM with immersive VR reflected the growing potential of Heritage Building Information Modelling (H-BIM) to support conservation decisions[799]. The outcomes were

[796] Szymon Kowalski, Silvia La Placa, and Alberto Pettineo, “From Archives Sources to Virtual 3D Reconstruction of Military Heritage – The Case Study of Port Battery, Gdańsk,” *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XLVIII-M-2-2023 (2023): 885–893, https://doi.org/10.5194/isprs-archives-XLVIII-M-2-2023-885-2023.

[797] Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant. PROMETHEUS Informative 3D systems. (N° 821870). Funded by: European Union, Horizon 2020 research and innovation programme, EXCELLENT SCIENCE - Marie Skłodowska-Curie Actions. Total Budget: 391 000 Euro

[798] Silvia La Placa, Andrea Bongini, Szymon Kowalski, and Jakub Szczepański, *The Canal System, Stone Sluice, Locks and Defence: Gdańsk Urban Fortifications. Report of Achieved Research Experiences for the Development of the H2020 Prometheus Project* (Pavia: Pavia University Press, forthcoming).

[799] The author recognises the significant potential of virtual reality for future applications, including architectural adaptations and other forms of intervention. Nevertheless, as the primary aim of this dissertation is the digital reconstruction of the past, such uses are addressed only briefly, serving mainly to illustrate the phenomenon and to reflect

presented during Gdańsk DigiWeek 2023 and later published in collaboration with Silvia La Placa and Andrea Bongini, who contributed design visualisations of the proposed restoration.

Fig. 162. Adaptive reuse concept design. Visualisations of exterior and interior of adapted watermill showing the potential conceptual design using BIM software with TLS laser scan integration. Source: Silvia La Placa, Andrea Bongini and author.

5.2. Interior Scale - Saint Nicolaus Church in Gdańsk.

5.2.1 Introduction

The first case study of this extensive research, which the author intends to present in this doctoral dissertation, focuses on Saint Nicholas Church in Gdańsk. This object was chosen due to the author's involvement in research led by one of his supervisors, Piotr Samól in 2019[800]. The results of an emergency architectural investigation, prompted by the structural failure of one of the pillars, provided the foundation for a comprehensive case study. This study examined the concept of an immersive virtual reconstruction of the interior space, specifically the Gothic sacristy of Saint Nicholas Church in Gdańsk.

This case will focus solely on the sacristy, due to the author’s direct involvement in its architectural investigations, while the rest of the structure has been researched extensively by other authors[801]. It will also showcase the development and advancements of the author’s measurement methods, progressing from traditional techniques to photogrammetry and, ultimately, laser scanning[802]. The

the author’s practical experience with these approaches. The simulation of architectural interventions in heritage objects will be explored in a subsequent publication. While Building Information Modelling (BIM) can be applied to virtual reconstruction, it was deliberately not adopted in this study, as BIM is primarily geared toward project delivery and offers limited flexibility for highly detailed 3D modelling.

[800] As a recent master's graduate in architecture, the author was invited to assist in research conducted by Piotr Samól in 2019.

[801] Most recently by: Piotr Samól, *Architektura kościołów dominikańskich w średniowiecznych Prusach* (Gdańsk: Wydawnictwo Słowo/Obraz Terytoria, 2022); Ewa Łużyniecka, *Kościół Dominikanów w Gdańsku: Architektura i jej przeobrażenia* (Wrocław: Oficyna Wydawnicza Politechniki Wrocławskiej, 2022).

[802] This progression was directly influenced by the resources available to the author. Initially, the work began with modest equipment, consisting of a set of tape measures and a rangefinder. As the author delved deeper into the research topic, he explored more precise measurement methods, eventually transitioning to digital techniques. This led to the purchase of a Canon 70D camera, which has successfully served the author to this day.

The technological limitations of photogrammetry and software also posed challenges, which were gradually addressed as the author gained knowledge and proficiency in these methods. The laser scanning process itself unfolded in two stages.

work on the sacristy perfectly illustrates the author's ongoing development in the field of digitalisation and the full implementation of various measurement methods and the definition of their strengths and weaknesses.

The topic of the Dominican monastery in Gdańsk and immersive virtual reconstructions will be addressed extensively within the framework of the research grant *PRELUDIUM 22*, "Technologia wirtualnej rzeczywistości w dziedzictwie architektonicznym i jej wpływ na podejście do konserwacji zabytków" (*Virtual Reality Technology in Architectural Heritage and Its Impact on Approaches to Monument Conservation*), awarded by the National Science Centre (Narodowe Centrum Nauki, NCN) under agreement no. UMO-2023/49/N/HS2/03520, with a total budget of 189,000 PLN[803].

The Dominican Order's St. Nicholas Church in Gdańsk, a medieval structure with a history spanning over 800 years, stands as a significant architectural and cultural landmark. Remarkably, it is one of the few buildings in Gdańsk to have survived World War II largely intact, preserving its interior with a very high level of authenticity due to its well-preserved original substance. This substance is particularly valuable, as it reflects not only the church's various construction phases but also the dismantling of the friary and the preservation efforts initiated in the 19th century by Prussian authorities and continued after the Second World War by Poles in the 20th century[804].

The first stage was made possible through the generosity of scientific colleagues from the University of Pavia, Silvia La Placa and Elisabetta Doria, whom the author would like to thank here. They conducted a scan of the sacristy interior using a TLS Leica RTC 360 scanner.

The culmination of the author's efforts over a five-year period was the acquisition of a Faro Focus 70 laser scanner, made possible through the CUPRUM project, led by Prof. Jakub Szczepański, the supervisor of this dissertation.

[803] "Technologia wirtualnej rzeczywistości w dziedzictwie architektonicznym i jej wpływ na konserwację zabytków," *Most Wiedzy – Gdańsk University of Technology*, accessed July 1, 2025, https://mostwiedzy.pl/pl/project/technologia-wirtualnej-rzeczywistosci-w-dziedzictwie-architektonicznym-i-jej-wplyw-na-podejscie-do-k,1206-1.

[804] The Dominican Order settled in Gdańsk in 1227, when a small Romanesque church was donated to them, likely rebuilt after being damaged during a Prussian raid. The Dominicans expanded eastwards, incorporating the Romanesque structure into the monastery, which was probably destroyed in 1308 during the Teutonic siege. According to Piotr Samól, the present Gothic church was not built directly on the earlier foundations. Its first phase, begun in 1344, comprised the presbytery, sacristy, and a short tower with oratory, completed by the mid-fifteenth century. The second phase added a three-aisled nave, internal buttresses, a bell tower (ca. 1400), and, by 1500, vaults, a western gable, and a slender tower above the chancel arch.

The monastery and church remained under Dominican care and Catholic confession during the Reformation, while most Gdańsk churches turned Lutheran. In 1813, during the Napoleonic siege, the monastery was heavily damaged. Under Prussian rule, the Dominicans were dissolved (1835), and the monastery was demolished, replaced by a municipal market hall in 1896. Remarkably, the church itself escaped serious destruction during World War II, and in 1945 the Dominicans returned to resume care of the building.

See Piotr Samól, *Architektura kościołów dominikańskich w średniowiecznych Prusach* (Gdańsk: Wydawnictwo Słowo/Obraz Terytoria, 2022), 165, 184–185.

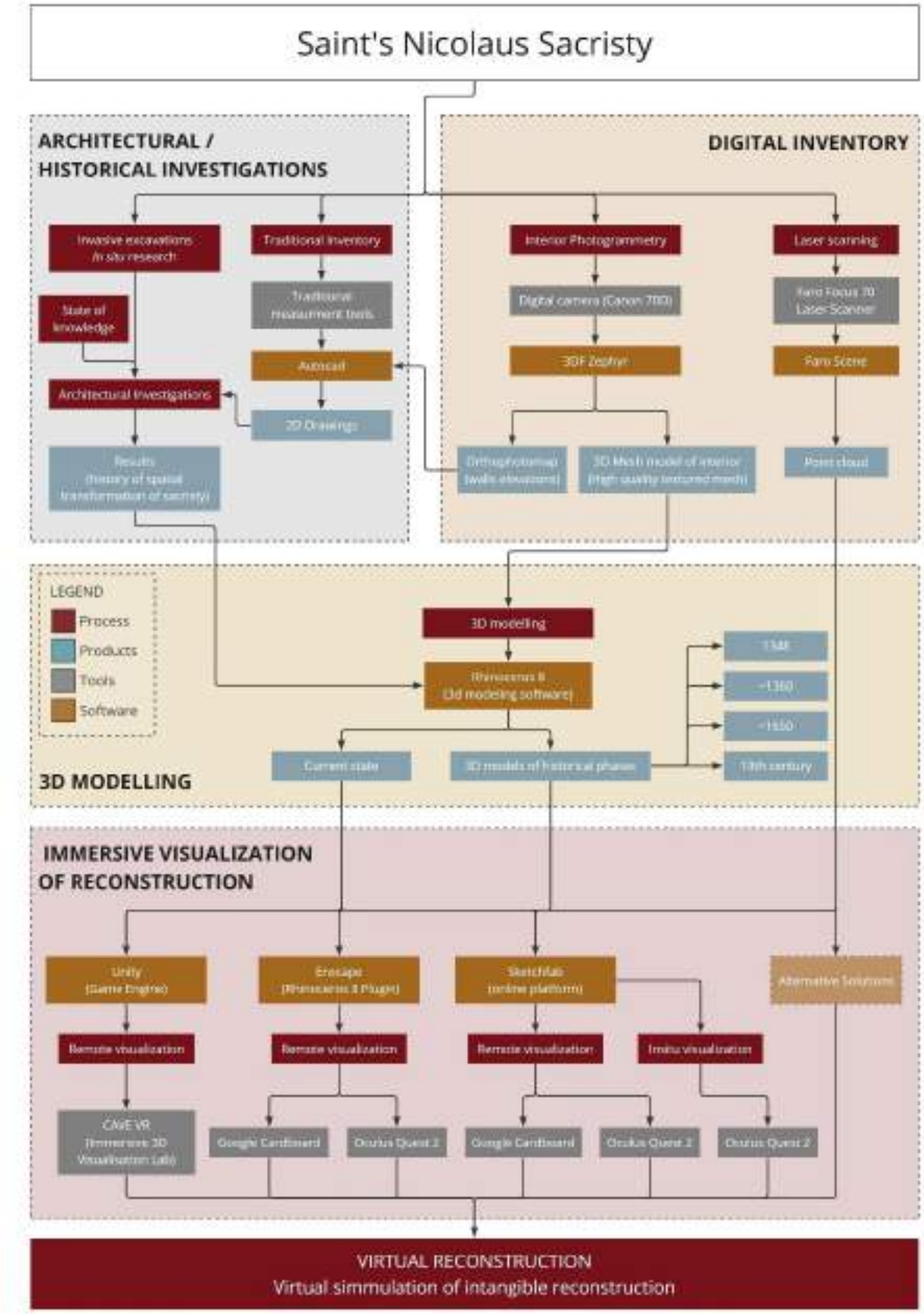


Fig. 163. Methodological scheme of the case study. Source: author.

State of knowledge[805]

The current state of knowledge on St. Nicholas Church is the result of cumulative efforts by scholars, architects, archaeologists, and historians. The earliest account appears in Bartel Ranisch's *Beschreibung Aller Kirchen-Gebäude der Stadt Dantzig* (1695), , which took the form of an inventory of Gdańsk's churches, including Dominican monastery[806].

Fig. 164. Northern elevation of the church and monastery plan, after Bartel Ranisch, (source: Ranish 1695 [807]).

In 1917, Mieczysław Nawrowski[808] presented his doctoral thesis on St. Nicholas Church[809], marking the first in situ architectural study of the monument, supervised by Prof. Adalbert Matthei[810]. Nawrowski sought to reconstruct the entire building history of St. Nicholas, supporting his analysis with few unpublished inventory drawings. Based on his examination of the structure, he hypothesized that the Gothic chancel had been erected as part of a reconstruction effort that followed the outline of an earlier Romanesque church, dated to 1227[811]. He also investigated the northern wall of the sacristy, becoming the first researcher to describe and document traces of earlier vault outlines[812]. Nawrowski further argued that the pointed-arch passages between the presbytery and sacristy were the result of extending the presbytery through the incorporation of an annex chapel. His observations laid the foundation for subsequent studies of the sacristy's architectural transformations[813].

---

[805] The state of knowledge will focus on both general history and the context of sacristy, as it is crucial for research.

[806] Ranisch was also the creator of numerous documentary drawings, including both plans and elevations. While he aimed for a realistic representation, the result often presented the elevations in a form resembling a rectangular projection. Additionally, he created schematic diagrams to trace the geometry of Gothic vaults, which proved invaluable in the described later virtual reconstruction process.

[807] Bartel Ranisch, *Beschreibung Aller Kirchen-Gebäude der Stadt Dantzig* (Gdańsk: Jan Zachariasz Stolle, 1695), 83, 88

[808] Former vice president of Bydgoszcz, shot dead by the Germans in 1941 in Bydgoszcz.

See "Mieczysław Nawrowski – architekt" (*ArchiMemory*), accessed February 2, 2025, https://www.archimemory.pl/pokaz/mieczyslaw_nawrowski,26179.

[809] Mieczysław Nawrowski, *Die baugeschichtliche Entwickelung der Dominikanerkirche St. Nikolaus in Danzig* (Danzig, 1917).

[810] Prof. Adalbert Matthaei was a German architect and academic known for his contributions to architectural history and preservation. From 1904, he served as a professor of the history of construction and the history of art at the Technical University of Gdańsk. Between 1909 and 1912, he held the position of rector at the university.

See "Prof. Adalbert Matthaei (historia budownictwa i historia sztuki)," *Politechnika Gdańska*, accessed February 2, 2025, https://pg.edu.pl/uczelnia/ludzie-pg/rektorzy-poprzednich-kadencji/prof-adalbert-matthaei-historia-budownictwa-i.

[811] It should be noted that Nawrowski was unaware of the Romanesque church discovered by Maciej Szyszka in 2003 beneath the market hall in Gdańsk. This significant archaeological finding has since provided new insights into the early phases of the church's construction and the broader history of the site.

[812] Rediscovered in 2019 by the research team, under the supervision of Piotr Samól.

[813] The north wall of the sacristy contains far more information than Nawrowski was able to identify in his research.

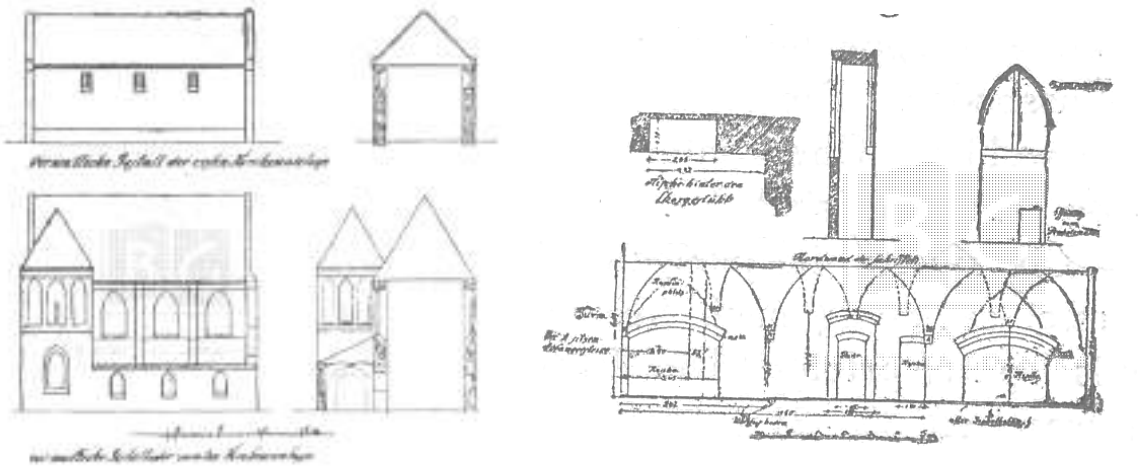


Fig. 165. Left: Reconstruction of the first Romanesque church of St. Nicholas and its relation to the Gothic presbytery and sacristy, (source: Nawrowski 1917 [814]). Right: Elevation of the southern wall of the presbytery seen from the interior of the sacristy, (source: Nawrowski 1917 [815]).

Nawrowski's proposals formed the basis for archaeological investigations undertaken during the city's post-war reconstruction (1955–1957) under the supervision of Prof. Andrzej Zbierski. These studies revealed an anomaly in the floor plan consisting of two different foundation alignments, probably remnants of an earlier structure. This discovery led to a revision of Nawrowski's hypothesis that the Gothic presbytery had been erected on the remains of a rebuilt Romanesque church. Zbierski presented this reinterpretation in 1957[816].

Between 2001 and 2005, archaeological investigations conducted alongside the modernization of the nineteenth-century Market Hall uncovered the remains of the first Romanesque church of the Dominican Order, identified by Maciej Szyszka[817]. The exposed layers, including relics of the chancel and part of the nave, were preserved as an open-air archaeological museum. This discovery clarified earlier hypotheses, including those of Nawrowski, but since the church was found in a different location, questions raised by Zbierski about earlier foundations remain unresolved. Even so, the find greatly advanced knowledge of the Dominican Order's early presence in Gdańsk.

The same discovery prompted in situ architectural investigations of the Gothic monastery, carried out by Prof. Ewa Łużyniecka of the Wrocław University of Technology between 2004 and 2007 and again in 2010. Assisted by students, she produced several inventory drawings of the church and in 2013 published partial results of her extensive research[818]. Building on Nawrowski's earlier findings,

[814] Mieczysław Nawrowski, *Die baugeschichtliche Entwickelung der Dominikanerkirche St. Nikolaus in Danzig* (Danzig, 1917), 52.

[815] Mieczysław Nawrowski, *Die baugeschichtliche Entwickelung der Dominikanerkirche St. Nikolaus in Danzig* (Danzig, 1917), 33.

[816] Andrzej Zbierski, "Dotychczasowe wyniki badań archeologicznych w kościołach św. Mikołaja i św. Katarzyny w Gdańsku," *Rocznik Gdański*, no. 15–16 (1956/1957): 53–77.

[817] Maciej Szyszka, "Badania ratunkowe w piwnicach Hali Targowej w Gdańsku," in *Dominikanie. Gdańsk – Polska – Europa*, ed. Andrzej Gołębnik, Marcin Grubka OP, and Dariusz Aleksander Dekański OP (Gdańsk–Pelplin: Dominikańskie Centrum św. Jacka w Gdańsku, 2003), 485–499; Maciej Szyszka, "Romański kościół pw. św. Mikołaja i trzynastowieczny zespół podominikański w świetle badań archeologicznych na stanowisku 5 w Gdańsku," in *Architektura romańska w Polsce. Nowe odkrycia i interpretacje*, ed. Tomasz Janiak and Dariusz Stryniak (Gniezno: Muzeum Początków Państwa Polskiego w Gnieźnie, 2009), 610–640.

[818] Ewa Łużyniecka, "Próba odtworzenia przeobrażeń rozplanowania klasztoru dominikanów w Gdańsku," in *Architektura romańska w Polsce. Nowe odkrycia i interpretacje*, ed. Tomasz Janiak and Dariusz Stryniak (Gniezno: Muzeum Początków Państwa Polskiego w Gnieźnie, 2013), 145–172.

Łużyniecka hypothesized that before the sacristy was established, a two-aisled, cross-vaulted chapel with a separate room occupied the site. She argued that passageways existed between this chapel and the presbytery, consistent with the wall evidence documented by Nawrowski. She also identified additional drawing sources concerning the southern part of the church and sacristy, concluding that a second storey was added in the late sixteenth century and further reconstruction took place at the end of the nineteenth century.

An important contribution was made by Piotr Samól, who, under the supervision of Prof. Aleksander Piwek, devoted his doctoral thesis to the architecture of the Dominican Order in medieval Prussia. Completed in 2015 and later expanded[819] into a monograph published in 2022[820], the work drew on intensive *in situ* research at six Dominican churches and incorporated the results of rescue architectural investigations at the Dominican monastery in Gdańsk conducted between 2019 and 2022. The author participated in these investigations as part of a research team with Michał Kwasek, under the supervision of Piotr Samól, which led to several new discoveries.

At the same time as Piotr Samól's work, Ewa Łużyniecka published the culmination of her extensive research in a 2022 monograph[821] on the Dominican monastery. In addition, Katarzyna Darecka investigated the Gothic sacristy door, overseeing its restoration and documenting its rhomboidal truss structure and richly coloured decoration, which she presented in a dedicated monograph[822]. Together, these studies testify to decades of sustained scholarly attention to the church and monastery.

Construction failure

The author's work on St. Nicholas Church was prompted by the structural failure of a pillar between the main and southern naves, caused by soil instability that produced shear stress and a vertical crack in the Gothic arcade, raising serious concerns about the building's stability. The situation became critical in late 2018, when extensive cracks appeared in the walls and vaults, forcing the authorities to close the church to the public[823]. A rescue committee of specialists[824] was established to investigate the causes and propose stabilization measures. The greatest threat was the potential collapse of the southern nave vaults, which prompted the installation of emergency scaffolding with vertical shores to

[819] Piotr Samól, "O odkrywaniu historii budowlanej kościoła św. Mikołaja w Gdańsku. Architektura świątyni dominikanów w świetle badań architektonicznych, archeologicznych i konserwatorskich," in *Dominikanie w Gdańsku. 800 lat zakonu dominikanów w Polsce*, ed. Anna Frąckowska and Katarzyna Darecka (Gdańsk: Muzeum Gdańska, 2021), 65–75.

[820] Piotr Samól, *Architektura kościołów dominikańskich w średniowiecznych Prusach* (Gdańsk: Wydawnictwo słowo/obraz terytoria, 2022).

[821] Ewa Łużyniecka, *Kościół dominikanów w Gdańsku: architektura i jej przeobrażenia* (Wrocław: Oficyna Wydawnicza Politechniki Wrocławskiej, 2022).

[822] Katarzyna Darecka, *Drzwi i wrota w Gdańsku. Od średniowiecza do współczesności* (Gdańsk: Muzeum Gdańska, 2024), 67–68, 71.

[823] "Konserwator: inne zabytki zagrożone jak kościół św. Mikołaja," *Trojmiasto.pl*, October 31, 2018, accessed January 12, 2024, https://www.trojmiasto.pl/wiadomosci/Konserwator-inne-zabytki-zagrozone-jak-kosciol-sw-Mikolaja-n128856.html; "Katastrofa budowlana wisi nad kościołem w sercu Gdańska. Startuje akcja ratownicza," *Trojmiasto.wyborcza.pl*, accessed January 12, 2024, https://trojmiasto.wyborcza.pl/trojmiasto/7,35612,24114753,katastrofa-budowlana-wisi-nad-kosciolem-w-sercu-gdanska-startuje.html; "Pochylone wieżyczki, sypiące cegły. Pogorszył się stan kościoła," *Trojmiasto.wyborcza.pl*, accessed January 12, 2024, https://trojmiasto.wyborcza.pl/trojmiasto/7,35612,24686287,pochylone-wiezyczki-sypiace-cegly-pogorszyl-sie-stan-kosciola.html; Katarzyna Moritz, "Sklepienia i filary w kościele św. Mikołaja przestały się ruszać," *Trojmiasto.pl*, December 9, 2018, accessed January 12, 2024, https://www.trojmiasto.pl/wiadomosci/Sklepienia-i-filary-w-kosciele-sw-Mikolaja-przestaly-sie-ruszac-n129985.html.

[824] Piotr Samól, as an expert in the historical and architectural aspects of the Dominican Order, was appointed to the committee and was responsible for overseeing the architecture and conservation efforts.

support the weakened structure[825]. Subsequent steps included structural monitoring and rescue archaeological investigations to examine the foundations[826]. Ultimately, a comprehensive restoration plan was implemented, culminating in the construction of a reinforced concrete shell with a carbon net to stabilize the vaulting[827], and the church was reopened in 2020 after more than two years of closure[828].

Fig. 166. Support structure in the southern nave with vertical shoring and visible crack in the arcade. Source: author.

5.2.2. Invasive architectonical investigations

The structural failure created an opportunity to carry out extensive rescue architectural investigations, which not only verified existing knowledge but also significantly expanded it. Under the supervision of Piotr Samól, and with the support of Michał Kwasek and the author, the team conducted comprehensive invasive research throughout the entire church. This work led to the uncovering of

[825] The author would like to express his gratitude to Piotr Samól, Dominican Prior Michael Osek, and Waldemar Raikowski for the opportunity to participate in and observe such an interesting project as the stabilization of the southern nave at St. Nicholas Church.

[826] Szymon Zięba, "Rusztowania wsparły sklepienie kościoła św. Mikołaja," *Trojmiasto.pl*, December 10, 2019, accessed January 12, 2024, https://www.trojmiasto.pl/wiadomosci/rusztowania-w-kosciele-sw-Mikolaja-n140347.html; Katarzyna Moritz, "Drewniane rusztowanie na ratunek sklepieniom św. Mikołaja," *Trojmiasto.pl*, February 25, 2019, accessed January 12, 2024, https://www.trojmiasto.pl/wiadomosci/Drewniane-rusztowanie-na-ratowanie-sklepienia-Mikolaja-n132138.html; Katarzyna Moritz, "Kościół św. Mikołaja stoi na kamiennych ławach. To zaskoczenie," *Trojmiasto.pl*, July 16, 2019, accessed January 12, 2024, https://www.trojmiasto.pl/wiadomosci/Kosciol-sw-Mikolaja-stoi-na-kamiennych-lawach-n136321.html.

[827] The author was also directly involved in the creation of the rescue inventory of the vault from above, prior to the casting of the concrete shell. This involvement raises the important question of the reversibility of the stabilization measures implemented in a monument like the Church of St. Nicholas, considering the long-term preservation of its historical and architectural integrity.

[828] Aleksandra Nietopiel, "Sklepienia w Mikołaju już po remoncie. Rusztowanie zostaje," *Trojmiasto.pl*, December 22, 2022, accessed January 12, 2024, https://www.trojmiasto.pl/wiadomosci/Sklepienia-w-Mikolaju-juz-po-remoncie-Rusztowanie-zostaje-n173856.html; "Kościół św. Mikołaja. Pękające sklepienie naprawione, ale na całkowite otwarcie trzeba poczekać," *Gdansk.pl*, December 21, 2021, accessed January 12, 2024, https://www.gdansk.pl/wiadomosci/Kosciol-sw-Mikolaja-w-Gdansku-koniec-remontu-nawy-poludniowej-sklepienia-naprawione,a,210932; "Kościół św. Mikołaja znów otwarty dla wiernych i zwiedzających," *Trojmiasto.wyborcza.pl*, accessed January 12, 2024, https://trojmiasto.wyborcza.pl/trojmiasto/7,35612,26088693,kosciol-sw-mikolaja-znowu-otwarty-dla-wiernych-i-zwierdzajacych.html.

numerous architectural nodes (building joints)[829], clarifying and confirming the developmental phases of St. Nicholas Church. The documentation of the first stage of investigations was subsequently prepared, presenting the findings in detail. It includes records of 86 research excavations conducted within the church, accompanied by large-format drawings, such as overall plans and characteristic sections through the tower and sacristy[830].

The investigations in the sacristy interior of St. Nicholas Church[831] focused on invasive methods, particularly the removal of plaster, which allowed a thorough examination of historical transformations. This approach enabled detailed analysis of the walls, including brick patterns, mortar compositions, and statistical measurements of brick dimensions, with particular attention given to identifying construction nodes that were subsequently compared with historical sources. The removal of plaster applied in the 1970s revealed traces of successive vaulting systems and multiple modifications over time, illustrating the architectural evolution of the sacristy. It also exposed damage to the walls caused by the insertion of horizontal reinforced-concrete bracings and the installation of electrical systems[832]. As the research progressed, the exposed walls were systematically documented and inventoried[833], while further invasive work involved lifting sections of the floor to conduct shallow archaeological excavations aimed at determining the original floor level and examining wall structures concealed beneath the current surface.

Fig. 167. Invasive research conducted in the sacristy of St. Nicholas Church, 2019, showing plaster removal. Source: author.

Results of investigations

The in situ invasive research provided a foundation for understanding the transformation of the sacristy interior, including the geometry of its vaults. The investigation identified three distinct vault outlines and confirmed the hypothesis of the chapel's conversion into a sacristy, as proposed by Ewa Łużyniecka on the basis of Nawrowski's work, while disproving the existence of suggested passageways later bricked up and converted into recesses. Excavations beneath the floor uncovered traces of an earlier pavement composed of black-and-white tiles and several broken bricks shaped as vault ribs. In total, 48 structural nodes were analyzed within the sacristy and tower, and statistical data from 350 bricks

[829] The nodal method in the study of architectural objects is an analytical approach that focuses on key structural points of a building, such as wall corners and junctions, referred to as nodes. The analysis of these nodes provides valuable insights into construction phases, the materials used, and the evolution of architectural object over time.

[830] Alle created by team; Piotr Samól, Michał Kwasek and Szymon Kowalski.

[831] The author focuses exclusively on the sacristy, as it offers a comprehensive illustration of architectural changes and provides a complete case study for examining the challenges of immersive virtual reconstruction. The broader scope of the entire church will be addressed in future research within the framework of a scientific grant initiative.

[832] The author, together with Waldemar Raikowski, actively participated in the removal of the plaster layer, thereby combining scientific research with practical, hands-on experience under the supervision of Piotr Samól.

[833] As the cement plaster was removed, traces of an earlier lime plaster layer were uncovered, corresponding to the historical period prior to the introduction of cement-based plasters. This layer had most likely been stripped away during conservation works carried out in the 1970s.

revealed six distinct brick types corresponding to different construction phases. Combined with historical studies, these findings allowed for a comprehensive reconstruction of the interior's building history and formed the basis for the author's virtual reconstruction and immersive simulation of its successive states. Following these investigations and the subsequent conservation commission, the Provincial Conservator of Monuments approved the uncovering of nearly two-thirds834 of the sacristy's northern wall and the repair of damage caused by earlier construction works, demonstrating the direct translation of research findings into the physical revalorization of the interior space.

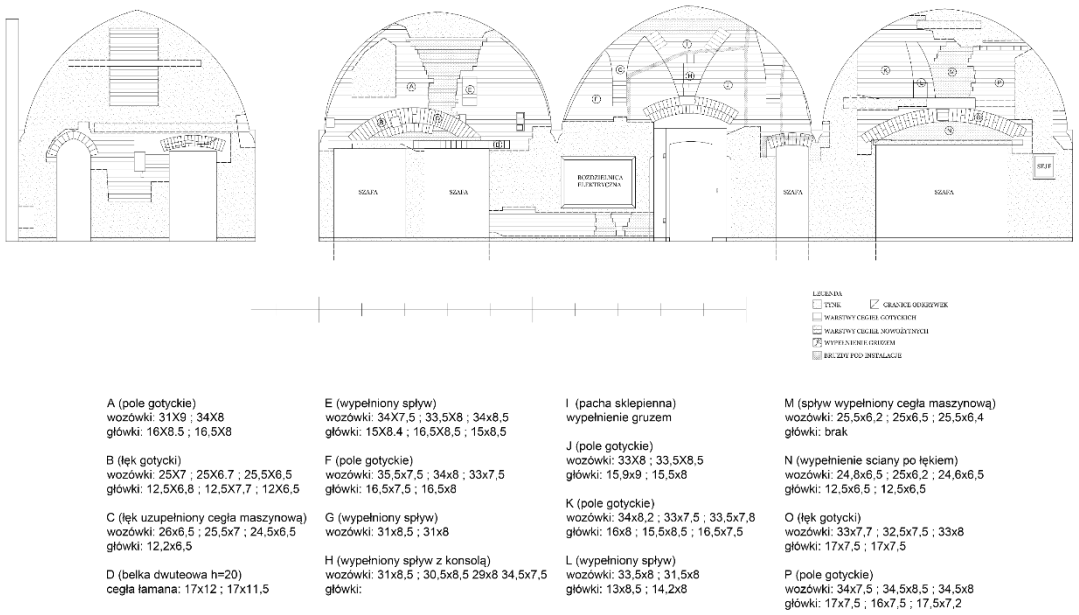


Fig. 168. Statistical analysis of brick proportions used to identify production batches and corresponding construction phases. Source: author.

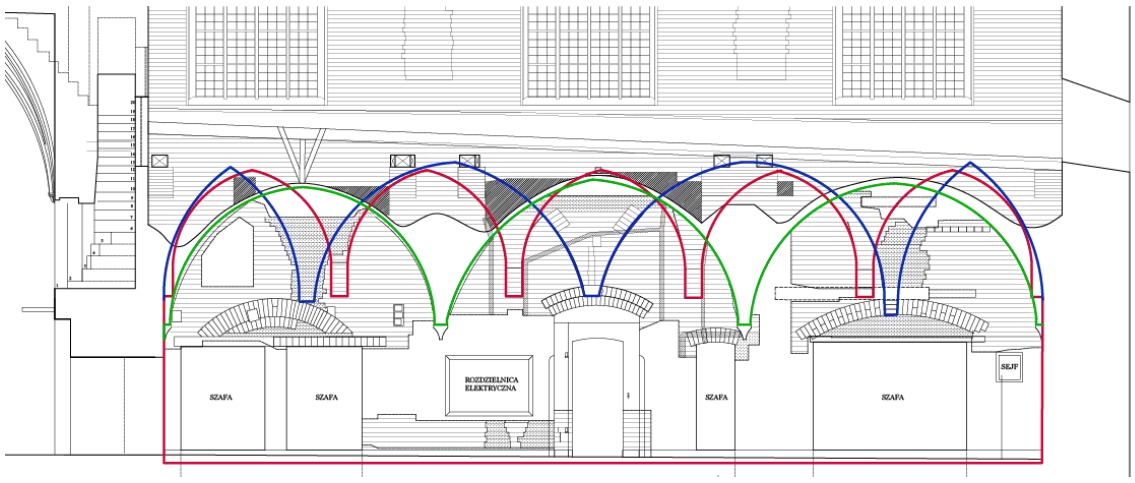


Fig. 169. Outline of 3 different vault forms superimposed on 2019 inventory. Source: Drawing by author based on Piotr Samól's research[835].

834 Because of extensive damage and major alterations in the brickwork of the remaining third of the northern wall, it was decided not to uncover it fully; instead, only characteristic features, such as the arch and vault outlines, were revealed.

835 Piotr Samól, *Architektura kościołów dominikańskich w średniowiecznych Prusach* (Gdańsk: Wydawnictwo słowo/obraz terytoria, 2022), 172-173.

The conservation problem and the authenticity context

The sacristy of St. Nicholas provides a valuable case study for reconstructing the complete spatial history of an interior through invasive research. Its current form reveals successive vaulting systems uncovered beneath removed plaster. The star-shaped vault installed in 1904, modeled on the adjacent Chapel of St. Joseph, exemplifies the practice of stylistic restoration discussed in Chapter II. Although inspired by Viollet-le-Duc and embraced within Prussian restoration practice, this intervention is historically inaccurate, as research has demonstrated that such a vault never existed in the church interior. Prussian conservators, however, were convinced that a star vault had originally been present and therefore introduced a Neo-Gothic design intended to appear original, seeking to recreate what they believed to be an earlier state of the interior without undertaking the proper investigations that might have led to accurate conclusions. Nevertheless, the vault now possesses considerable documentary value as evidence of stylistic restoration practices in Prussia and Gdańsk.

Although more than 120 years old and supported by extensive documentation of earlier phases, the 1904 vault should not be dismantled to reinstate a previous state, as this would compromise the authenticity of the interior, erase its stratification, and interrupt its historical continuity. Instead, the knowledge gained from studying its successive phases can serve as the foundation for an intangible, immersive virtual reconstruction. Such a digital recreation would enable users to explore and experience earlier stages of the sacristy without altering its material fabric, thereby preserving its current condition while still responding to the widespread desire to engage with the past.

5.2.3. Digitalisation of the interior

During the research period, and in line with the thesis objectives, the author employed a range of digitization methods to create a digital representation of the sacristy interior, beginning with photogrammetry and later supplemented by laser scanning. The first comprehensive digital replica[836] of the interior was produced in 2020 using photogrammetry[837]. A Canon EOS 70D camera was used to capture approximately 2,910 photographs, which were processed and reconstructed in 3DF Zephyr software[838]. The same technique was applied to digitize brick rib fragments uncovered during archaeological excavations beneath the sacristy floor, as well as to document distinctive interior features such as the Gothic polychrome in the chancel, the sedilia, the Gothic door, and the portal to the sacristy.

[836] The author had previously created a series of drawings illustrating the interior of the sacristy. These drawings synthesised the existing state, developed using traditional measurement methods. This underscored the need for a more precise digital representation.

[837] As mentioned earlier, the author chose this measurement technique as the most cost-effective option, yielding reasonably satisfactory results for digitalisation. At this stage of research, the author did not have access to a laser scanner.

[838] The author faced a significant challenge while scanning the interior using photogrammetry methods. The white walls, newly restored during conservation work, featured the grainy texture of lime plaster but were otherwise unblemished. This lack of distinguishing features made it impossible to link the photographs into a coherent series within the 3DF Zephyr software. A partial solution was the use of blue markers (masking tape) which facilitated the integration of the interior photographs into a network.

Fig. 170. Sacristy during conservation works, with blue markers introduced for photogrammetry scanning. Source: author.

Fig. 171. Digitized elevation of the northern wall of the sacristy, with blue markers introduced to correct distortion during photogrammetry scanning. Source: author.

Fig. 172. Brick measurement for photogrammetry scaling and digitized Gothic rib profile bricks. Source: author.

Another stage of digitization involved laser scanning of the interior[839]. The first attempt was made possible through the generosity of scientific colleagues from the University of Pavia, Silvia La Placa and

[839] Another scan was likely carried out by the foundation *Wirtualne Dziedzictwo*, but no traces or published results of this work are available, despite the fact that it was publicly funded by the Ministry of Culture and National Heritage. The author has never had the opportunity to examine this material and therefore wishes to distinguish his own contribution from earlier attempts to document the interior of the church through laser scanning.

Elisabetta Doria, who in February 2023 conducted a scan of the sacristy interior using a Leica RTC 360 TLS scanner, prior to the acquisition of a laser scanner by the author and the Faculty of Architecture at Gdańsk University of Technology. This scan focused on the presbytery and sacristy in order to address the research topic concerning the interior and its earliest construction phases at St. Nicholas Church in Gdańsk. The resulting master point cloud was created by aligning 19 separate scans.

Following the acquisition of his own laser scanner (Faro Focus 70), the author undertook a comprehensive initiative to document the entire church interior, including a second scan of the sacristy. Between March and July 2024, 88 individual scans were conducted, covering the presbytery, sacristy, Chapel of St. Hyacinth (Jack) Odrowąż, Chapel of the Holy Cross (beneath the tower), the tower itself, the nave with supporting scaffolding, the organ gallery, and several ancillary spaces. The final registered point cloud achieved an estimated error of approximately 3.4 mm and comprised 2,499,803,572 coloured points. Limited to only sacristy scan was published at Sketchfab for online access[840].

Fig. 173. Cross-section of the sacristy represented as a laser point cloud after conservation works, showing the northern wall with visible masonry anomalies that confirm the existence of earlier vaulting systems. Registered in February 2023. Source: author

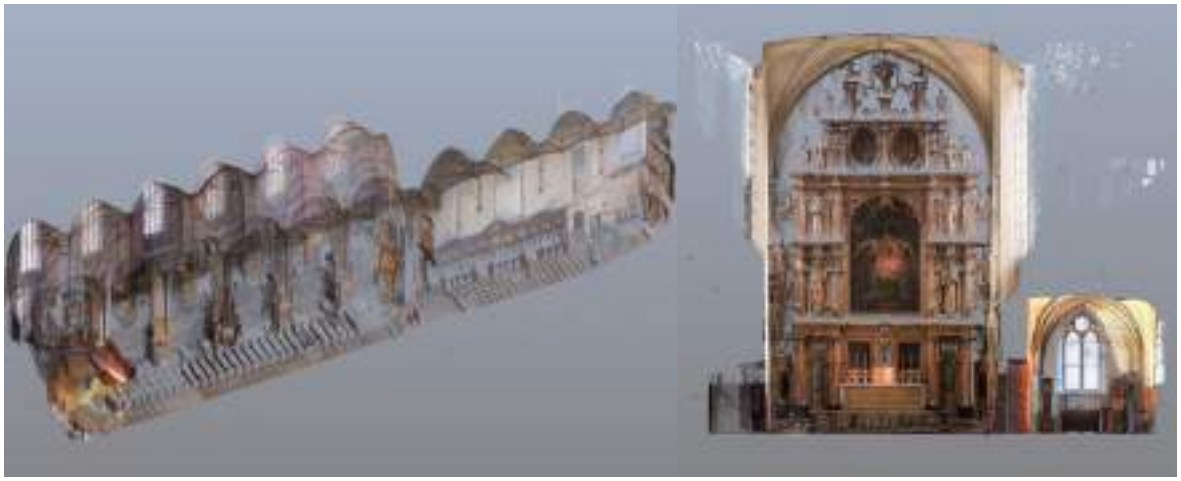


Fig. 174. The laser point cloud of the interior of Saint Nicolaus Church. Registered in July 2024. Source: author.

See *"Bazylika św. Mikołaja w Gdańsku." Wirtualne Dziedzictwo. March 15, 2021. Accessed June 2, 2023. https://wirtualnedziedzictwo.pl/projekty/bazylika-sw-mikolaja-w-gdansku/.*

358.[840] Dominikanie Gdańsk, *Zakrystia Św. Mikołaja w Gdańsku. Skan laserowy*, 3D model, model by Szymon Kowalski and Piotr Samól, Sketchfab, February 28, 2024; accessed 3 March 2024, https://sketchfab.com/3d-models/zakrystia-sw-mikoaja-w-gdansku-skan-laserowy-30c3bf9b57df475cb6489cc6a76949fc.

5.2.4. Virtual Reconstruction

Development of virtual reconstruction

To create the virtual reconstruction, the scanned interior was first converted into a mesh model in .obj format and imported into SketchUp. However, because SketchUp proved insufficient for handling complex meshes, the workflow was transferred to Rhinoceros 7, which offered greater flexibility and precision for reconstruction using NURBS[841]. On the basis of the architectural investigation and the synthesis of accumulated knowledge, five 3D models were developed, each representing a distinct phase in the transformation of the sacristy interior. The geometry of the vaults was reconstructed by combining the preserved wall outlines with the schemes presented by Bartel Ranisch in his aforementioned book, which provided the mathematical framework for their form[842]. The Neo-Gothic star-shaped vaults were modelled using the retopology method[843].

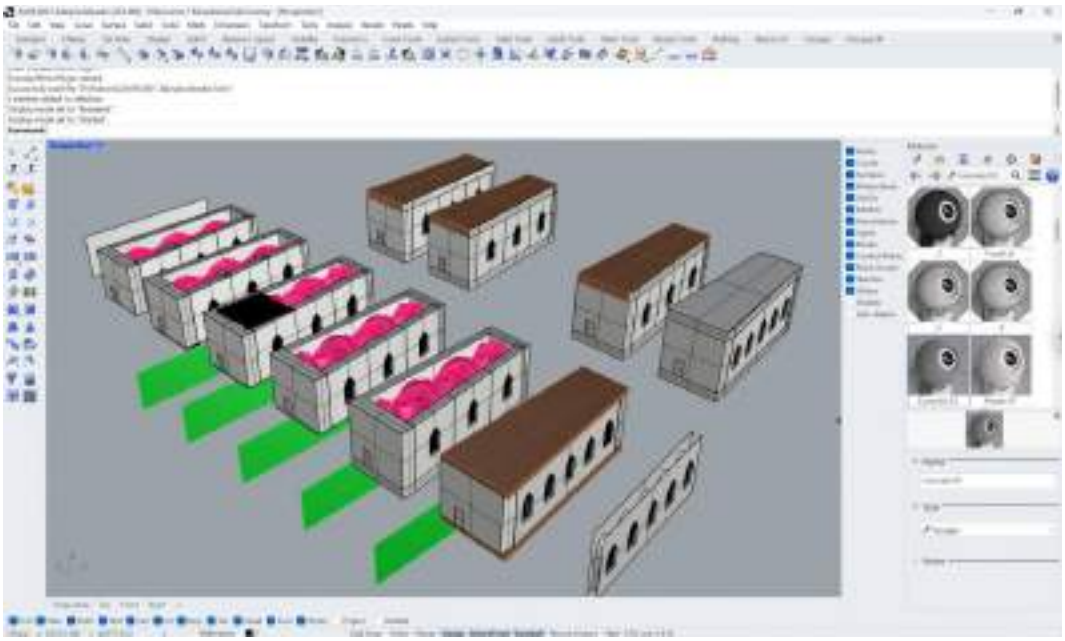


Fig. 175. Development of 3d models of the interior based on the digital representation in Rhinoceros software. Source: author.

[841] The initial use of SketchUp was motivated by the author's familiarity with the software, developed through academic teaching and its widespread application in professional architectural practice. However, the transition to Rhinoceros 7 proved essential for methodological reasons, as Rhino is based on NURBS geometry, which allows for mathematically precise modelling of curves and surfaces. This accuracy is crucial in architectural reconstruction, where vaults, ribs, and other non-linear elements must be represented with fidelity to their historical geometry. In contrast, SketchUp relies on mesh-based modelling, which, while sufficient for simpler forms, lacks the precision required for complex architectural elements. Rhino also provides a broader spectrum of functions, including native support for point cloud import, which ensured direct integration of the laser scanning data into the reconstruction workflow. Blender was also tested within the process, primarily for mesh optimization and trial reconstructions, as it offers advanced tools for retopology and polygon reduction. While effective in streamlining dense point cloud meshes, Blender was ultimately regarded as insufficient for the final reconstruction work, since it relies on mesh-based geometry and lacks the parametric precision of NURBS modelling necessary for accurate architectural representation.

[842] Bartel Ranisch, *Beschreibung Aller Kirchen-Gebäude der Stadt Dantzig* (Gdańsk: Jan Zachariasz Stolle, 1695), 76

[843] Retopology is a 3D modelling technique used to reconstruct complex meshes into cleaner and more efficient geometry. Its primary purpose is to reduce polygon count while preserving the essential shape and details of the model. By generating optimized geometry with improved edge flow, retopology enhances both performance and the suitability of the model for further editing, visualization, or simulation.

Fig. 176. Early stage of the development of 3D models based on the photogrammetry scan. Source: author.

Visualization of historical changes / virtual reconstruction844

Stage 1 ca. 1348

Fig. 177. Original design of a simple five-span cross-ribbed vault sacristy, ca. 1348. The southern wall is shown in transparent form to indicate the hypothetical layout[845]. Source: author and Piotr Samól.

At the beginning of construction of the sacristy and church, between 1344 and 1348, the Dominicans were compelled to adjust the boundaries of their plot. This modification altered the axis of the foundation and produced the broken line of the southern wall, still visible in the building's plan today. Research has shown that the original northern wall was designed to carry five spans of vaulting that were never realized. The initial concept for the sacristy was therefore only partially implemented, likely

844 To present the issues related to the sacristy comprehensively, the research outcomes are integrated with visualizations, each depicting the interior in a separate figure accompanied by descriptions. The text itself derives directly from architectural research conducted by a team led by Piotr Samól, in which the author participated as a collaborator rather than as the sole contributor. Portions of these findings were previously published in *Architecture of Dominican Churches in Medieval Prussia*, edited by Piotr Samól (2022). In addition, this chapter will form the basis of a separate article currently being prepared for publication.

The research outcomes were also published on the website of the Dominican Monastery in Gdańsk as part of a popularisation and dissemination initiative, co-financed by the Municipality of Gdańsk.

See Dominikanie Gdańsk, "Wirtualna rekonstrukcja zakrystii," *Dominikanie Gdańsk*, August 9, 2022, accessed March 3, 2025, https://gdansk.dominikanie.pl/2022/08/wirtualna-rekonstrukcja-zachrystii.

845 Since the wall was later rebuilt to accommodate a new design, no material evidence of this phase survives; however, the outlines of the vaults from the same stage remain visible on the opposite wall of the sacristy.

because of the decision to raise the presbytery and the need to reinforce it with buttress arches. Bricks obtained from Teutonic brickworks were used in the construction, their dimensions corresponding to those of the high defensive wall then being built around the Main City of Gdańsk. The probable appearance of this unexecuted scheme was visualized through a transparent model. The niches in the northern wall were intended to serve as a treasury for books, while the portal indicates that the sacristy door was originally meant to remain closed off from the interior[846].

Stage 2 1360-1370

Fig. 178. Interior of completed one-storey sacristy from around 1360-1370, covered with the vaults based on triangles. Source: author and Piotr Samól.

The vaulting was eventually executed with three arcades along the southern wall and four supporting arches along the northern wall. The outlines of the vaults between the bays on the northern side were integrated into recesses and consoles made of lime artificial stone. In the 15th century, a low floor was likely added above the sacristy, accessible from the tower. Originally, the chancel wall had been reinforced by three flying buttresses, beneath which a second floor was later constructed in the sacristy attic to serve as a library. Access between this floor and the sacristy was provided by a staircase concealed within the wall's thickness[847].

Stage 3 ca.1650

In 1577, the Catholic church was demolished by Protestants, and the Dominican order temporarily abandoned the monastery, returning only in the 1650s after receiving financial compensation from the inhabitants of Gdańsk. Upon their return, the monks expanded the complex, including the reconstruction of the sacristy, which gained an additional floor providing easier access to the oratory and tower. This intervention required the demolition of the vaulted bay near the tower and the insertion of a wooden staircase. At the same time, the sacristy was divided by a half-timber partition wall, separating the staircase from the main space, an arrangement confirmed by the numerous beam sockets identified during investigations. The new upper floor contained additional cabinets for books and storage areas, while a cellar dug beneath the sacristy was likely used as a burial crypt during the

[846] Dominikanie Gdańsk, *Zakrystia Św. Mikołaja w Gdańsku Etap 1*, 3D model, model by Szymon Kowalski and Piotr Samól, Sketchfab, published September 27, 2021; accessed March 3, 2024, https://sketchfab.com/3d-models/zakrystia-sw-mikoaja-w-gdansku-etap-1-8f1eb18757144a92b93a15de593895ff.

[847] Dominikanie Gdańsk. *Zakrystia Św. Mikołaja w Gdańsku Etap 2*. 3D model. Model by Szymon Kowalski and Piotr Samól. Sketchfab. Accessed March 3, 2024. https://sketchfab.com/3d-models/zakrystia-sw-mikoaja-w-gdansku-etap-2-411ebf277f2f49deac6faeae277a8de3.

17th and 18th centuries. The outer wall was raised with a simple Mannerist attic pierced by windows, and the vault at the tower was modified. This phase is corroborated by the so-called *Stockholm View* (1599) and by the foundation plan documented by the municipal builder Bartel Ranisch before 1695[848].

Fig. 179. Interior of the sacristy dated ca.1650. Source: author and Piotr Samól.

Stage 4 19th century

Fig. 180. Interior of the Prussian stylistic restoration. Source: author and Piotr Samól.

After 1894, progressive deterioration led to a major stylistic, or purist, restoration at the end of the 19th century. Between 1903 and 1904, the sacristy interior was extensively transformed: the remains of the triangular vaults were demolished and replaced with a new Neo-Gothic three-span stellar vault. Entirely anachronistic and purely a conservation invention, this vault imitated the form of the vault in the tower. The restoration also introduced internal buttresses, hollowed out to function as smoke chimneys for a small stove used to heat the sacristy. The second floor and the half-timber partition wall were removed, creating a storage attic above the new vaults. A roof with inverted drainage (towards the north) was constructed, and new Neo-Gothic windows with tracery were installed. The south-eastern corner was rebuilt, and the walls were coated with bituminous felt for waterproofing, which

[848] Dominikanie Gdańsk, *Zakrystia Św. Mikołaja w Gdańsku Etap 3*, 3D model, model by Szymon Kowalski and Piotr Samól, Sketchfab, accessed March 3, 2024, https://sketchfab.com/3d-models/zakrystia-sw-mikoaja-w-gdansku-etap-3-32a039af27db45bfa5f9872609ac2cad.

significantly damaged the original wall texture. The staircase within the tower wall was also altered, with a new entrance carved from the exterior and made accessible behind the altar. Later works, carried out between 1928 and 1930, focused mainly on replacing the roof and repairing the attic[849].

Architectural restoration of the interior

Between 1955 and 1957, minor modifications were carried out to install electricity in the sacristy. In 1980, following a 1977 technical assessment of surface cracks in the northern wall, steel rods were inserted to reinforce the structure. This intervention, however, destroyed surviving traces of earlier vaults. At the same time, the Gothic book niches were narrowed and partially removed. Crucially, these works were undertaken without prior architectural research, resulting in the partial loss of the Gothic interior. Archaeological investigations in 2002 revealed traces of a basement and stairs leading to the crypt. Some of these alterations were later partially reversed during conservation efforts between 2019 and 2021. In 2019–2020, further research and conservation work were undertaken. Given the extensive changes made to the sacristy between 1903 and 1980, defining an appropriate scope of protection and restoration posed a major conservation challenge. After consultation with the Monument Protection Office, it was decided to reconstruct the northern wall recesses destroyed in the late 19th century, while retaining the Neo-Gothic windows and vaults as part of the building's historical stratigraphy. In addition, traces of earlier vaulting systems, including multiple support arches and consoles, were highlighted[850].

Virtual reality applications

The use of VR in the sacristy case study was extensively explored through a spectrum of immersive visualization methods, ranging from low-budget solutions to advanced laboratory systems. These approaches included spherical panoramas, smartphone-based VR using Google Cardboard, head-mounted displays (HMDs) both on-site and remotely, and finally a high-end CAVE environment.

Spherical panoramas

The first method employed involved rendering 360° panoramas directly from the visualization software, using the panorama rendering feature of the Enscape plugin for Rhinoceros. Unlike fully interactive 3D models, these panoramas provided static views from predetermined vantage points, viewable through a smartphone or with a Google Cardboard headset. This technique enabled a hybrid experience of both the real and virtual worlds, recalling the Baroque concepts of *punto stabile* and *quadratura* discussed in Chapter 3. In this case, the midpoint of the sacristy served as the fixed reference point, aligning the rendered panorama with the actual viewpoint.

Sketchfab models

A second method used Sketchfab to host the 3D models. Visitors could access them via the Sketchfab app in VR mode with Google Cardboard, allowing interaction with a fully navigable 3D environment rather than a static panorama. The same models were also accessible directly on smartphones without additional equipment, enabling users to rotate, pan, and zoom freely to address interactive virtual reconstruction with limited immersive aspect. To enrich interpretation, the models were annotated with historical insights about vaults, passages, and spatial changes identified during architectural

[849] Dominikanie Gdańsk. *Zakrystia Św. Mikołaja w Gdańsku Etap 4*. 3D model. Model by Szymon Kowalski and Piotr Samól. Sketchfab. Accessed March 3, 2024. https://sketchfab.com/3d-models/zakrystia-sw-mikoaja-w-gdansku-etap-4-265b56f421434509b5bca3024a990a95.

[850] Dominikanie Gdańsk, *Zakrystia Św. Mikołaja w Gdańsku Etap 5*, 3D model, model by Szymon Kowalski and Piotr Samól, Sketchfab, published October 6, 2021; accessed March 3, 2024, https://sketchfab.com/3d-models/zakrystia-sw-mikoaja-w-gdansku-etap-5-6392d74b7667471caaf1b520a5eacb5c.

investigations. On-site QR-coded information plates were also created, allowing visitors to access the online models instantly.

Fig. 181. The information plate with QR codes to access the model. Source: author and Piotr Samól.

VR headsets

Beyond low-cost solutions, immersive visualization was further developed using VR head-mounted displays (HMDs), which offered two main approaches: remote visitation, simulating the viewer's presence within the sacristy, and a form of mixed reality that aligned historical phases directly onto the existing interior for an enhanced spatial experience.

The remote visitation method involved exploring the virtual environment with a VR headset through several techniques. One option used models in the form of point clouds and meshes uploaded to the Sketchfab platform, enabling a wireless immersive experience via a built-in browser of VR goggles. Alternatively, a wired Oculus Link connection allowed processing and live rendering to be handled by a connected PC, producing more visually refined results. Enscape software was also used to simulate the virtual world, providing immersive access to all reconstructed phases of the sacristy. In addition, the entire church point cloud was visualized immersively using the Faro Scene VR plugin. Game engines such as Unity and Unreal Engine were also tested, offering the potential for interactive, game-like applications, though they required advanced technical skills. For the purposes of this research, however, VR headsets combined with the aforementioned software proved both effective and sufficient.

Fig. 182. Virtual remote sightseeing using the Oculus Link Cable connection with PC. Source: author.

Another highly interactive and immersive application was developed for on-site use. The solution devised by the author does not constitute mixed reality in the strict sense, since the virtual image was not superimposed on the real view but rather replaced it. However, by exploiting the built-in tracking capabilities of VR goggles, it became possible to align the virtual and physical spaces so precisely that the virtual walls appeared to coincide exactly with the authentic ones. This effect, described as the phenomenon of *synchronised worlds*, was achieved through manual pre-alignment, selecting a common starting point within the sacristy and configuring the VR system's safe zone to match the actual dimensions of the space. As a result, visitors could experience successive historical phases of the sacristy in real time while moving through the present-day interior, creating the striking sensation of touching the same wall in both realities, a powerful illusion of singularity that evoked technologically simulated time travel.

Fig. 183. The interior of the sacristy of St. Nicholas Church in Gdańsk, after restoration, experienced by the Dominican Prior through the *synchronised worlds* effect. Using a VR HMD, the Prior walks through the virtual sacristy, navigating earlier architectural stages while immersively exploring its evolution in real time. Source: author.

CAVE environment

The second method of immersive remote sightseeing employed a CAVE (Cave Automatic Virtual Environment), introduced earlier in Chapter 4. Through close collaboration with the Faculty of

Electronics, Telecommunications, and Informatics and the Immersive 3D Visualisation Lab, led by Prof. Jacek Lebiedź, it was possible to utilise this high-end system. The CAVE allowed multiple spectators to view the model simultaneously, creating a collective immersive experience. The environment was built in the Unity engine, which integrated all 3D models of the sacristy produced by the author on the basis of architectural investigations. Programming and scripting by members of the Immersive 3D Visualisation Lab (Ivan Vakulko, Robert Trzosowski, Marek Barański, and Błażej Kowalski) enabled the development of a fully interactive virtual scene. The virtual environment was constructed by precisely aligning the different phases of the sacristy's evolution on top of one another, allowing users to switch seamlessly between five historical stages. Movement tracking further enhanced immersion, while additional functions were assigned to controller buttons, including the ability to toggle between phases with a single click. The controller also functioned as a virtual laser pointer for highlighting specific architectural elements. Finally, interactive "pins" were embedded in the model, displaying historical descriptions when selected and providing visitors with deeper insights into the sacristy's architectural development.

Fig. 184.Simulation of the sacristy interior projected in the CAVE system at the Immersive 3D Visualisation Laboratory, Gdańsk University of Technology. Source: author.

Fig. 185. Interior view of different phases of the sacristy during a group immersive tour in the CAVE system. The blurred appearance results from stereoscopic imaging, which enhances depth perception when viewed with specialised glasses. Source: author.

Comparative evaluation of visualization methods

Each method presented distinct advantages and limitations. Spherical panoramas were simple and highly accessible but limited to static views. Sketchfab offered broader interactivity and excellent outreach potential, especially with annotations and QR-code access, though it relied on stable internet and lacked full immersion. VR headsets provided the strongest sense of presence, with the "synchronised worlds" approach achieving an especially powerful alignment of virtual and real space, though equipment availability and calibration were challenges. The CAVE system delivered the richest collective immersive experience but required specialised infrastructure and expertise, restricting its use to research and demonstration. Together, these methods illustrate the spectrum of VR applications in heritage: from low-cost tools suited for public engagement to advanced systems capable of supporting scholarly research and interpretive innovation, while maintaining the principles of non-invasiveness and reversibility central to conservation practice.

5.3. Object scale - Westerplatte

5.3.1. Introduction

The Westerplatte case study originated in the author's master's thesis[851]. Confronted with the complex political, commemorative, scientific, and conservation challenges surrounding the Westerplatte open-field museum, the author proposed a dual approach that combined architectural design with an Immersive Virtual Solution. This concept fulfilled the requirements of an architectural diploma while also offering a unique perspective on the contested site.

Fig. 186. 360° scene from the author's master's thesis illustrating the blending of reality and digital reconstruction: on board the "Schleswig-Holstein" during the first day of the siege of Westerplatte. Source: author.

Fig. 187. 360° scene from the author's master's thesis illustrating the blending of reality and digital reconstruction. Left: digital reconstruction of the "Old Barracks." Right: German assault. Source: author.

Given the limited resources available at the time, such as basic VR headsets and constraints in creating dynamic VR environments, the author employed a budget-friendly Google Cardboard setup, integrating smartphones with dedicated software to create stereographic panoramic image scenes. These static spherical scenes reconstructed the peninsula's architecture and visualized the battle for Westerplatte

[851] *Protection of Historic Landscape of the Battlefield. Open Air Museum Of Westerplatte,* Supervisors: prof. dr hab. Inż. Arch. Jakub Szczepański, dr hab. inż. Arch. Piotr Samól, in which with success I have undertaken the idea of virtual reconstruction. The project was awarded of innovative design Mainprize of Association of Monument Conservators for master thesis and the Mainprize of President of Gdańsk for master thesis

from both Polish and German perspectives, offering a nuanced and multifaceted interpretation of the historical context. The outcomes were later presented in a scientific article[852].

The core idea was to vividly reconstruct historical events in their original locations. Many of today's major battlefields, such as Grunwald, Leipzig, Waterloo, Westerplatte, and Normandy, are vast, empty landscapes marked only by monuments and memorabilia, which makes it difficult for visitors to grasp the magnitude of the events that took place there. Modern technology offers the potential to enrich these landscapes by enabling visitors to visualise reconstructions of the battles that once unfolded on the same ground. In this way, digital overlays complement the otherwise vacant "fields," embedding them with historical narratives that contribute to more engaging visitor experiences. By allowing audiences to "see" reconstructed events, these visualisations provide not only educational value but also immersive experiences that stimulate the senses and deepen appreciation of such sites. Achieving this effect requires the application of advanced VR and AR technologies, which can transport users into virtual historical environments and effectively bridge past and present. Beyond passive viewing, this digital "theatre of history" enables the reconstruction and re-experiencing of pivotal events, offering a contemporary means of commemoration and interpretation[853]. Crucially, such digital reconstructions are non-invasive, reversible, and transparent in their methodology, aligning with international conservation principles such as those articulated in the Venice Charter, the London Charter, and the Seville Principles. In this way, immersive technologies not only enhance public engagement but also remain consistent with the ethical frameworks of heritage conservation.

Motivated by the potential of the research and the outcomes of the thesis, the author chose to continue this work during PhD studies, with the aim of deepening the investigation and refining the methodologies employed. During this period, two peer-reviewed articles on Westerplatte were published[854], each contributing valuable insights to the field. The first, *Where the Second World War in Europe Broke Out: The Landscape History of Westerplatte, Gdańsk/Danzig*[855], examined the urban and landscape transformation of the peninsula over time, providing a historical framework for understanding its evolution. The second, *Architecture and History of the New Barracks at Westerplatte 1933–2023*[856], focused on the remains of the New Barracks, presenting the findings of detailed architectural investigations carried out on site. The decision to publish these studies separately reflected the distinct scales of inquiry and the extensive scope of the material, allowing each dimension to be explored comprehensively. Although these publications represent significant progress, the topic remains open and continues to pose multifaceted challenges. Research on Westerplatte is ongoing, and further articles are planned for publication following the completion of this dissertation.

---

[852] Agnieszka Gębczyńska-Janowicz, "Virtual Reality Technology in Architectural Education," *World Transactions on Engineering and Technology Education* 18 (2020): 24–28.

[853] During the master thesis the goal was archived partially, with use of low budged technologies, but later was extended with the studies that covered the PhD topic.

[854] The publication of the two multi-author articles in peer-reviewed journals was the result of joint cooperation with colleagues who had also been researching the Westerplatte Peninsula. The author of this thesis was a contributing co-author, and it is important to emphasize that the work was a collaborative effort rather than an individual endeavour. This collective approach highlights the interdisciplinary and shared commitment to advancing the understanding of this complex and historically significant site.

[855] Wojciech Samól, Szymon Kowalski, Arkadiusz Woźniakowski, and Piotr Samól, "Where the Second World War in Europe Broke Out: The Landscape History of Westerplatte, Gdańsk/Danzig," *Land* 12, no. 3 (2023): 596, https://doi.org/10.3390/land12030596.

[856] Szymon Kowalski and Wojciech Samól, "Architektura oraz historia tzw. nowych koszar na Westerplatte w latach 1933–2023 [Architecture and History of the New Barracks at Westerplatte 1933–2023]," *Przegląd Wojskowo-Historyczny* 2024, no. 2: 92–139, https://doi.org/10.32089/WBH.PHW.2024.2(288).0004.

Building on these foundations, the Museum of the Second World War in Gdańsk recognized the value of the research outcomes and initiated the project *Cyfrowe Westerplatte* (Digital Westerplatte), which it also funded. This initiative focused on scanning and digitally representing objects, producing 3D-printed models, and creating digital reconstructions based on prior studies. Previously scanned objects were also donated to the museum as part of the scientific cooperation between the Department of Architecture at Gdańsk University of Technology and the museum. The project seeks to address ongoing disputes surrounding Westerplatte through technological means and the virtualization of heritage, while simultaneously broadening access to the site. Among its outcomes are virtual tours of restricted-access areas such as the bunker beneath Guardhouse No. 1 and the interior of the "Fort" emplacement. In this way, *Digital Westerplatte* not only enhances accessibility and public engagement but also demonstrates how digital methods can provide non-invasive, reversible, and transparent approaches to interpreting contested heritage.

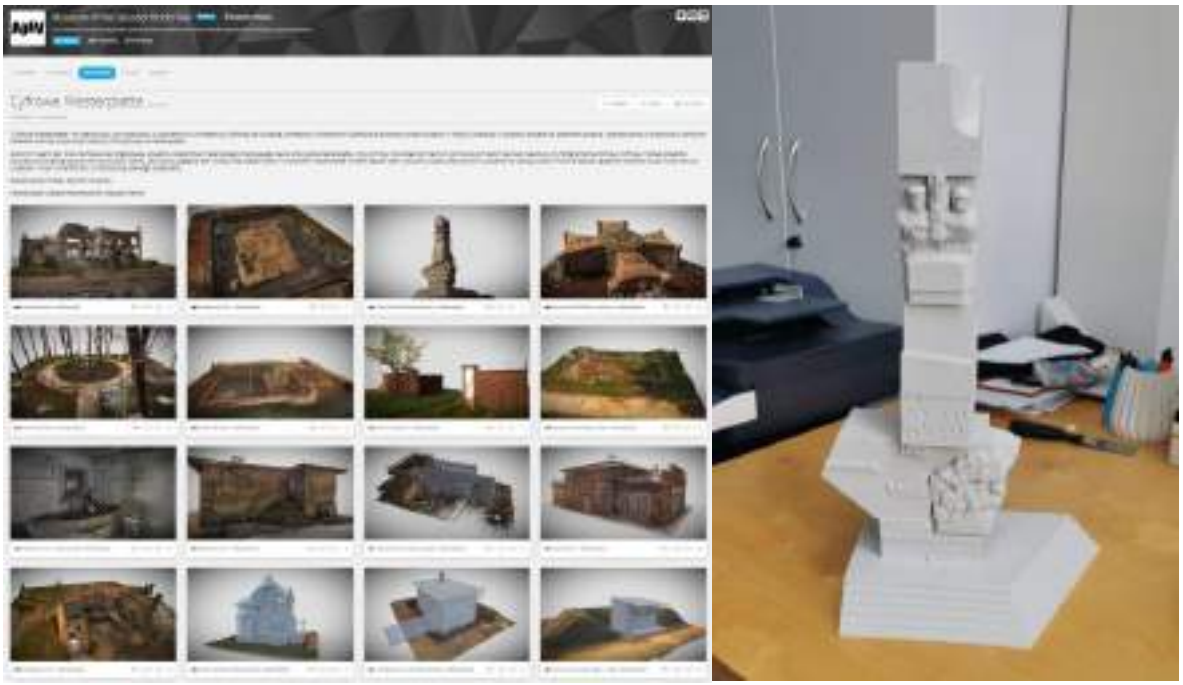


Fig. 188. Project "Digital Westerplatte." Left: 3D models of scanned and digitally reconstructed objects around Westerplatte, made available online via the Sketchfab platform. Right: 3D-printed model of a scanned monument. Source: author.

State of knowledge

The history of Westerplatte has been examined extensively, with particular emphasis on the defence of September 1939. The literature can be divided into several groups corresponding to different historical phases of the peninsula[857].

The earliest studies focus on the fortifications at the mouth of the Vistula River and the role of the Wisłoujście Fortress in shaping the area's development. This contextual background is essential, as it situates Westerplatte within the broader defensive system of Gdańsk. A second body of works addresses the 19th century, when Westerplatte flourished as a sea-bathing resort connected to the

[857] Given the extensive body of literature on the topic, the author will focus solely on works directly related to the subject of this study. These include those addressing the architectural history, the archaeological research on the buildings, conservation issues, and the commemoration of the peninsula.

neighbouring New Port[858]. Although this period has attracted less scholarly attention, it is crucial for understanding the peninsula's transformation prior to its military use, and it marks the point of transition from leisure landscape to fortified site.

The years 1918–1945 constitute the most intensively researched period, with September 1939 forming the historiographical core. Among the most influential works is the memoir of Franciszek Dąbrowski[859], second-in-command during the defence, which provides a vivid first-hand account. Its value lies in perspective, though like all memoirs it must be read critically. Complementing this is Michał Jałowiecki's *Wolne Miasto*[860], which, through the author's family connections, offers unique insight into the acquisition of land for the Military Transit Depot. Post-war syntheses, such as Zbigniew Flisowski's 1959 volume[861] and Stanisława Górkiewicz's[862] related account, established the dominant narrative for decades, relying heavily on soldiers' recollections. Their importance is undeniable, though they often present a heroic, sometimes uncritical perspective shaped by their time of writing. Rafał Witkowski's work advanced the field by moving beyond narrative synthesis to examine investment works, fortifications, and storage facilities in detail, thereby linking the architectural remains directly to the outbreak of the Second World War[863]. This shift from recollection to material culture marked an important historiographical turning point.

Subsequent studies have been especially marked by Andrzej Drzycimski, whose long-standing engagement produced a series of studies addressing personnel composition, the verification of memories, and the broader military history of the depot[864]. His work remains central for scholars seeking a more critical and source-based approach. Other contributions, such as those by Mariusz Wojtowicz-Podhorski, associated with the reconstruction group *Stowarzyszenie Rekonstrukcji Historycznej Wojskowej Składnicy Tranzytowej na Westerplatte*, reflect the intersection of scholarship, reenactment, and popular history[865]. In addition, studies disseminated through the Museum of the Second World War's website have broadened public access to new findings[866], while Krzysztof Zajączkowski has examined the mythologisation of the Polish defence, critically addressing the ways in which memory and narrative have shaped perceptions of Westerplatte[867].

In recent years, archaeological excavations have significantly expanded the scope of research findings[868]. These investigations have generated a substantial body of scientific literature, contributing

[858] Janusz Dargacz, *Od Sopotu po Stogi. Początki kąpielisk morskich w okolicach Gdańska (1800–1870)*, Monografie Muzeum Gdańska, t. 3 (Gdańsk: Muzeum Gdańska, 2020).

[859] Franciszek Dąbrowski, *Wspomnienia z obrony Westerplatte* (Gdańsk: Gdańskie Towarzystwo Naukowe, 1957).

[860] Mieczysław Jałowiecki, *Wolne Miasto*, ed. and arranged by Michał Jałowiecki (Warszawa: Czytelnik, 2002).

[861] Zbigniew Flisowski, *Westerplatte* (Warszawa: Wydawnictwo Ministerstwa Obrony Narodowej, 1965).

[862] Stanisława Górnikiewicz, *Lwy z Westerplatte* (Gdańsk: Wydawnictwo Morskie, 1983).

[863] Rafał Witkowski, *Westerplatte. Historia i dzień dzisiejszy* (Gdańsk: Wydawnictwo Morskie, 1977).

[864] Andrzej Drzycimski, *Westerplatte 1939: historia i legenda: przed szturmem* (Gdańsk: Słowo/obraz terytoria, 2009); Andrzej Drzycimski, *Reduta w budowie* (Gdańsk: Fundacja Gdańska, 2014); Andrzej Drzycimski, *Reduta wojenna* (Gdańsk: Fundacja Gdańska, 2014); Andrzej Drzycimski, *Westerplatte: kulisy niemieckiej wojny propagandowej* (Gdańsk: Muzeum Gdańska, 2019).

[865] Mariusz Wójtowicz-Podhorski, *Westerplatte 1939* (Gdańsk: AJ-Press, 2009).

[866] "Historia półwyspu Westerplatte," *Muzeum II Wojny Światowej*, April 1, 2020, accessed January 24, 2025, https://muzeum1939.pl/historia-polwyspu-westerplatte-m2wswirtualnie/aktualnosci/3298.html.

[867] Krzysztof Zajączkowski, *Westerplatte jako miejsce pamięci 1945–1989* (Warszawa: Wydawnictwo IPN, 2015).

[868] Adam Dziewanowski, Filip Kuczma, and Wojciech Samól, "Badania archeologiczne pola bitwy na Westerplatte," in *Materialne pozostałości konfliktów i zbrodni XX wieku w świetle najnowszych badań archeologicznych*, ed. Hanna Mik and Wirginia Węglińska (Gdańsk: Muzeum II Wojny Światowej, 2019), 235–75; 2. Arkadiusz Woźniakowski, "Historia i materialne relikty fortyfikacji Westerplatte sprzed 1920 r.," in *Materialne pozostałości konfliktów i zbrodni XX wieku w świetle najnowszych badań archeologicznych*, ed. Hanna Mik and Wirginia Węglińska (Gdańsk: Muzeum II Wojny Światowej, 2019),

new insights into the peninsula's material culture and validating, challenging, or refining earlier narratives. Finally, a distinct category of works focuses on Westerplatte as a commemorative site and the conflicts surrounding memory policy[869]. Several of these emerged from conferences organised by the Museum of Gdańsk, which highlighted competing approaches to reconstruction and commemoration, demonstrating that Westerplatte is not only a site of history but also of ongoing debate about heritage, identity, and memory politics[870].

History of the peninsula[871]

> *The Westerplatte Peninsula, located at the former mouth of the Vistula River in Gdańsk, has a complex history shaped by military, political, recreational, and economic interests. Above all, it is remembered as the site of the first battle of the Second World War and as a symbol of Polish resistance and martyrology.*
>
> *Westerplatte emerged in the late seventeenth century as two islands, Osterplatte and Westerplatte, formed by river alluvium. Separated from the mainland by a shallow lagoon later regulated as a canal, the area became Gdańsk's main harbour entrance after a dam was built to prevent silting. Its military role began during the War of the Polish Succession (1733–1738), when French troops supporting Stanisław Leszczyński constructed provisional fortifications that were soon abandoned.*
>
> *The First Partition of Poland (1772) increased the peninsula's importance under Prussian control. A tax chamber and warehouses were established, followed by earthen batteries and ramparts in the 1780s. During the Napoleonic Wars, Gdańsk became a Free City under French protection, and Westerplatte's fortifications were strengthened but tested and damaged during the 1813 siege.*
>
> *Natural disasters in 1828 and 1840 reshaped the Vistula's course, turning Westerplatte from an island into a peninsula. This enabled the development of a popular spa resort with sea*

276–303; Andrzej Ditrich, "Rekonstrukcje komputerowe historycznych budowli na terenie byłej Wojskowej Składnicy Tranzytowej na Westerplatte," in *Materialne pozostałości konfliktów i zbrodni XX wieku w świetle najnowszych badań archeologicznych*, ed. Hanna Mik and Wirginia Węglińska (Gdańsk: Muzeum II Wojny Światowej, 2019), 363–92; Adam Dziewanowski, Piotr Kalka, Filip Kuczma, and Wojciech Samól, "Badania archeologiczne pola bitwy na Westerplatte. Wyniki prac prowadzonych w latach 2018–2019 na obszarze kasyna podoficerskiego Wojskowej Składnicy Tranzytowej," *Wojna i Pamięć,* no. 4 (2022): 154–93;

[869] Tomasz Błyskosz, "Westerplatte – przekształcenia pola bitwy po 1945 r. (do początku XXI w.)," in *Materialne pozostałości konfliktów i zbrodni XX wieku w świetle najnowszych badań archeologicznych*, ed. Hanna Mik and Wirginia Węglińska (Gdańsk: Muzeum II Wojny Światowej w Gdańsku, 2019), 342–62; Waldemar Ossowski, "Westerplatte – obraz przemian po II wojnie," in *Historia jako pokusa. Spojrzenie przez pryzmat Westerplatte*, ed. Janusz Marszalec (Gdańsk: Wydawnictwo Muzeum Gdańska, 2021), 127–46; Monika Trojanowska, "The New Approach to Commemorating Open-Air War Sites on the Example of the Museum of Westerplatte and the 1939 War in Gdańsk, Poland," *Muzeológia a kultúrne dedičstvo* 11, no. 3 (2023): 37–51, https://doi.org/10.46284/mkd.2023.11.3.3; Trojanowska, Monika. 2023. "The New Approach to Commemorating Open-Air War Sites on the Example of the Museum of Westerplatte and the 1939 War in Gdańsk, Poland." Muzeológia a Kultúrne Dedičstvo 11 (3): 37–51. https://doi.org/10.46284/mkd.2023.11.3.3.

[870] Małgorzata Omilanowska, "Architektura rekonstrukcyjna pomiędzy polityką historyczną a komercją," in *Historia jako pokusa. Spojrzenie przez pryzmat Westerplatte*, ed. Janusz Marszalec (Gdańsk: Wydawnictwo Muzeum Gdańska, 2021), 107–26.

[871] The history of the peninsula has already been presented in detail in a publication. For the sake of clarity, the present work includes only a highly abridged version of that study, intended to introduce the reader to the topic and summarised by the author as a direct continuation of the research. This approach has been adopted to avoid self-plagiarism and to emphasise the collaborative nature of the project. All literature references and archival materials cited in the original article are not repeated here but may be consulted in the published text.

See Wojciech Samól, Szymon Kowalski, Arkadiusz Woźniakowski, and Piotr Samól, "Where the Second World War in Europe Broke Out: The Landscape History of Westerplatte, Gdańsk/Danzig," *Land* 12, no. 3 (2023): 596, https://doi.org/10.3390/land12030596.

baths, hotels, and villas, while Prussian authorities continued to fortify the area with coastal batteries. By the turn of the twentieth century, observation bunkers and new artillery emplacements were added.

The Treaty of Versailles (1919) made Gdańsk a demilitarised Free City, though Poland was granted rights to use the port. In 1924 the League of Nations authorised a Polish Military Transit Depot on Westerplatte. Poland secretly purchased land, building warehouses, barracks, guardhouses, and shelters, discreetly strengthening defences despite League restrictions.

On 1 September 1939, German forces attacked Westerplatte, where a small Polish garrison resisted for seven days before surrendering. The defence became a national symbol of courage. Afterwards, German forces dismantled much of the depot with forced labour from the Stutthof concentration camp, leaving the peninsula largely neglected for the rest of the war.

After 1945, Westerplatte lost its military role but grew as a commemorative site. A symbolic cemetery for the defenders was created in 1946, and in 1966 a monumental modernist memorial was erected on an artificial hill, which still dominates the site.

Today, Westerplatte remains a place of national remembrance but also of debate, as military use, port expansion, and conservation interests compete. Its layered history reflects broader geopolitical forces that have shaped both Gdańsk and Poland.

5.3.2. Conservation, authenticity and shifting memory politics[872]

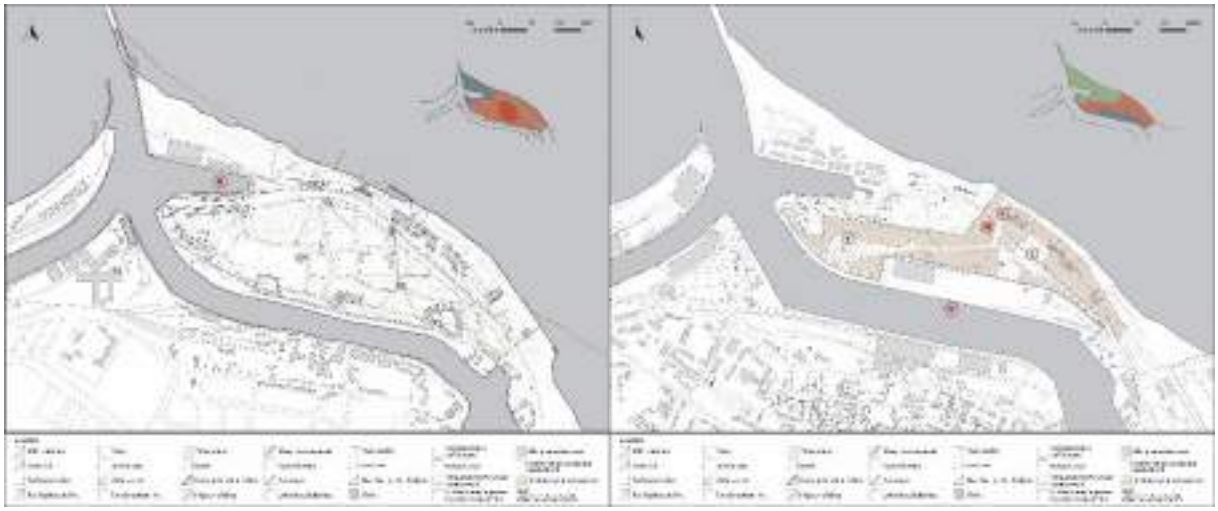


Fig. 189. Comparison between Westerplatte layout. Left map dated 1936, Right map dated 2021, (Source: Samól et al., "Where the Second World War in Europe Broke Out," *Land*, 2023 [873]).

The politics of conservation and commemoration at Westerplatte have been widely discussed, though often in uneven depth. Monika Trojanowska's 2023 article[874] offered a descriptive overview but treated

[872] This paragraph represents a broad development and update of the work the author began during his master's thesis.

[873] Wojciech Samól, Szymon Kowalski, Arkadiusz Woźniakowski, and Piotr Samól, "Where the Second World War in Europe Broke Out: The Landscape History of Westerplatte, Gdańsk/Danzig," *Land* 12, no. 3 (2023): 596, https://doi.org/10.3390/land12030596.

[874] Trojanowska, Monika. "The New Approach to Commemorating Open-Air War Sites on the Example of the Museum of Westerplatte and the 1939 War in Gdańsk, Poland." *Muzeológia a kultúrne dedičstvo* 11, no. 3 (2023): 37–51. https://doi.org/10.46284/mkd.2023.11.3.3.

the issue of authenticity only superficially, omitting the long-term shifts in memory politics[875]. More valuable contributions have been made by Krzysztof Zajączkowski[876], Tomasz Błyskosz[877] and Waldemar Ossowski[878], who document the site's commemorative history. Nevertheless, the complexity of Westerplatte requires a dedicated synthesis focusing on authenticity, architectural remains, and their role in the evolving politics of memory.

1945–1966: Early commemorations and deliberate destruction

The problem of authenticity emerged immediately after the war. The New Barracks, a central structure of the Military Transit Depot and a direct witness to the 1939 battle, survived both the September bombardments and the 1945 fighting. Yet it was deliberately demolished by sappers disposing of explosives. This act erased one of the most significant relics of the site and symbolically severed links to the material culture of the Second Polish Republic[879].

The first commemorative gesture occurred in 1945, when Franciszek Dąbrowski[880] erected a cross at Guardhouse No. 5, destroyed by a Stuka air raid on 2 September 1939. Around this cross, the first cemetery for Polish defenders was created. In 1962, however, the cross was removed by communist authorities and replaced with a Soviet T-34 tank[881], an ideological substitution tied partly to the anticipated, though ultimately unrealised, visit of Nikita Khrushchev[882].

1966–2016: Monumentalisation and compromised preservation

In 1963, a national competition was launched for the development of a commemorative complex[883]. The winning design, by Franciszek Duszeńko, Adam Haupt, and Henryk Kitowski, envisioned a monumental composition with a mound crowned by a massive sculpture[884]. Only the central monument was realised[885], inaugurated in 1966, but it became one of Poland's most recognisable memorials. Its construction, however, had significant consequences: new pathways and car parks ignored the garrison layout, and the main compositional axis cut through the ruins of the New

[875] In the author's view, the article is highly unsatisfactory, despite its publication in a top-tier journal listed by the Polish Ministry of Science. Although it recounts the site's history, it overlooks key issues, particularly the shifting politics of remembrance that have shaped Westerplatte over time, not only those related to the 2019 conflict. This omission narrows the scope of analysis and excludes essential context for understanding the complexities of the site's conservation and commemoration.

[876] Zajączkowski, Krzysztof. *Westerplatte jako miejsce pamięci 1945–1989*. Warszawa: Wydawnictwo IPN, 2015.

[877] Tomasz Błyskosz, "Westerplatte – przekształcenia pola bitwy po 1945 r. (do początku XXI w.)," in *Materialne pozostałości konfliktów i zbrodni XX wieku w świetle najnowszych badań archeologicznych*, ed. Hanna Mik and Wirginia Węglińska (Gdańsk: Muzeum II Wojny Światowej w Gdańsku, 2019), 342–62.

[878] Waldemar Ossowski, "Westerplatte – obraz przemian po II wojnie," in *Historia jako pokusa. Spojrzenie przez pryzmat Westerplatte*, ed. Janusz Marszalec (Gdańsk: Wydawnictwo Muzeum Gdańska, 2021), 127–46.

[879] Szymon Kowalski and Wojciech Samól, "Architektura oraz historia tzw. nowych koszar na Westerplatte w latach 1933–2023," *Przegląd Historyczno-Wojskowy* 25, no. 2 (2024): 92–138, https://doi.org/10.32089/wbh.phw.2024.2(288).0004..

[880] Commanding officer and defender of Westerplatte in September 1939.

[881] The removal of the cross in 1962 and its replacement with a Soviet T-34 tank at Westerplatte can be seen as an act similar to the intentional destruction of the New Barracks. Both actions reflect deliberate efforts to reshape the site's historical narrative and symbolism, aligning it with the prevailing political ideologies of the time.

[882] "Wystawa „1945–2022. Dzieje krzyża na Westerplatte," *Muzeum II Wojny Światowej w Gdańsku*, accessed December 19, 2024, https://muzeum1939.pl/wystawa-19452022-dzieje-krzyza-na-westerplatte/aktualnosci/4805.html.

[883] Interestingly, the maps provided to competition participants still showed material traces of the original 1939 layout.

[884] Source material: APG 2230/114

[885] Ultimately, the museum building, although planned, was never realised. Notable differences also emerged between the initial project layout and its final execution, particularly in the varying sculptural concepts for the monument itself. The absence of the museum was long regarded as a significant shortcoming. In 2023, however, a competition for a new museum building was concluded, and the investment process is now underway.

Barracks[886], further erasing authentic remains. Additional service buildings such as bus stops, a café, a souvenir shop, and toilets were executed in stark, bunker-like, brutalist forms that blurred distinctions between authentic wartime relics and modern additions. While the monument itself has since become a protected heritage object embedded in national identity, it also marked the culmination of a process in which symbolic representation was prioritised over the preservation of authentic fabric, including remnants of the former spa district that underpinned the 1939 depot[887].

At the same time, Guardhouse No. 1 faced demolition during port canal expansion. Its preservation was secured in 1967 thanks to the *Towarzystwo Opieki nad Zabytkami* (Society for the Care of Historical Monuments), which relocated the structure 80 metres inland using a specially designed rail platform[888]. Adapted as a memorial room and small museum, the guardhouse remains one of the few surviving elements of the 1939 battle. In 1974 the peninsula was inscribed in the register of monuments, and in 2003 it was elevated to the rank of Polish historical monument by presidential decree[889].

2016–today: Conflicts, archaeology, and new projects

Over the years, the Westerplatte site has largely adhered to the vision established in the 1966 concept[890]. In 2016, memory politics around Westerplatte entered a new phase. The Museum of the Second World War in Gdańsk, founded in 2008[891] under Prime Minister Donald Tusk to present the war in a broad international context[892], was merged in 2017 with the Westerplatte Museum under the Ministry of Culture[893]. This merger led to changes in the main exhibition and the dismissal of its director,

[886] Szymon Kowalski and Wojciech Samól, "Architektura oraz historia tzw. nowych koszar na Westerplatte w latach 1933–2023," *Przegląd Historyczno-Wojskowy* 25, no. 2 (2024): 98, https://doi.org/10.32089/wbh.phw.2024.2(288).0004

[887] Other competition entries likewise proposed a comprehensive redevelopment of the peninsula, with little regard for preserving the surviving relics apart from the already demolished barracks, despite the site's central place in Polish historical memory. As a result, these interventions have diminished visitors' ability to recognise the authenticity and integrity that are fundamental to a historical landmark.

[888] "Przesunięcie Wartowni nr 1," *Muzeum II Wojny Światowej w Gdańsku*, accessed December 22, 2024, https://muzeum1939.pl/przesuniecie-wartowni-nr-1/timeline/217.html; "Przesunięcie Wartowni nr 1," *personal site of Tomasz Pluciński* (University of Gdańsk), accessed December 22, 2024, http://www.tomek.strony.ug.edu.pl/wartownia; "Wartownia nr 1 na Westerplatte," *Muzeum Gdańska*, accessed December 22, 2024, https://muzeumgdansk.pl/oddzialy-muzeum/wartownia-nr-1-na-westerplatte/.

[889] "Pole bitwy na Westerplatte," *Zabytek.pl*, accessed December 24, 2024, https://zabytek.pl/pl/obiekty/gdansk-pole-bitwy-na-westerplatte-111.

[890] Conservation measures have been undertaken at Westerplatte to stabilise the permanent ruins of the New Barracks. Another issue concerns the eventual removal of the Soviet-made T-34 tank, once presented as belonging to the 1st Brigade of Heroes of Westerplatte. Initially placed in the cemetery and later moved onto a pedestal, the tank has since been removed, although the pedestal remains to this day.

[891] *Zarządzenie Nr 29 Ministra Kultury i Dziedzictwa Narodowego z dnia 1 września 2008 r. w sprawie utworzenia Muzeum Westerplatte w Gdańsku* (Dz. Urz. MKiDN Nr 5, poz. 48).

[892] "Muzeum II Wojny Światowej," *Culture.pl*, added October 8, 2010, accessed December 23, 2024, https://culture.pl/pl/miejsce/muzeum-ii-wojny-swiatowej.

[893] The theme of Westerplatte became a focal point in the conflict surrounding the Second World War Museum in Gdańsk, particularly after the 2017 decision to merge it with the Westerplatte and 1939 War Museum. The Ministry of Culture justified the merger by arguing that the new institution should more prominently highlight the heroism of Polish soldiers and the defence of Westerplatte as a symbol of Polish resistance. The changes, however, provoked controversy, with some academics criticising the disproportionate emphasis on Westerplatte for narrowing the museum's broader international narrative.

See *Zarządzenie nr 41 Ministra Kultury i Dziedzictwa Narodowego z dnia 26 listopada 2008 r. zmieniające zarządzenie w sprawie utworzenia Muzeum Westerplatte w Gdańsku*, Dz. Urz. MKiDN nr 7, poz. 70 (2008); *Obwieszczenie Ministra Kultury i Dziedzictwa Narodowego z dnia 15 kwietnia 2016 r. o zamiarze i przyczynach połączenia państwowych instytucji kultury Muzeum II Wojny Światowej w Gdańsku oraz Muzeum Westerplatte i Wojny 1939*, Biuletyn Informacji Publicznej MKiDN (2016)

Professor Paweł Machcewicz[894]. The shift narrowed the interpretative focus to Polish martyrdom and resistance, sparking criticism of political interference in museum narratives[895]. The controversy soon grew into a broader debate about the independence of cultural institutions and the politics of historical memory in Poland[896].

The institutional restructuring also initiated systematic archaeological research for the first time since 1945[897]. Excavations uncovered a wealth of artefacts, ordnance[898], and the remains of both Polish and German soldiers, expanding knowledge of the site's material history[899].

In 2019, the government created the Museum of Westerplatte and the 1939 War as a branch of the Museum of the Second World War, assuming control of the peninsula through a controversial expropriation law[900]. Following the acquisition of the site, initiatives have been launched to construct

[894] Decisions regarding the changes became the subject of litigation. In 2017, the Provincial Administrative Court temporarily halted the merger of the museums; however, the Supreme Administrative Court ultimately ruled in favour of the Ministry.

[895] "Poland vs. History Museum, Gdańsk," *The New York Review of Books*, May 3, 2016, accessed December 23, 2024, https://www.nybooks.com/online/2016/05/03/poland-vs-history-museum-gdansk; "Trzy recenzje są podstawą krytyki PiS wobec Muzeum II Wojny Światowej: jako pierwsi ujawniamy, co w nich jest," *Gdansk.pl*, July 9, 2016, accessed December 23, 2024, https://www.gdansk.pl/wiadomosci/Trzy-recenzje-sa-podstawa-krytyki-PiS-wobec-Muzeum-II-Wojny-Swiatowej-Jako-pierwsi-ujawniamy-co-w-nich-jest,a,57214; "MIIWŚ. Nowy dyrektor zapowiada rychłe zmiany na wystawie," *Gdansk.pl*, May 21, 2017, accessed December 23, 2024, https://www.gdansk.pl/wiadomosci/MIIWS-Nowy-dyrektor-zapowiada-rychle-zmiany-na-wystawie,a,78475#.WSHitVP8v6w.facebook; Michał Sutowski and Agnieszka Wiśniewska, "Muzeum refleksyjne, czyli sprzeczne z polską racją stanu," *Krytyka Polityczna*, April 5, 2017 (updated February 5, 2020), accessed December 23, 2024, https://krytykapolityczna.pl/kraj/muzeum-ii-wojny; "Historycy z całego świata przeciwni łączeniu Muzeum II WS – oświadczenie," *Trojmiasto.wyborcza.pl*, accessed December 23, 2024, https://trojmiasto.wyborcza.pl/trojmiasto/7,35612,21641103,historycy-z-calego-swiata-przeciwni-laczeniu-muzeum-ii-ws-oswiadczenie.html?disableRedirects=true.

[896] **The author wishes to emphasise that the political conflict described serves only as contextual background to the issues surrounding the Westerplatte Peninsula. The author seeks to distance himself from this political dispute, adopting the role of a passive observer and focusing solely on reporting the existing situation in this work.**

[897] By December 2024, 11 phases of archaeological excavations had been completed.

Alongside the archaeological excavations and research, some of the foundations of other buildings were uncovered. While some remains remain buried underground, they have been excavated, studied, documented, and reburied to support future conservation efforts. Therefore, it is possible to consider these as authentic relics.

At this point, I would also like to express my gratitude to Wojciech Samól for providing me with the opportunity to visit the ongoing excavations on multiple occasions, starting in 2019.

See "Badania archeologiczne na Westerplatte," *Muzeum II Wojny Światowej w Gdańsku*, accessed December 23, 2024, https://muzeum1939.pl/badania-archeologiczne-Westerplatte.

[898] "Ponad 4700 niebezpiecznych przedmiotów i niemalże 3800 historycznych artefaktów znaleziono podczas prac saperskich na Westerplatte!," *Muzeum II Wojny Światowej w Gdańsku*, June 7, 2024, accessed December 23, 2024, https://muzeum1939.pl/ponad-4700-niebezpiecznych-przedmiotow-i-niemalze-3800-historycznych-artefaktow-znaleziono-podczas/aktualnosci/7045.html; "Poznaj obrońców," *Muzeum II Wojny Światowej w Gdańsku*, accessed December 23, 2024, https://muzeum1939.pl/node/5954.

[899] Sławomir Rut, Wojciech Samól, and Jarosław Tuliszka, *Westerplatczycy – lista 1939: skład załogi Wojskowej Składnicy Tranzytowej na Westerplatte w Wolnym Mieście Gdańsku 1 września 1939 r.* (Gdańsk: Muzeum II Wojny Światowej, 2023); Wojciech Samól, "Stan osobowy Wartowni nr 5 a pochówki przy willi oficerskiej na Westerplatte we wrześniu 1939 r. w świetle źródeł archiwalnych, wspomnień i relacji," *Wojna i Pamięć: Czasopismo Muzeum II Wojny Światowej w Gdańsku* 1 (2020): 46–99; Adam Dziewanowski, Piotr Kalka, Filip Kuczma, and Wojciech Samól, "Badania archeologiczne pola bitwy na Westerplatte. Wyniki prac prowadzonych w latach 2018–2019 na obszarze kasyna podoficerskiego Wojskowej Składnicy Tranzytowej," *Wojna i Pamięć: Czasopismo Muzeum II Wojny Światowej w Gdańsku* 4 (2022): 154–93; Filip Kuczma, Wojciech Samól, and Karol Szejko, eds., *Westerplatte w 7 odsłonach: prezentacja zabytków pierwszego etapu badań archeologicznych na Westerplatte* (Gdańsk: Muzeum II Wojny Światowej, 2019); Adam Dziewanowski, Filip Kuczma, and Wojciech Samól, "Badania archeologiczne pola bitwy na Westerplatte. Wyniki prac prowadzonych w latach 2016–2017," in *Materialne pozostałości konfliktów i zbrodni XX wieku w świetle najnowszych badań archeologicznych*, ed. Hanna Mik and Wirginia Węglińska (Gdańsk: Muzeum II Wojny Światowej, 2019), 235–75.

[900] "Oficjalnie: PiS znacjonalizował Westerplatte. Gdańsk stracił teren," *Trojmiasto.wyborcza.pl*, accessed December 23, 2024, https://trojmiasto.wyborcza.pl/trojmiasto/7,35612,26191279,oficjalnie-pis-znacjonalizowal-westerplatte-gdansk-stracil.html; "Sesja Rady Miasta Gdańska: radni przyjęli apel w obronie terenów Westerplatte," *Gdansk.pl*, accessed

a dedicated exhibition building for the Museum of Westerplatte[901]. Plans announced by Jarosław Sellin[902] and Karol Nawrocki[903] to reconstruct several depot buildings, including villas, warehouses, and gates[904], at a projected cost of over 200 million PLN provoked criticism from scholars, who argued that creating non-authentic fabric would distort the historical record[905].

December 23, 2024, https://www.gdansk.pl/wiadomosci/Sesja-Rady-Miasta-Gdanska-Radni-przyjeli-apel-w-obronie-terenow-Westerplatte,a,146892; "Westerplatte: oświadczenie Muzeum Gdańska w sprawie rzekomej prywatyzacji," *Media.gdansk.pl*, accessed December 23, 2024, https://media.gdansk.pl/komunikaty/445507/westerplatte-oswiadczenie-muzeum-gdanska-w-sprawie-rzekomej-prywatyzac; "Muzeum II Wojny twierdzi, że po wyroku NSA nadal jest posiadaczem terenu," *Trojmiasto.wyborcza.pl*, accessed December 23, 2024, https://trojmiasto.wyborcza.pl/trojmiasto/7,35612,27583465,muzeum-ii-wojny-twierdzi-ze-po-wyroku-nsa-nadal-jest-posiadaczem.html; "Teren Westerplatte wraca do miasta Gdańska. Jest ostateczny wyrok," *Trojmiasto.wyborcza.pl*, accessed December 23, 2024, https://trojmiasto.wyborcza.pl/trojmiasto/7,35612,27582288,teren-westerplatte-wraca-do-miasta-gdanska-jest-ostateczny.html; "Blisko 14 mln zł odszkodowania dla Gdańska za przejęcie Westerplatte," *Trojmiasto.pl*, accessed December 23, 2024, https://www.trojmiasto.pl/wiadomosci/Blisko-14-mln-zl-odszkodowania-dla-Gdanska-za-przejecie-Westerplatte-n189799.html; "Westerplatte w księdze wieczystej nadal własnością Gdańska," *Trojmiasto.wyborcza.pl*, accessed December 23, 2024, https://trojmiasto.wyborcza.pl/trojmiasto/7,35612,27625242,westerplatte-w-ksiedze-wieczystej-nadal-wlasnoscia-gdanska.html; "Gdańsk: radni protestują ws. wywłaszczenia Westerplatte," *Interia.pl*, accessed December 23, 2024, https://wydarzenia.interia.pl/pomorskie/news-gdansk-radni-protestuja-ws-wywlaszczenia-westerplatte,nId,3018266; Socha, Ryszarda. "Wojna o Westerplatte wciąż trwa." *Polityka*, July 10, 2018. Accessed December 23, 2024. https://www.polityka.pl/tygodnikpolityka/spoleczenstwo/1755390,1,wojna-o-westerplatte-wciaz-trwa.read

[901] "Dyrektor MIIWŚ: jesteśmy zdeterminowani, aby na Westerplatte powstało muzeum," *Dzieje.pl*, April 25, 2018, accessed December 23, 2024, https://dzieje.pl/aktualnosci/dyrektor-miiws-jestesmy-zdeterminowani-aby-na-westerplatte-powstalo-muzeum.

[902] Jarosław Sellin, *"There will be seven reconstructed buildings of the military transit depot. The area of the permanent exhibition of the Museum of Westerplatte and the War of 1939 will be almost 3,500 m². The whole, so we estimate today, to complete this investment, will cost over 200 million zlotys."*

See Muzeum II Wojny Światowej w Gdańsku, Recording of the Full Conference Program, YouTube video, accessed December 23, 2024, *Prezentacja założeń programowych dla inwestycji Muzeum Westerplatte i Wojny 1939*, YouTube video, [documented by Muzeum II Wojny Światowej w Gdańsku], https://www.youtube.com/watch?v=RQ_1hNy63ao; "Budowa Muzeum Westerplatte i Wojny 1939 – założenia programowe," *Ministerstwo Kultury i Dziedzictwa Narodowego*, August 25, 2020, accessed December 23, 2024, https://www.gov.pl/web/kultura/budowa-muzeum-westerplatte-i-wojny-1939--zalozenia-programowe.

[903] Karol Nawrocki, *"Our experts have prepared a concept in which we will find a certain balance between conservation activities, reconstruction of part of the Depot and creation of a modern museum space. According to our research, this is exactly how Poles imagine Westerplatte. 75% of them declare that an open-air museum on Westerplatte is the best solution, the reconstruction of historical buildings is supported by 51% of respondents, and 36% expect the Museum to combine modern architecture with the reconstruction of relics. Our vision meets social expectations,"*
See Muzeum II Wojny Światowej w Gdańsku, Recording of the Full Conference Program, YouTube video, accessed December 23, 2024, *Prezentacja założeń programowych dla inwestycji Muzeum Westerplatte i Wojny 1939*, YouTube video, [documented by Muzeum II Wojny Światowej w Gdańsku], https://www.youtube.com/watch?v=RQ_1hNy63ao; "Budowa Muzeum Westerplatte i Wojny 1939 – założenia programowe," *Ministerstwo Kultury i Dziedzictwa Narodowego*, August 25, 2020, accessed December 23, 2024, https://www.gov.pl/web/kultura/budowa-muzeum-westerplatte-i-wojny-1939--zalozenia-programowe.

[904] This approach stands in fundamental contradiction to the principles of preservation. By reconstructing the destroyed buildings, it would create a temporal distortion, suggesting that the battles of September 1939 and March 1945 had left the structures intact. In reality, the Westerplatte Peninsula witnessed fierce combat in both campaigns: in 1939, Polish forces resisted the German invasion, while in 1945, German troops defended the site against the Soviet advance. Such reconstructions would thus amount to fabricating non-authentic heritage objects, ultimately compromising the historical integrity of the site.

[905] Małgorzata Omilanowska, "Architektura rekonstrukcyjna pomiędzy polityką historyczną a komercją," in *Historia jako pokusa. Spojrzenie przez pryzmat Westerplatte*, ed. Janusz Marszalec (Gdańsk: Wydawnictwo Muzeum Gdańska, 2021), 107–26; Małgorzata Omilanowska, "Omilanowska o rewitalizacji Westerplatte: to skrajna niekompetencja," *Trojmiasto.wyborcza.pl*, accessed December 22, 2024, https://trojmiasto.wyborcza.pl/trojmiasto/7,35612,23327590,omilanowska-o-rewitalizacji-westerplatte-to-skrajna-niekompetencja.html; Małgorzata Omilanowska, "Co dalej z Westerplatte? Odpowiada prof. Małgorzata Omilanowska," *Gdańsk.pl*, April 26, 2018; updated May 1, 2018, accessed December 22, 2024, https://www.gdansk.pl/przerobka/co-dalej-z-westerplatte-odpowiada-prof-malgorzata-omilanowska,a,107688.

In response, the City of Gdańsk organised the *Westerplatte Seminar – In Search of Authenticity* (2018), commissioning alternative architectural proposals by Fort Targowski, Restudio, and Proconcept[906]. The architects' presentations, followed by a debate among museum professionals and historians, sparked a broader discussion within the city about the future of this historic site, which holds significant importance[907].

Fig. 190. Conceptual visualisations of reconstructed objects: the railway gate and station building, the non-commissioned officers' villa, the officers' villa, and the munitions warehouse, (source: Gazeta Wyborcza Trójmiasto[908]).

[906] "Jak może wyglądać Westerplatte? Zobacz trzy koncepcje. WIZUALIZACJE," *Gdańsk.pl*, July 12, 2018, accessed December 22, 2024, https://www.gdansk.pl/wiadomosci/Jak-moze-wygladac-Westerplatte-Idee-architektoniczne-i-dyskusja-historykow-w-Dworze-Artusa,a,119656; "Westerplatte – w poszukiwaniu autentyzmu," *Muzeum Gdańska*, accessed December 22, 2024, https://muzeumgdansk.pl/wydarzenia/szczegoly/news/westerplatte-w-poszukiwaniu-autentyzmu/.

[907] Although the concept of the Museum of the Second World War was both ambitious and controversial in terms of conservation doctrine, the work carried out by the Gdańsk Museum proved comparatively limited, involving only minimal intervention in the battlefield, which itself constitutes a monument. This restrained approach avoided harm to the surviving historical fabric but also failed to adequately interpret or present it. Confronted with this tension, the author chose in 2018 to dedicate his master's thesis to Westerplatte, a project that subsequently expanded into a series of scientific studies and ultimately culminated in the present doctoral dissertation. The author's scholarly publications likewise emerged as a direct response to the knowledge gaps revealed in the course of this research.

[908] Visualisations by Aleksandra Wolter, Mezzano. 3D models and architectural reconstructions by Andrzej Ditrich. „Nawrockiego plan na Westerplatte — rekonstrukcja za 100 mln." Gazeta Wyborcza Trójmiasto, April 25, 2018. https://trojmiasto.wyborcza.pl/trojmiasto/7,35612,23321323,nawrockiego-plan-na-westerplatte-rekonstrukcja-za-100-mln.html.

Fig. 191. Conceptual Visualisations by Proconcept, Restudio and Fort Targowski, (source: Museum of Gdańsk[909]).

Excavations carried out during Phase VII uncovered the remains of the Officers' Villa and Guardhouse No. 5, which required the relocation of the 1946 cemetery. These works revealed authentic structural remains, thereby expanding the inventory of historic features on the peninsula and adding new points of interest to its cultural landscape[910]. The newly designed Westerplatte Defenders' Cemetery, created by NM Architects and inaugurated in November 2022, now houses the remains of nine identified Polish defenders[911].

Fig. 192. New Cemetery at Westerplatte Peninsula during night time. Source: author.

[909] Muzeum Gdańska, *Westerplatte… w poszukiwaniu autentyzmu*. Accessed July 1, 2025. https://muzeumgdansk.pl/wydarzenia/szczegoly/news/westerplatte-w-poszukiwaniu-autentyzmu/.

[910] Muzeum II Wojny Światowej. "Etap VII – badania archeologiczne Westerplatte." Accessed December 23, 2024. https://muzeum1939.pl/etapVII-badania-Westerplatte

[911] Muzeum II Wojny Światowej. "Polish Army Soldiers' Cemetery at Westerplatte." Accessed December 23, 2024. https://muzeum1939.pl/cmentarz-zolnierzy-wojska-polskiego-na-westerplatte/.

A two-stage competition in 2023 produced a winning concept[912] for a new museum building on the site originally reserved for the 1966 project[913]. The guidelines prepared for the 2023 design concept emphasise reinforcing authenticity and organising the site in a thoughtful and coherent manner. Unlike earlier reconstruction-oriented visions, this approach adopts a more conservative stance, prioritising authenticity, interpretation, and the careful spatial reorganisation of the peninsula[914].

Fig. 193. Winning design, (source: Architektura i Biznes[915]).

The case of Westerplatte illustrates the complex interplay of politics, conservation, and memory in shaping one of Poland's most symbolic battlefields. The peninsula's layered history, from the 1946 memorial cross to successive archaeological campaigns and contemporary redevelopment plans, reflects shifting interpretations of how the site should be presented. Comparable to Oradour-sur-Glane, Pointe du Hoc, and the USS Arizona Memorial, Westerplatte exemplifies broader debates on authenticity, commemoration, and the role of heritage in constructing national narratives. The

912 "Znamy wyniki konkursu na opracowanie koncepcji projektowej Muzeum Westerplatte i Wojny 1939 – oddziału Muzeum II Wojny Światowej w Gdańsku," *Ministerstwo Kultury i Dziedzictwa Narodowego*, October 31, 2023, accessed December 23, 2024, https://www.gov.pl/web/kultura/znamy-wyniki-konkursu-na-opracowanie-koncepcji-projektowej-muzeum-westerplatte-i-wojny-1939; "Wyniki konkursu na koncepcję projektową MWiW 1939," *Muzeum II Wojny Światowej w Gdańsku*, accessed December 23, 2024, https://muzeum1939.pl/node/5832; "Rozstrzygnięto konkurs na koncepcję Muzeum Westerplatte. Jak wygląda zwycięski projekt," *Gdańsk.pl*, October 31, 2023, accessed December 23, 2024, https://www.gdansk.pl/wiadomosci/Rozstrzygnieto-konkurs-na-koncepcje-Muzeum-Westerplatte-Jak-wyglada-zwycieski-projekt-Muzeum-II-Wojny-Swiatowej-Sellin,a,252784; "Wyniki konkursu na opracowanie koncepcji projektowej Muzeum Westerplatte i Wojny 1939," *Architektura i Biznes*, published October 2023 (approx.), accessed December 23, 2024, https://www.architekturaibiznes.pl/konkurs-wyniki/wyniki-konkursu-na-muzeum-ii-wojny-swiatowej-w-gdansku,30523.html.

913 This concept can be seen as an attempt to realise the previous museum concepts that were never completed. The building was designed for the area originally intended for the first museum project from 1966. It seems that the development concept for Westerplatte is finally set to be fully realised and comprehensive.

914 The current museum's narrative mentions the reconstruction of secondary structures such as warehouses to increase the exhibition space. There is no mention of the reconstruction of the New Barracks, the Officers' Villa, the Non-Commissioned Officer's Villa.

915 "Wyniki konkursu na opracowanie architektoniczno-budowlanej koncepcji projektowej Muzeum Westerplatte i Wojny 1939 – Oddziału Muzeum II Wojny Światowej w Gdańsku," *Architektura i Biznes*, October 2023, accessed December 24, 2024, https://www.architekturaibiznes.pl/konkurs-wyniki/wyniki-konkursu-na-muzeum-ii-wojny-swiatowej-w-gdansku,30523.html.

methodological approach applied here seeks to address these challenges by combining precise documentation with digital reconstruction, enabling both the preservation of authentic fabric and the creation of immersive environments that make the site's history accessible to diverse audiences.

5.3.3 *Guardhouse No. 1* and the *Fort* emplacement – scan-based digitalisation and virtual sightseeing of inaccessible spaces

While the political debates surrounding Westerplatte underscore the contested meaning of authenticity, the preserved structures, such as Guardhouse No. 1 and the Fort, highlight a different challenge: their interiors are physically inaccessible to visitors. In these cases, the role of digitalisation is not to reconstruct lost forms but to provide virtual access through high-resolution laser scanning and immersive sightseeing platforms.

The methodology of virtual sightseeing was first tested with the New Barracks (described later), but it was also extended to the other structures[916]. One example is the bunker beneath Guardhouse No. 1[917], inaccessible to tourists due to its hazardous descent and extremely cramped conditions. Another is the "fort emplacement"[918], originally an artillery rangefinder position built for the coastal batteries in 1911, during the 1939 converted into the strongpoint. Both objects are of particular interest because of their authentic interiors: the bunker remains well preserved, containing machine-gun emplacements and traces of the special construction techniques applied during its relocation in the 1960s, while the fort retains remnants of technical installations, including a radio communication centre.

Following the same approach as with the New Barracks, the author carried out scanning[919] of both interiors and exteriors and prepared scan-based virtual tours on the Sketchfab platform[920]. These digital tours demonstrate the potential of immersive technologies to enhance the visitor experience, providing access through smartphones, web browsers, or full VR emulation. By focusing on the

[916] An additional example addressed by the author during the digitalisation phase, although treated differently from the simulations of inaccessible spaces, is the Westerplatte Monument, also known as the Monument to the Defenders of the Coast. Due to the monument's scale and vertical dimensions, which exceed 25 metres, aerial photogrammetry was employed, as terrestrial laser scanning alone would have been highly inefficient for documenting the upper sections. This method enabled precise data acquisition of the elevated portions, ensuring comprehensive and accurate documentation. The resulting model was presented in a digital guide that allows users to rotate the structure and interact with it in order to examine inscriptions and architectural details. The significance of this case lies less in its technical dimension than in its interpretive implications, as the monument reflects political influence on memory policy, including the incorporation of battlesites such as Studzianki or Lenino, which bore no direct connection to the coastal defence.

See Museum of the Second World War, *Pomnik Obrońców Wybrzeża – Westerplatte*, 3D model by Szymon Kowalski and Wojciech Samól, Sketchfab, published April 9, 2024, https://sketchfab.com/3d-models/pomnik-obroncow-wybrzeza-westerplatte-8d8df2c4c84c4625b8ff59e97baf09eb.

[917] Museum of the Second World War, *Wartownia nr 1 (Izba bojowa) – Westerplatte*, 3D model, model by Szymon Kowalski and Wojciech Samól, Sketchfab, May 20, 2024, https://sketchfab.com/3d-models/wartownia-nr-1-izba-bojowa-westerplatte-c2cab609af9f435ab3bc3de620dc30a5. Sketchfab; Museum of the Second World War, *Wartownia nr1 – Westerplatte*, 3D model, model by Szymon Kowalski and Wojciech Samól, Sketchfab, accessed December 28, 2024, https://sketchfab.com/3d-models/wartownia-nr1-westerplatte-9da2d59a77f848738ada2d8eca6e78df.

[918] Museum of the Second World War, *Placówka "Fort" – Westerplatte*, 3D model, model by Szymon Kowalski and Wojciech Samól, Sketchfab, published August 21, 2024; accessed December 28, 2024, https://sketchfab.com/3d-models/placowka-fort-westerplatte-fb47ac1307ee44c7bf1b499b5c6cd023

[919] The author used the Faro Focus 70 TLS with Faro Scene software, applying the same type of post-production methodology.

[920] Sketchfab is an online platform that allows users to upload, share, and explore 3D models in real time. It supports multiple file formats and interactive viewing, including virtual reality, which has made it a widely used tool for global dissemination. After reviewing alternative platforms, the author selected Sketchfab as the most suitable solution, as its technological capabilities provided all the necessary functions for this project. Its compatibility across devices ensures broad accessibility, while interactive features such as annotations enhance interpretation and support heritage education.

documentation of interiors that remain inaccessible yet materially intact, the virtual tours safeguard authenticity while extending access to otherwise hidden heritage. This approach also broadens the interpretive experience, allowing visitors to engage with authentic spaces without physical risk, thereby democratizing access to fragile sites. In contrast to the New Barracks, where reconstruction fills interpretive gaps, Guardhouse No. 1 and the Fort emphasise the complementary role of pure digitalisation in revealing and preserving existing fabric. Such applications directly align with international conservation doctrine, particularly the principles of non-invasiveness, reversibility, and transparency.

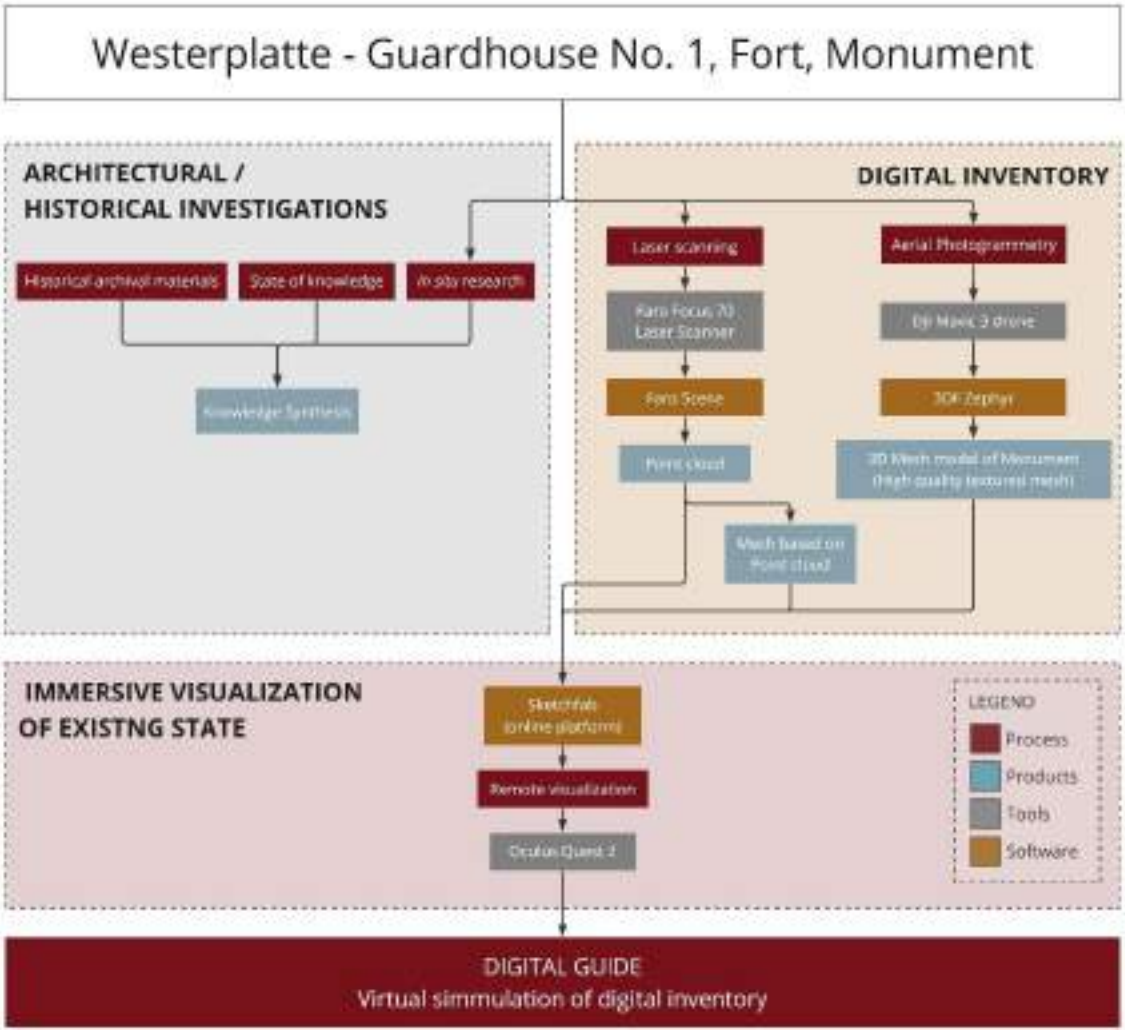


Fig. 194. Methodological scheme of the case study. Source: author.

Fig. 195. Virtual tours of inaccessible spaces: the bunker beneath Guardhouse No. 1 and the fort. Source: author.

5.3.4. *Officers' Villa, Guardhouse No. 5, and Warehouse No. 10* – excavated remains and partial virtual/augmenter reality reconstructions

Beyond the cases of Guardhouse No. 1 and Fort emplacement, several partially preserved and excavated buildings such as the Officers' Villa, Guardhouse No. 5 and Warehouse No. 10 illustrate the potential of combining digital survey with hypothetical reconstruction. Unearthed during a series of archaeological excavations on the peninsula[921], these objects are presented together due to their shared methodological treatment and similar state of preservation[922], limited to the exposed outlines of foundations. In this context, AR overlays tested in situ serve as interpretive tools that suggest past architectural forms while maintaining visible traces of authenticity.

Architectural digital inventory

Similar to the previous example, the initial stage involved creating a digital representation of the remains after conservation, achieved through a series of laser scans that provided a highly accurate record of reality. The entire composition of the new graveyard at Westerplatte was documented to enable online access, with the dataset segmented into distinct models[923], including the remains of the

[921] Muzeum II Wojny Światowej, *Badania archeologiczne na Westerplatte*, accessed December 28, 2024, https://muzeum1939.pl/badania-archeologiczne-Westerplatte; Muzeum II Wojny Światowej, *Etap VII – Badania archeologiczne na Westerplatte*, accessed December 28, 2024, https://muzeum1939.pl/etapVII-badania-Westerplatte.

[922] The authenticity of the site may be understood in relative terms, even though the exposed foundations represent original remnants of the villa. To enhance clarity, aid interpretation, and support preservation, an additional top brick layer was introduced. This layer functions as a visual guide for visitors, reinforcing the intent of the exposition. However, because it is exposed to atmospheric conditions and subject to inevitable weathering, it will require periodic replacement in order to preserve both its structural and aesthetic integrity. This intervention exemplifies the balance between safeguarding historical authenticity and ensuring that the site remains comprehensible and accessible to contemporary audiences.

[923] This decision was driven by clarity and optimisation constraints, as the maximum allowable file size for upload on the Sketchfab platform was 500 MB. Given the extent of the scanned area, the overall number of points had to be reduced. To maintain higher resolution and consequently a greater density of points per square metre, the dataset was divided into smaller models.

Officers' Villa[924], Guardhouse No. 5[925], the new cemetery[926], and the Virtuti Militari Cross[927]. All of these models, prepared by the author, are accessible on the Sketchfab platform as tools for virtual sightseeing.

Fig. 196. Digital Inventory of the remains of Officers' Villa and Guardhouse no. 5. Source: author.

Virtual Reconstruction

To ensure maximum accuracy for virtual reconstruction, the laser scan served as the foundation. The author employed a process of "meshification" (triangulation)[928] , using both the built-in function in Faro Scene and the Poisson Reconstruction function in CloudCompare[929]. This workflow produced a highly accurate 3D mesh model, which then formed the basis for subsequent digital modelling efforts that aimed to recreate objects once present at Westerplatte.

Officers Villa

For the virtual reconstruction model of the Officer's Villa, the author analysed a wide range of archival sources, including photographs retrieved from online platforms as well as materials provided by Wojciech Samól, obtained through his archival queries. Particularly valuable was the electrical installation project, which offered detailed information about the building's interior layout and the partition walls dividing the rooms. The scan provided a precise reference for the building's dimensions, while the photographs contributed essential data about the exterior, even though some views were obstructed by vegetation. To resolve these gaps, the mathematical method of perspective restitution

[924] Museum of the Second World War, *Willa Oficerska – Westerplatte*, 3D model, model by Szymon Kowalski and Wojciech Samól, Sketchfab, published April 24, 2024; accessed December 28, 2024, https://sketchfab.com/3d-models/willa-oficerska-westerplatte-afb7a6a40f6e4e78805b4d69f0f971ac;

[925] Museum of the Second World War, *Wartownia nr 5 – Westerplatte*, 3D model, model by Szymon Kowalski and Wojciech Samól, Sketchfab, published March 29, 2024; accessed December 28, 2024, https://sketchfab.com/3d-models/wartownia-nr-5-westerplatte-586e4f5c93f14bfbbb89c34ed9384b81.

[926] Museum of the Second World War, *Nowy Cmentarz – Westerplatte*, 3D model, model by Szymon Kowalski and Wojciech Samól, Sketchfab, published April 24, 2024; accessed December 28, 2024, https://sketchfab.com/3d-models/nowy-cmentarz-westerplatte-430ad76b72f0436fbddb4784bf08efb3.

[927]Museum of the Second World War, *Krzyż Virtuti Militari, cmentarz – Westerplatte*, 3D model, model by Szymon Kowalski and Wojciech Samól, Sketchfab, April 24, 2024; accessed December 28, 2024, https://sketchfab.com/3d-models/krzyz-virtuti-militari-cmentarz-westerplatte-0f9fd7897e844e429aa3c431880fdccd.

[928] Meshification of a point cloud involves converting the cloud of discrete 3D points into a continuous surface representation. This process typically uses algorithms to connect the points with edges and faces, forming a mesh of triangles or polygons. The resulting mesh provides a structured and visually interpretable model suitable for analysis, visualization, and 3D printing.

[929] CloudCompare offers a wider range of post-production and manipulation functions than Faro Scene, which made it necessary to integrate both applications into the workflow and required the author to gain proficiency in each. A comparison of their approaches to generating a mesh model from the laser scan point cloud revealed a preference for the Poisson Reconstruction plugin in CloudCompare, as it can process a larger number of points during reconstruction, whereas the built-in function in Faro Scene is limited by point capacity.

was applied, using known dimensions from the scanned foundations to establish the accurate height of the building.

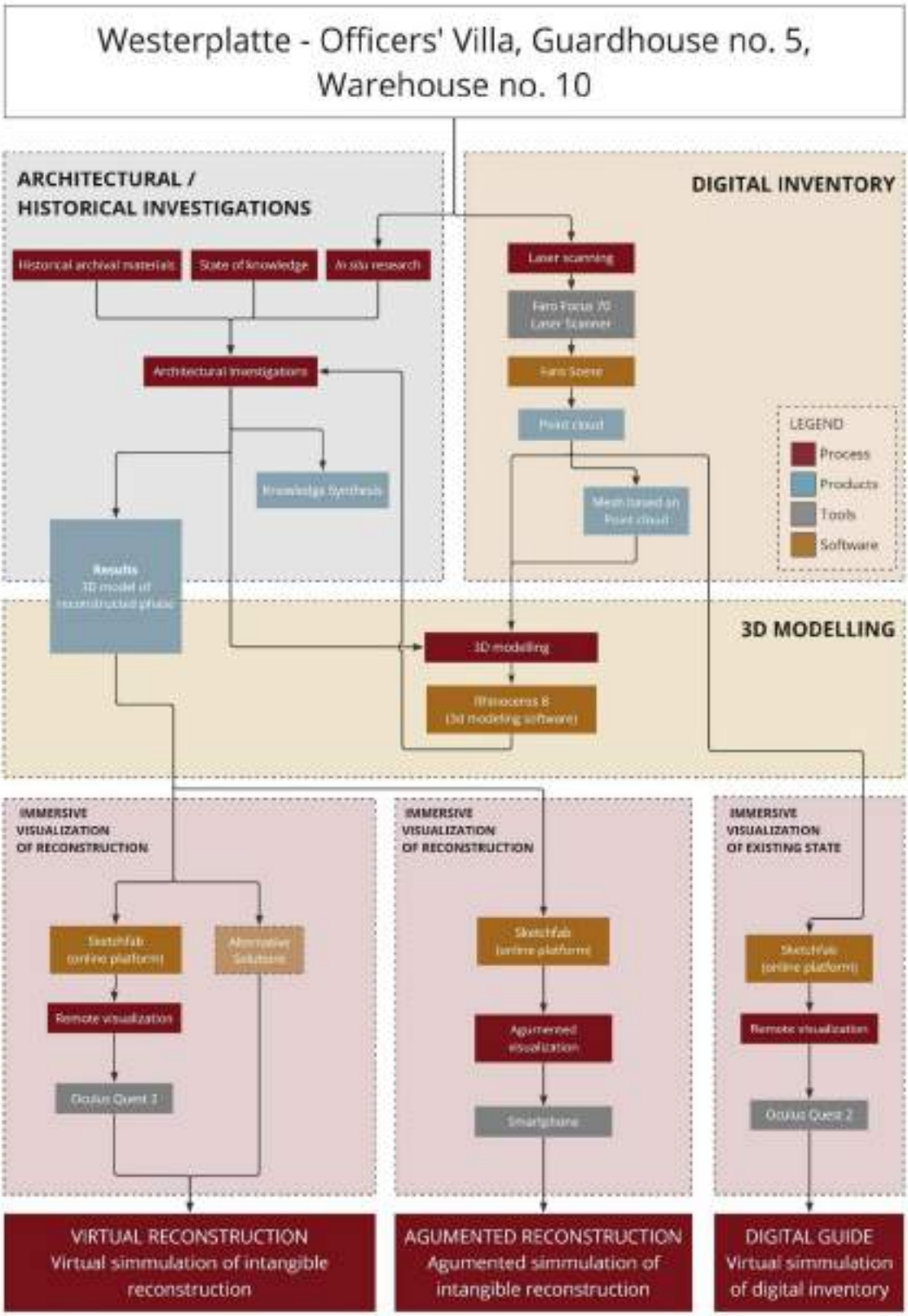


Fig. 197. Methodological scheme of the case study. Source: author.

Fig. 198. Archival photographs of the Officer's Villa. Top row: the villa during the resort period; bottom row: the villa after the battle in September 1939. Source: Materials obtained through the archival research of Wojciech Samól, Museum of the Second World War.

Fig. 199. Colourisation of digitally restored black-and-white archival photographs of the Officer's Villa using AI tools. Source: author.

While the geometry, scale, dimensions, and overall form of the structure were relatively straightforward to reconstruct, the colour scheme of the façade posed a significant challenge. As the demolished buildings survive only as archaeological relics, they provide little evidence of surface appearance, such as façade colours[930]. All available archival sources were limited to black-and-white

[930] Typical colour studies rely on stratigraphic analysis of materially preserved fragments, but in this case the absence of such evidence made such investigations impossible. Only a careful examination of the available archival sources could provide indications of the colour scheme, although any outcome would necessarily remain an approximation. According to Wojciech Samól, archaeological excavations uncovered numerous physical remains of the structure that offered clues regarding its original colours. However, due to restricted access, the author was unable to examine these artefacts directly.

It was not the author's intention to replicate the methodology and results of a full reconstruction, as in the case of the New Barracks. Instead, the Villa required a different approach. Limited access to evidence led, in the author's view, to an intriguing outcome: an exploration of reconstruction possibilities under conditions of significant constraint.

photographs. To address this gap, the author experimented with an artificial intelligence–based colourisation plugin in Photoshop, which yielded partial results but could not reliably determine the building's authentic palette[931]. This uncertainty ultimately led to the decision to produce a "ghost reconstruction" that emphasised the structure's form rather than speculative colour schemes[932].

Fig. 200. Elevations of digitally reconstructed model of officers' villa, synthesis of knowledge. Source: author.

Fig. 201. Elevations of digitally reconstructed model of officers' villa, synthesis of knowledge. Source: author.

[931] Colorizing black and white photos using AI tools presents several challenges. One major issue is ensuring accurate colour choices, as AI models often rely on patterns or training data that may not reflect the true colours of historical subjects or environments. This can lead to anachronisms or unrealistic colour palettes. Another challenge is the lack of context or information about the original colours, which might result in the AI making assumptions that don't match the actual scene. Additionally, AI models may struggle with subtle details like lighting, texture, and shadow nuances, which can affect the final realism. Another challenge arises from the different methods used to acquire photographs, particularly when it comes to how lighting is preserved on black-and-white photo film. The way light interacts with the film can cause overexposure, which results in a loss of detail in bright areas and an overall washed-out appearance. This overexposure can complicate the process of interpretation and reconstruction, as it obscures finer textures, contrasts, and other subtle visual elements necessary for accurate colourisation or 3D modelling. These photographic limitations add another layer of difficulty to restoring or reconstructing the original appearance of the structure.

[932] This decision and its consequences will be discussed in more detail in the summary of this chapter.

During the analysis, the author identified at least two distinct architectural phases of the Officer's Villa: the resort period and the Polish garrison period. These phases reflect significant changes in both the function and the design of the building. A further aspect concerns the two different colour schemes revealed through the colourisation of archival photographs. As shown in the figure above, the alcove exhibits two distinct surface treatments on its exposed skeletal construction. The resort phase featured a brownish finish, whereas the later refurbishment produced a markedly white or light grey appearance[933]. It is important to emphasise the difference in approach compared to the New Barracks, where preserved material remains, including sections of exterior plaster, made it possible to recreate the full colour scheme with greater certainty.

One of the most notable alterations of the Villa was the probable construction of a combat shelter beneath the structure during its adaptation for military use[934]. This transformation included the rebuilding and extension of the southeast corner, where two annexes were added to accommodate an extended interior staircase and, most likely, a hatch to the basement. A distinctive feature of this modification was the introduction of horizontal windows and altered window frames, characteristic of modernist architectural design, which appeared only in the annexes[935]. The precise dating of these extensions is difficult to determine due to limited documentation and photographic evidence, but they can likely be attributed to the period between 1933 and 1936, corresponding to the intensification of fortification works on Westerplatte. Photographic sources also indicate another alteration: the disassembly of the roof above the southern terrace shortly before the outbreak of the war. Accordingly, the virtual reconstruction represents the villa's pre-war appearance as it stood in 1939.

Warehouse no. 10

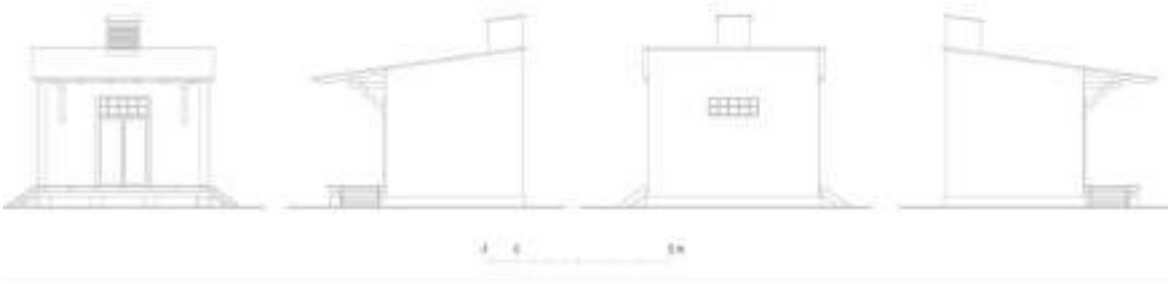


Fig. 202. Elevation of digitally reconstructed model of Warehouse no. 10. Source: author.

The case of Warehouse No. 10 shows significant parallels with that of the Officer's Villa. By combining archival photographs, and perspective restitution, it was possible to synthesise this evidence into a coherent 3D model. Essential to this process was the original project documentation, provided by Wojciech Samól, for the construction of this type of "small" warehouse. Closer analysis, however, revealed that the realised structure deviated slightly from the project, particularly in the design and placement of the ventilation chimney. As with the Officer's Villa, the laser scan provided the

933 This may appear to be a minor detail; however, the author intends to revisit this issue in the reconstruction concepts, where the object's heterogeneity and successive transformations are often overlooked.

934 In close proximity to the Officer's Villa, the Non-Commissioned Officers' Villa underwent a comparable fortification process as part of a covert effort to transform resort buildings into military installations while retaining an outward appearance that avoided unwanted attention. These modifications, carried out discreetly, were intended to strengthen the structures for defensive purposes. Similar combat shelters were also constructed beneath other key buildings on the peninsula, including the guardhouses and the New Barracks..

935 The author cannot confirm whether this extension had been previously noted, but it is certain that the element did not belong to the original design of the picturesque villa within the Westerplatte resort.

foundational basis for determining the building's dimensions and outline, ensuring accuracy in the reconstruction while integrating insights derived from historical study.

Fig. 203. Digital Reconstructions of Ammunition Warehouse and Officers' Villa at Westerplatte, based on meshified laser scans. Source: author.

Guardhouse no. 5

The case of Guardhouse No. 5 was unique in that no materials were available to provide essential information about the structure's geometry. While the 3D model was prepared by the author, the underlying findings and guidelines were supplied by Wojciech Samól[936]. The final reconstruction synthesised the results of archaeological excavations, which uncovered partially preserved remains such as foundations and wall sections, together with comparative studies of Guardhouses No. 1, No. 6 and No. 4.

AR application

Building on the previously developed 3D reconstruction models, it became possible to test their potential directly on-site. This was achieved through the augmented reality functionality of the Sketchfab AR plugin, used in conjunction with the Google AR viewer on a smartphone[937]. By enabling the blending option, the reconstructed model could be realistically superimposed onto the surviving remains, producing an augmented reality reconstruction. To underline the hypothetical character of the intervention, the artistic "ghost" effect, consistent with the models uploaded to the Sketchfab platform, was applied. This visual treatment highlighted the inherent uncertainty of the reconstruction and made explicit its basis in the synthesis of research conclusions[938].

[936] Wojciech Samól is currently preparing a publication on this subject; therefore, the author refers to it only briefly and does not present the model, as he is not the originator of the key findings. Full credit for the research on Guardhouse No. 5 belongs to Wojciech Samól.

[937] In this case the Huawei P30 smartphone was used.

[938] The results should be regarded as only partially satisfactory, as the author does not possess a programming background and approaches the subject as an architect with expertise in 3D modelling and remote sensing rather than in game design or information technology. A review of comparable applications employing site-specific targets indicates that more advanced solutions for superimposing reconstructions onto authentic remains are feasible. The author nonetheless expresses a strong commitment to overcoming these limitations and intends to pursue further refinement of the concept within the framework of a future scientific project dedicated to Westerplatte.

Fig. 204. Augmented Reality Application in situ. Frames of Digital reconstructions superimposed on the ruins at Westerplatte Peninsula, Sketchfab AR visualizer with use of smartphone[939]. Source: author.

During a brief on-site testing phase in October 2024, the author conducted oral interviews with eight randomly selected visitors at Westerplatte, directly at the site of the former Officer's Villa. The purpose of these interviews was to assess initial reactions to the augmented reality application and to evaluate its potential as a tool for interpretation.

All participants agreed that AR-based superimposed reconstructions offered an intriguing way of engaging with the site, particularly given their limited knowledge of the villa's pre-war appearance, of which only the foundations are visible today. When asked about the authenticity of the exposed remains, the visitors acknowledged their value, although several noted difficulty in visualising the original building. Importantly, the precise architectural form was not considered essential; instead, the general presence of the villa was perceived as significant. Fine details such as cornice profiles or shutters were regarded as secondary, since they were not clearly discernible in the AR model. What visitors valued most was the possibility of understanding the building's function, which they identified as the main interpretive takeaway from the experience.

Several additional points emerged. One participant highlighted the absence of visual material on the nearby information boards and expressed a wish for photographs or drawings to supplement the physical remains. Another raised the issue of technological accessibility: some visitors were hesitant to use the application, feeling uncomfortable with the technology. For these individuals, the reconstruction appeared abstract and distant, limiting their engagement.

Overall, however, the responses were positive. Most participants found the approach an innovative way of combining the authentic foundations with their reconstructed form, and they saw potential for such applications to enrich public understanding of Westerplatte. When asked about the possibility of materially reconstructing the villa, opinions were divided. Some supported physical reconstruction, while others expressed satisfaction with the existing presentation, supplemented by virtual interpretation.

The feedback indicates that visitors did not expect a fully detailed or photorealistic reconstruction. Instead, they valued the broader sense of presence and the interpretive clarity it provided. This

[939] The limited computing power and memory of modern smartphones result in relatively weak live rendering of digital models in augmented reality applications. However, this issue will likely be resolved as smartphones become more advanced.

challenges the common assumption that audiences demand exact visual fidelity. Rather, it suggests that immersive reconstructions can achieve their purpose by conveying function and atmosphere, even when architectural details remain uncertain. Such findings highlight the potential of virtual overlays to enhance the legibility of authentic remains without materially altering them, aligning with the principles of non-invasiveness.

5.3.5. New Barracks

At the core of Westerplatte stands the ruin of the New Barracks, the most substantial structure on the peninsula and the focal point of ongoing conservation debates. Preserved today as a permanent ruin, the New Barracks witnessed the outbreak of the Second World War on 1 September 1939. Following the conflict, the site was reshaped by political transformations in Poland and further altered during the creation of the memorial landscape and spatial reorganisation of 1966. Today, the surviving southern wing remains a defining feature of the peninsula, incorporated into the sightseeing route leading to the Monument to the Defenders of the Coast. As both an architectural remnant and a symbolic marker, it stands as a testimony to the sacrifices of the Polish soldiers of 1939 and to the broader wartime experience.

The history and development of the New Barracks have been addressed in detail in a scholarly article co-authored by the author with Wojciech Samól[940]. That study examined the building's structural solutions, its wartime fate, and the conservation challenges it faces, while also outlining guidelines for future archaeological excavations. Drawing on archival query[941] and in situ architectural investigations, it was possible to reconstruct the history of the site with a high degree of accuracy, providing a solid foundation for the digital reconstruction efforts presented in this chapter[942].

[940] Szymon Kowalski and Wojciech Samól, "Architektura oraz historia tzw. Nowych Koszar na Westerplatte w latach 1933–2023," *Przegląd Historyczno-Wojskowy* 25, no. 2 (2024): 92–138, https://doi.org/10.32089/wbh.phw.2024.2(288).0004.

[941] Archival query was carried out by Wojciech Samól.

[942] A detailed account of the history and development of the New Barracks has already been published by the author in collaboration with Wojciech Samól. To avoid unnecessary repetition and issues of self-plagiarism, this dissertation does not reproduce that discussion in full. Instead, the present section builds on the results of that publication, focusing primarily on the digital documentation, reconstruction process, and their implications for conservation.

See Szymon Kowalski and Wojciech Samól, "Architektura oraz historia tzw. Nowych Koszar na Westerplatte w latach 1933–2023," *Przegląd Historyczno-Wojskowy* 25, no. 2 (2024): 92–138, https://doi.org/10.32089/wbh.phw.2024.2(288).0004.

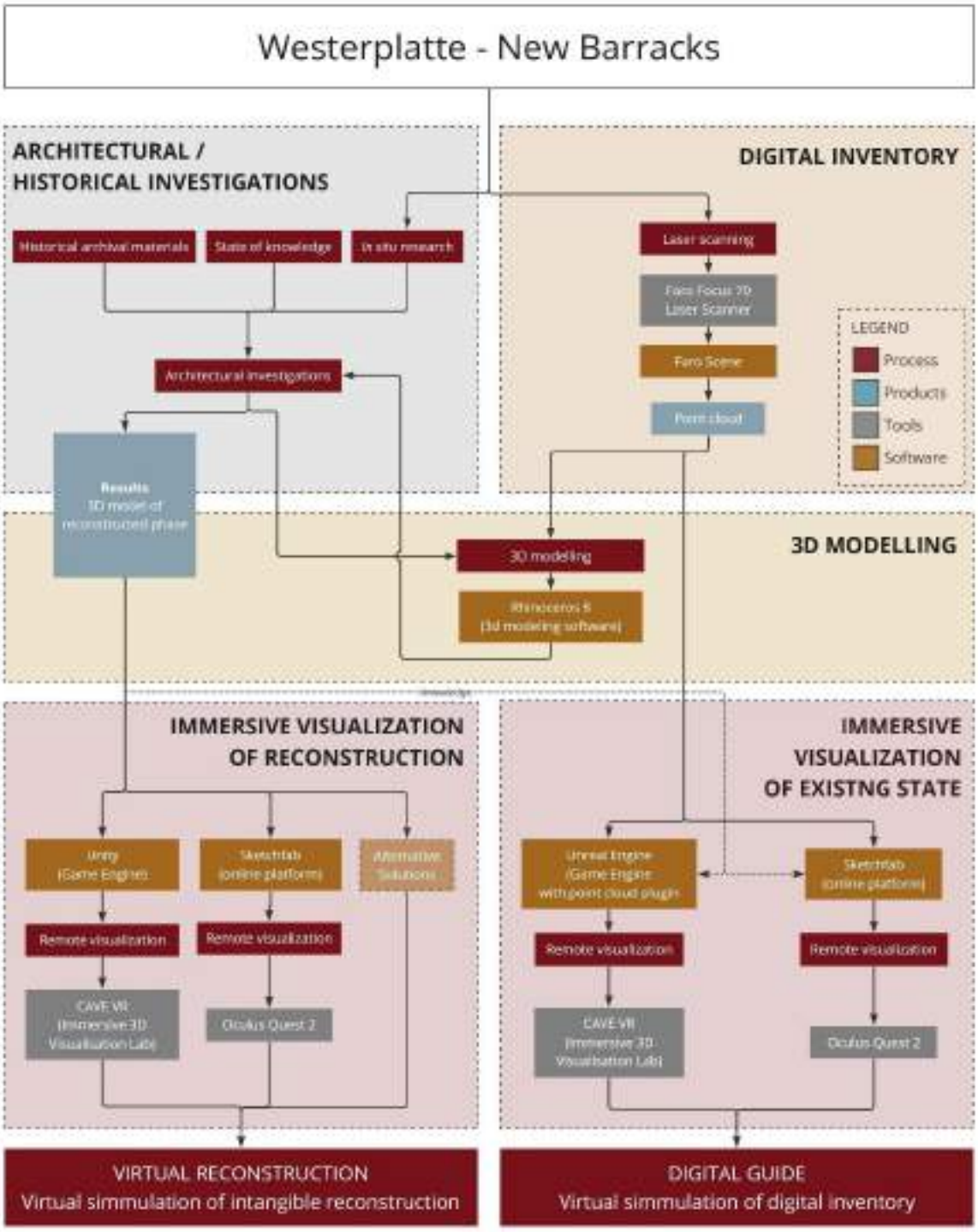


Fig. 205. Methodological scheme of the case study. Source: author.

Architectural digital inventory

The initial step for both historical-architectural investigations and digital reconstruction was the creation of a digital representation of the current state of the New Barracks at Westerplatte. Using the Faro Focus 70 terrestrial laser scanner, the entire structure was documented, including the basement,

all floors, the roof, and the elevations[943]. The master scan consisted of 142 individual stations, aligned into a single point-cloud cluster in Faro Scene software, resulting in a dataset of 1,949,725,000 points. This provided a highly detailed digital inventory of the current condition, enabling precise measurements of concrete slabs and walls as well as thorough documentation of the ruin. The inventory also served as the basis for cross-verifying findings presented in the earlier publication, including the analysis of bomb craters on the roof and their correspondence to different phases of the fighting.

Fig. 206. Laser scan of New Barracks. Left – full raw scan, visualized in Faro Scene Software. Right – axonometric view after the cleaning and optimalization process. Source: author.

Digital Guide

This digital inventory was subsequently incorporated into the methodology for creating an immersive digital guide. The author carried out the post-production process in Faro Scene, which involved optimising the large point-cloud dataset by reducing duplicate points and removing elements that obscured the view of the ruins, such as trees, people, market stalls, and other noise[944]. The processed file was exported in the *.e57* format for documentation and archival storage.

The dataset was then further processed in the open-source software CloudCompare, where the number of points was decimated to 11.5 million vertices, resulting in a file size of approximately 499 MB, and exported in the *.ply* format[945]. These optimised models were uploaded to the Sketchfab platform to make them accessible to a wide audience. The online environment allows access from both personal computers and smartphones, including directly on-site. Using Sketchfab's visualisation engine, the author created an interactive digital guide by adding a series of pins marking distinctive rooms and structural elements, based on previous research. These annotations provide contextual information,

[943] The author wishes to express sincere gratitude to the Museum of the Second World War and to Wojciech Samól for their help in enabling the complete scanning of the ruins and for granting access to every part of the structure.

[944] Noise in a point cloud refers to unwanted deviations or inaccuracies in the spatial data, often caused by factors such as sensor reflections on glass surfaces, environmental interference, or suboptimal data acquisition techniques. It can manifest as random points, outliers, or distortions, which hinder the accuracy and clarity of the model and the visualisation of the scanned object.

[945] Due to the import and visualisation limitations of Sketchfab, it was not possible to upload the raw *.e57* file, which therefore had to be converted into the *.ply* format. The *.ply* (Polygon File Format) is a widely used standard for storing 3D models. It is capable of representing both geometry (vertices and faces) and additional attributes such as colour, texture, and normal vectors. The format is flexible, supporting both ASCII and binary encoding, and is commonly applied in fields such as computer graphics and computational geometry. Because it can store vertices as discrete points, the *.ply* format enabled the visualisation of the point-cloud model on online platforms such as Sketchfab.

facilitate historical interpretation, serve an educational role, and enable virtual access to otherwise inaccessible spaces such as the upper floors or roof.

Fig. 207. Laser scan of New Barracks, adapted to the form of digital remote sightseeing tour on the Sketchfab platform[946]. Source: author.

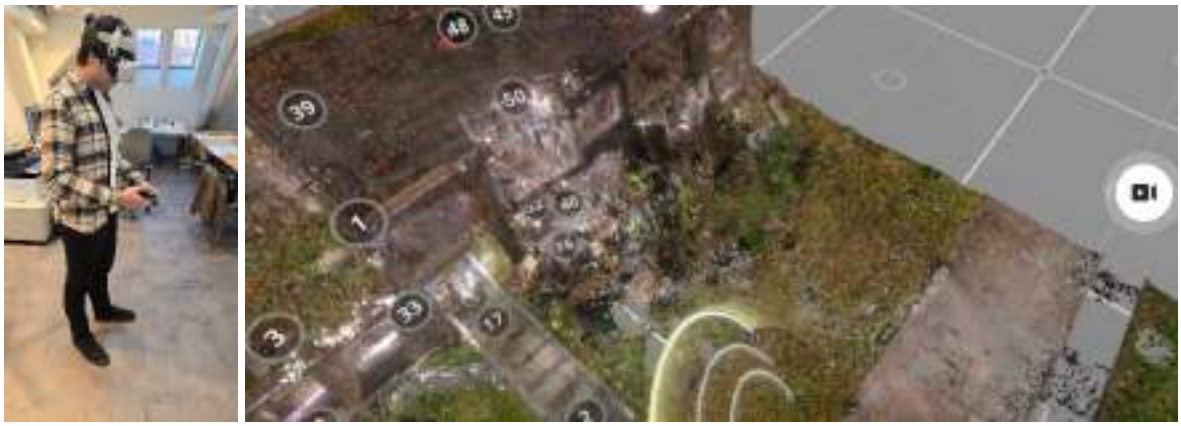


Fig. 208. Laser scan of New Barracks, adapted to the form of digital remote sightseeing tour on the Sketchfab platform. Immersive view screenshot. Source: author.

In addition to the guided mode, the model also supports free interaction. Users can rotate, zoom, pan, and manipulate the dataset to explore the ruins independently, tailoring the experience to their own interests and level of engagement. Beyond its technical function, the guide presents the ruin through interpretation without physical intervention and ensures wider accessibility by opening otherwise inaccessible spaces to visitors.

Virtual Reconstruction

While the digital guide focused solely on presenting the current state of the ruin, the virtual reconstruction aimed to enhance heritage presentation and knowledge transfer even further. The goal was to create the most accurate possible representation of the structure as it appeared in September 1939, while simultaneously highlighting the differences between the existing fragments and the missing portions in their permanent ruined state. The previously acquired TLS scan served as the foundation for this work, providing the geometric framework for the reconstruction.

[946] Museum of the Second World War. *Nowe Koszary – Westerplatte*. 3D model. Sketchfab. Published March 29, 2024. Accessed July 1, 2025. https://sketchfab.com/3d-models/nowe-koszary-westerplatte-de756a7e1ff54d5593fd314230da8efb.

Fig. 209. New Barracks. Left: around 7–8 September 1939; right: second half of September 1939. Source: Archival photographs courtesy of Wojciech Samól.

Fig. 210. New Barracks after the fighting. Around September 1939. Source: Archival photographs courtesy of Wojciech Samól.

The knowledge required to craft the reconstruction was derived from a combination of in-depth archival research and direct study of the surviving structure. Archival photographs, gathered through dedicated research, were analysed alongside the results of architectural investigations. The scan data supplied precise information on floor levels, cornices, window dimensions, and the construction system (a concrete skeleton with brick infill). The dimensions of the destroyed wing were also known, as the authors of the earlier article identified its corner and structural footprint. The existing building was examined using the nodal method and conventional architectural analysis to identify missing internal walls, rooms, and circulation patterns. Perspective restitution based on historic photographs further supported the reconstruction. In the co-authored article with Wojciech Samól, particular attention was given to the methodological issues of inferring from fragmentary documentation and verifying design intentions against the completed building.

On the basis of this evidence, the TLS point cloud was imported into Rhinoceros 3D[947] to serve as the modelling base. Using standard 3D modelling techniques, the author developed a reconstruction of the New Barracks as they appeared in 1939. A synthetic, object-focused approach was adopted, with the surrounding environment intentionally omitted. The modelling prioritised geometric accuracy over visual embellishment: advanced textures and beautification were excluded as secondary to the primary

[947] This program was chosen for its capability to handle both point clouds and 3D drawing and modelling, effectively meeting all the requirements of the methodology.

objective of recreating the architectural form[948]. The reconstruction was executed using NURBS curves, which provided greater precision than conventional mesh modelling[949].

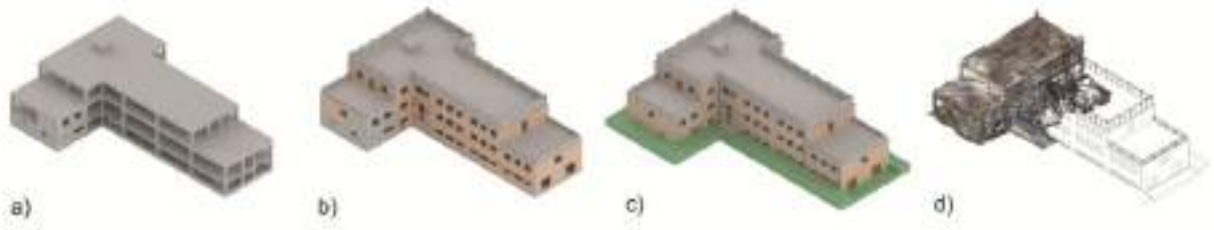


Fig. 211. 3D models of digital reconstruction, including: a) the construction, b) brick infill, coloristic c) reconstruction and d) integration with existing part of New Barracks. Source: author in collaboration with Wojciech Samól.

Fig. 212. Elevation of New Barracks. Source: author in collaboration with Wojciech Samól.

[948] The creation of photorealistic environments using computer graphics is indeed possible, but it is not the author's current intention, as it requires advanced knowledge and skills in the field of Visual Digital Art. The author's observations indicate that realism is often achieved through convincing surroundings—such as realistic trees, traces of use, diverse surfaces with accurate light reflections, and the accumulation of everyday objects. While the author aspires to create an almost photorealistic environment, these plans must be postponed due to a lack of financial resources and the necessary skills, which extends far beyond the scope of this scientific work.

[949] The terms NURBS and meshed refer to different methods of representing 3D geometry in computer graphics and modelling. NURBS (Non-Uniform Rational B-Splines) are a mathematical representation used for creating smooth and precise curves and surfaces, while meshed refers to the representation of 3D geometry using a network of polygons, typically triangles or quadrilaterals.

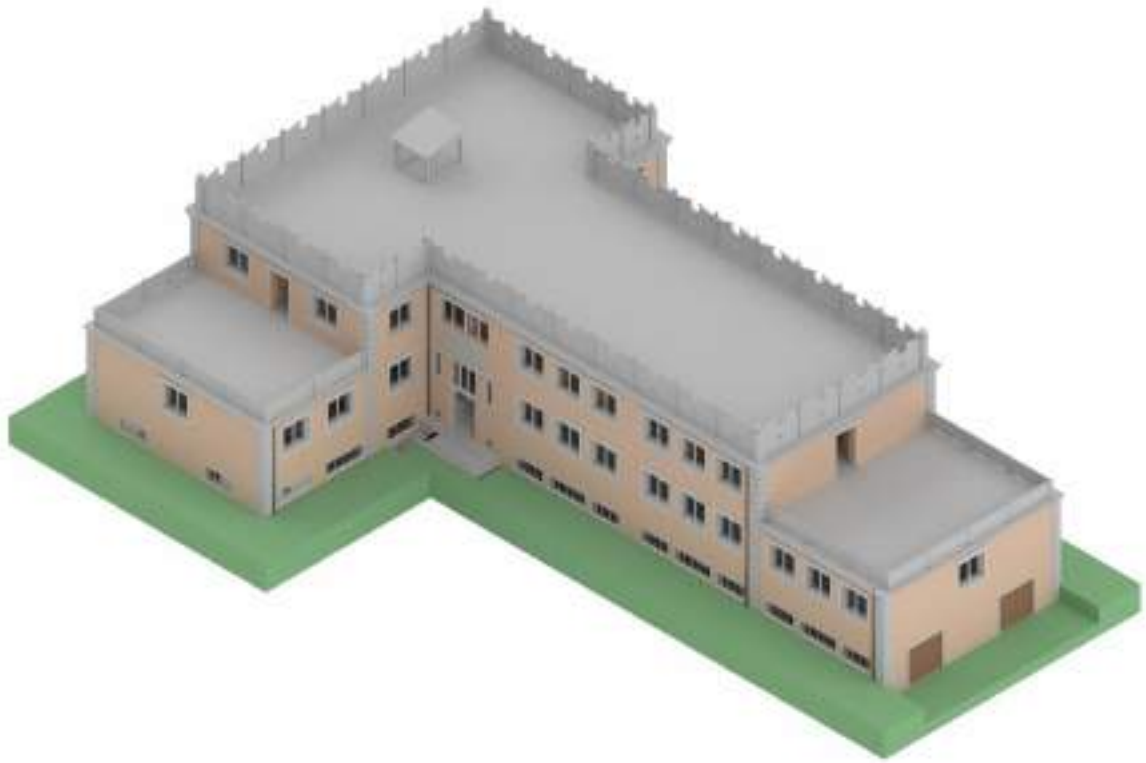


Fig. 213. 3D model of full digital reconstruction with colours of New Barracks. Source: author in collaboration with Wojciech Samól.

Following the completion of the reconstruction, different methods of visualisation were tested to create a semi-reconstruction or "ghost" model. The aim was to integrate the 1939 state with the surviving ruin in a way that conveyed absence without suggesting total certainty. To achieve this, opacity filters were applied to produce a translucent effect, while a grey colour palette was used to evoke a spectral, immaterial presence. This approach created a clear distinction between original and reconstructed parts, reinforcing transparency and interpretive caution.

A major challenge was the dissemination of the ghost model via online platforms. Sketchfab did not support mixed visualisation methods combining vertices and surfaces[950]. To overcome this, it was necessary to convert the reconstructed NURBS surfaces back into a point cloud[951], essentially reversing the earlier workflow. Once reprocessed, the reconstructed file was exported in *.ply* format and successfully uploaded, where it could be joined with the original scan and presented as an integrated model.

The digital reconstruction of the New Barracks demonstrates how advanced survey techniques, archival analysis, and interpretive modelling can be combined to visualise a lost structure with precision while preserving the authenticity of the surviving ruin. By adopting a ghost reconstruction approach and

[950] This is due to different shading models. In typical computer graphics, light is simulated by creating a virtual light source and then reflecting it off a surface. Point clouds in Sketchfab are visualized by describing circles on infinitely small points, always directed by the plane vector to the viewer's eye, which allows manipulation and changing the size of the plane created on the point. Unfortunately, the integration of these two processes is not possible on the Sketchfab online platform.

[951] The author devised a solution by generating vertices on surfaces that initially lacked them. This was achieved by converting the NURBS surface into a mesh surface and then subdividing the resulting triangles into smaller fragments, thereby obtaining a significant number of vertices. These vertices were subsequently extracted from the model and grouped into a point cloud. This new point cloud was then merged with the point cloud generated through the laser scanning process, creating a unified representation.

addressing technical constraints of dissemination, the project offers a transparent and reversible alternative to material rebuilding. At the same time, the process highlights the inevitable limits of digital reconstruction, which depends on interpretive choices and cannot fully resolve uncertainties in the historical record.

Fig. 214. Partial Digital Reconstruction of the missing wing of New Barracks, using the point cloud solution adjoined to the original scan, based on the architectural investigations[952]. Source: author in collaboration with Wojciech Samól.

3D print[953]

Thanks to the methodology of solid-based 3D modelling, the virtual reconstruction could be exported as an *.stl* file and processed for 3D printing. The author used Ultimaker Cura software to generate the printer path file and produced the model on an Ender 5 Plus filament printer at a scale of 1:50. This approach demonstrates how a single digital reconstruction can serve multiple purposes, enabling both immersive visualisation and the materialisation of the model as a tangible object. Although lacking the material authenticity of the original structure, the 3D print serves as a valuable educational and exhibition tool. It allows audiences to engage physically with the reconstruction, supports museum displays, and provides a tactile means of experiencing the architecture for visitors who may not have access to digital technologies.

[952]Source: Museum of the Second World War, *Nowe Koszary (rekonstrukcja) – Westerplatte*, 3D model, model by Szymon Kowalski and Wojciech Samól, Sketchfab, published August 13, 2024; accessed December 27, 2024, https://sketchfab.com/3d-models/nowe-koszary-rekonstrukcja-westerplatte-e20a83031134461fa826d8c6ca07065a.

[953] While this paragraph falls beyond the scope of this research work, the author wishes to highlight the extended capabilities of 3D modelling.

Fig. 215. 3D printed model of New Barracks. Source: author.

Immersive Simulation

All previous steps of documentation, modelling, and visualisation converged in the final phase: immersive simulation. The 3D models provided the basis for computer graphics visualisation, whether presented on a conventional screen or within an immersive environment. Besides method already covered in the digital guide section two other complementary methods were employed in this case study: the CAVE VR system at the Immersive 3D Visualisation Lab of the Faculty of Electronics, Telecommunications and Informatics, and the Oculus Quest 2 head-mounted display (HMD).

CAVE

To create a CAVE immersive visualisation[954], the point cloud was imported into *Unreal Engine 5.3* using the *LIDAR Point Cloud* plugin[955] to generate the environment. The *nDisplay* plugin[956] was then applied to project multiple images onto surrounding screens via projectors, producing a stereographic effect. This setup allowed the application to be launched on both the Midi and Big Cave systems, creating a fully immersive experience[957]. The principal advantage of the CAVE lies in its ability to facilitate group immersion, enabling several participants to explore the model simultaneously. Its limitations, however, include high technical requirements, immobility, and dependence on a dedicated facility.

[954] The method of visualisation and its technical aspects are described in Chapter 4.

[955] "LiDAR Point Cloud Plugin Overview in Unreal Engine," Epic Games Developer Documentation, accessed December 27, 2024, https://dev.epicgames.com/documentation/en-us/unreal-engine/lidar-point-cloud-plugin-overview-in-unreal-engine.

The plugin is required because the graphics engine operates on the principle of simulating light, with projections and reflections from surfaces. It is therefore necessary to generate a surface at each point. As the points in a point cloud are purely mathematical entities without diameter or physical dimension, they cannot be rendered directly. The plugin enables their visualisation by creating a sprite surface or voxel around each point.

[956] "nDisplay Overview for Unreal Engine," Epic Games Developer Documentation, accessed December 27, 2024, https://dev.epicgames.com/documentation/en-us/unreal-engine/ndisplay-overview-for-unreal-engine.

[957] The author is not the creator of the development of this methodology but is instead the originator of the idea to integrate scan data and its visualisation. The team at the Immersive 3D Visualisation Lab at the Faculty of Electronics, Telecommunication and Informatics, led by Prof. Jacek Lebiedź, developed this application, as an internal cooperation between Gdańsk University of Technology faculties. The team members include Ivan Vakulko, Marek Barański, Robert Trzosowski, and Błażej Kowalski.

Fig. 216. 3D immersive visualization. Left Big Cave, Right Midi Cave. Source: author.

HMD VR

While the CAVE system provides a collective experience, VR goggles enable a more individual and intimate level of immersion. The Oculus Quest 2 was tested using several emulation methods:

- Cable connection with workstation rendering. Through *Oculus Link* in conjunction with *SteamVR*, the goggles acted as a display while computations and rendering were performed by a workstation with architectural visualisation plugins Enscape. Extension plugin made it possible to create VR scenes directly in Rhinoceros 3D, enabling immersive exploration of the reconstructed model[958].
- Native VR scenes in Faro Scene. The same software used for point-cloud alignment also supports VR, allowing scan-based sightseeing directly within the environment.
- Standalone, cable-free VR. Uploading models to Sketchfab enabled an online VR environment accessible through the Oculus Quest 2's built-in browser. Despite limited tracking capabilities, this solution allowed in-situ visualisation, producing a partially mixed-reality effect similar to experiments conducted with the sacristy of St. Nicholas[959].

Fig. 217. Immersive visualisation of the New Barracks, using Enscape plugin. Source: author.

[958] This method is particularly accessible for architects, as it does not require advanced computer graphics or programming expertise, such as proficiency with game engines like *Unreal Engine* or *Unity*. Instead, it relies on techniques familiar from standard architectural visualisations, focusing on scene similarity rather than complex programming.

[959] The next generation of goggles used by the author, such as the Oculus Quest 3, offers enhanced interaction capabilities and includes advanced mixed reality modules. These devices illustrate the constant development of the field, where rapid technological progress continually expands the possibilities for immersive heritage applications.

5.4. Urban Scale *Royal Valley - Heiligenbrunn*

5.4.1. Introduction

The third case study addresses a different scale of intervention and applies an alternative measurement method compared with the previous examples. It operates at the urban scale, focusing on a section of the Wrzeszcz district, and employs aerial LiDAR data processed in GIS to generate 3D models of both the current condition and historically reconstructed states. The workflow follows a GIS-to-VR pipeline, preparing spatial subsets for subsequent virtual reality applications. The reconstruction models are grounded in the author's historical research, synthesising diverse literary sources and a wide range of archival materials. The objective is to demonstrate the diachronic spatial development of Wrzeszcz in an integrated and immersive form. This case study ultimately proved to be the most complex and challenging of the three, due the its scale factor.

This chapter extends the methodologies developed during the grant project *"Gdańsk's Digital Twin: An Interactive Model of City Development – From History to the Future,"*[960] funded by the Ministry of Education and Science within the programme *Student Scientific Circles Create Innovations*. The author co-authored the project proposal and participated as a team member.

Another important foundation for this chapter is the methodology developed in a multi-author article on the spatial history and transformation of the Westerplatte Peninsula[961]. That study established a framework for analysing historical change by integrating geospatial data, archival sources, and digital reconstruction techniques, which are here adapted to the Wrzeszcz context.

The selection of this area[962] was guided by several factors: first, the presence of a significant group of Baroque manors, one of which survives only as a ruin; second, the opportunity to build upon the research of the author's supervisors, Jakub Szczepański, who has studied Wrzeszcz and the development of the Gdańsk University of Technology[963], and Piotr Samól, who has examined the "Young City," the now-lost Church of All God's Angels, and the medieval origins of Heiligenbrunn[964]; third, the proximity to Gdańsk University of Technology, which facilitated fieldwork and enabled integration with other ongoing projects; and fourth, the availability of multiple reliable documentary sources, including maps, engravings, and etchings from the seventeenth century onward. These sources mark the point at which high-quality cartographic evidence allows for systematic analysis and reconstruction.

---

[960] Politechnika Gdańska, Wydział Architektury. *Cyfrowy bliźniak Gdańska. Interaktywny model rozwoju miasta – od historii do przyszłości*. Accessed March 5, 2025. https://arch.pg.edu.pl/nauka/projekty-badawcze-i-granty/gdansk-digi-city.

[961] Wojciech Samól, Szymon Kowalski, Arkadiusz Woźniakowski, and Piotr Samól, "Where the Second World War in Europe Broke Out: The Landscape History of Westerplatte, Gdańsk/Danzig," Land 12, no. 3 (2023): 596, https://doi.org/10.3390/land12030596.

[962] The author's initial idea was to focus on the spatial development of the city of Gdańsk within its fortified perimeter. This topic, however, has already been extensively studied by archaeologists, historians, architects, and art historians. Moreover, given the enormous scale of the subject, which is likely to be addressed in future research, the analysis revealed that it was too vast to be contained within a single case study.

[963] Jakub Szczepański, "Siedem i Pół Wieku Wrzeszcza," in *Wędrówki po Wrzeszczu*, ed. Jakub Szczepański and Katarzyna Szczepańska (Gdańsk: Słowo/obraz terytoria, 2011), 8–83; Jakub Szczepański, *Architektura zespołu Politechniki Gdańskiej 1904–2018* (Gdańsk: Słowo/obraz terytoria, 2019); Lucyna Nyka and Jakub Szczepański, "Ukryte potoki Wrzeszcza," in *Wędrówki po Wrzeszczu*, ed. Katarzyna Szczepańska and Jakub Szczepański (Gdańsk: Słowo/obraz terytoria, 2011), 277–92.

[964] Piotr Samól, "Rutki: Wieś patrymonialna Młodego Miasta Gdańska," *Studia z dziejów średniowiecza*, nr 16 (2011): 159–192; Piotr Samól, *Młode Miasto Gdańsk (1380-1455) i jego patrymonium* (Gdańsk: Wydawnictwo Uniwersytetu Gdańskiego, 2018);

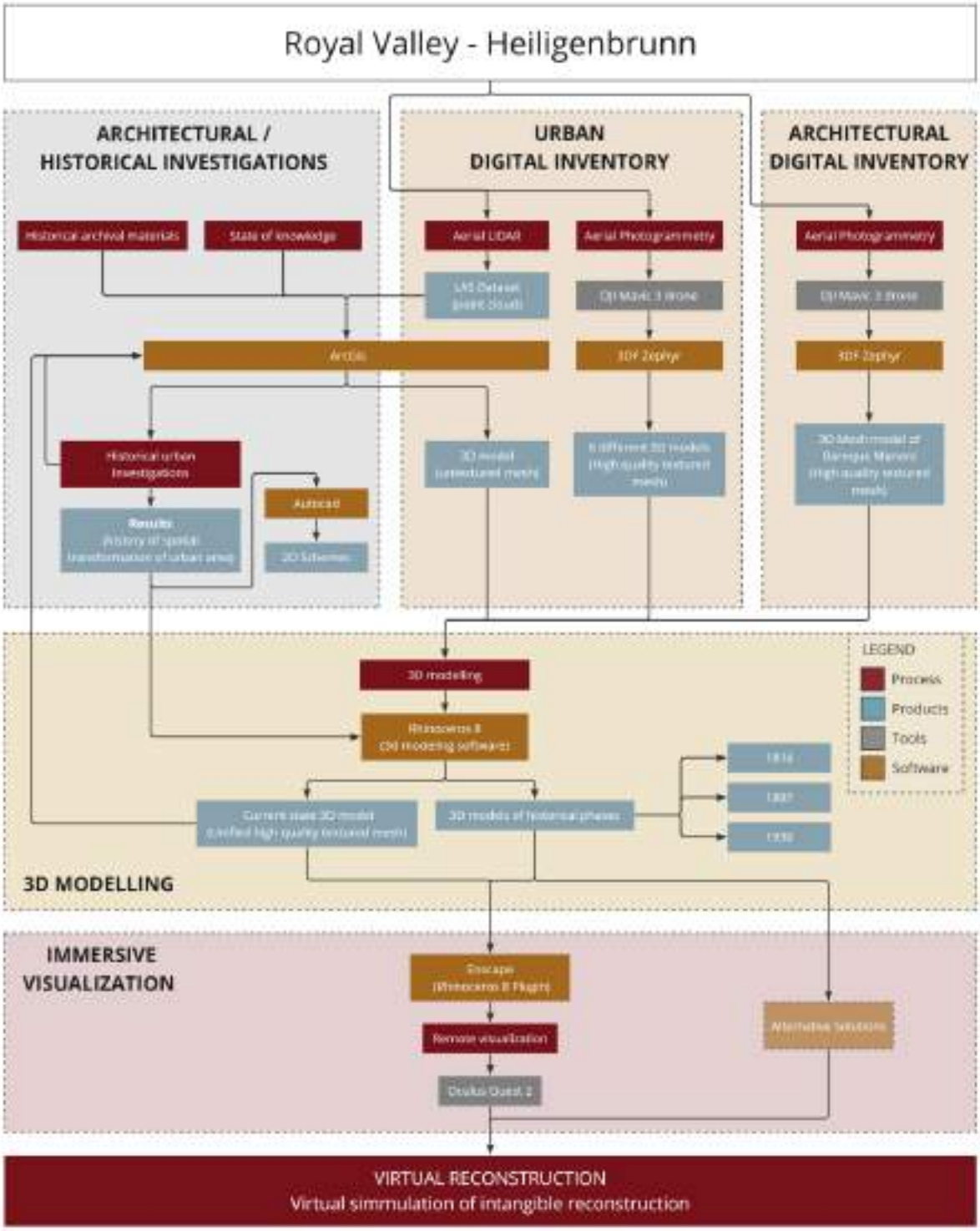


Fig. 218. Methodological scheme of the case study. Source: author.

State of knowledge

One of the earliest depictions of Heiligenbrunn Manor was created by Matthäus Deisch (1724–1789), a German engraver. In his collection *50 Prospecte von Danzig* (*50 Views of Gdańsk*)[965], published in 1765, plate 37 is dedicated to a view of the manor in its Baroque form. This engraving offers valuable insight into the estate's architectural character and surrounding landscape in the eighteenth century.

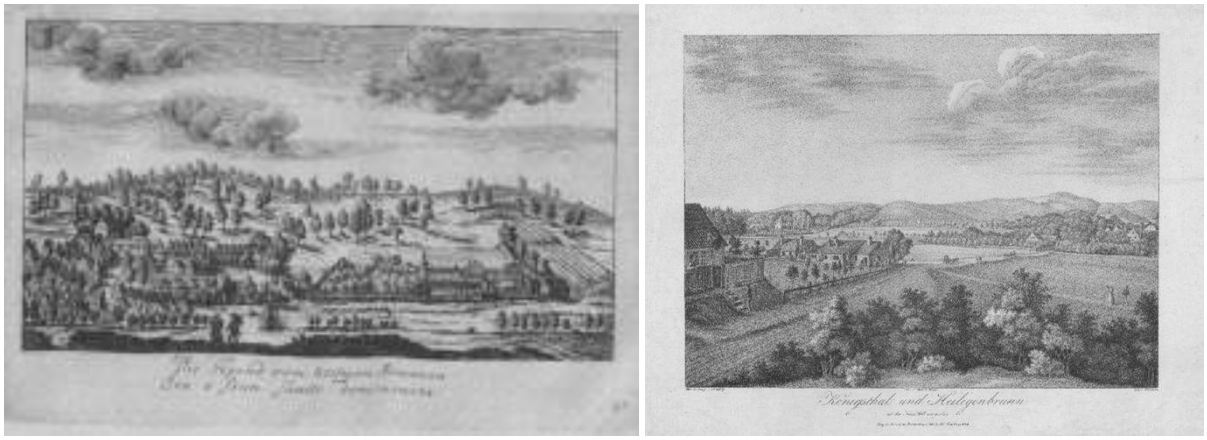


Fig. 219. Historical Etchings. Left: View on Heiligenbrunn Manor. 50 Views of Gdańsk, plate 37, (source: Deisch 1765[966]). Right: *Royal Valley* and *Heiligenbrunn* Manors on Helmsaurer's etching, (source:

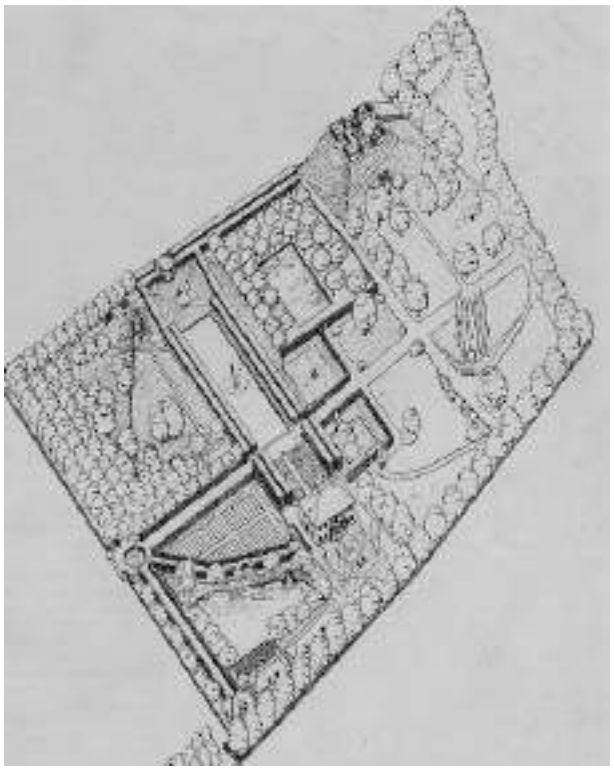


Fig. 220. Kings Valley (*Königstal*) Manor gardens, reconstructed by Hans Rechow, (source: Reichow, 1927[967]).

[965] Deisch, Matthäus. 1765. 50 Prospecte von Danzig. Gdansk, plate 37.

[966] Matthäus Deisch, *50 Prospecte von Danzig sind zu haben bey Matthäus Deisch* (ca. 1760–1789), tabl. 37, Polona, accessed September 17, 2025, https://polona.pl/item-view/83b6f445-bf39-44b7-99cd-d4b53bc9acc9?page=82.

[967] Hans Reichow, *Alte bürgerliche Gartenkunst* (PhD diss., Berlin, 1927; Berlin: Verlag der Gartenschönheit), 33.

Another depiction was produced by Carl August Helmsauer (1789–1844) in his *Königsthal und Heiligenbrunn von der Neuen Welt aus gesehen* (*Koenigsthal and Heiligenbrunn Seen from the New World*), which presents the valley around 1830, following the annexation of Gdańsk. Nearly a century later, Hans Reichow's doctoral thesis, *Reconstruction of the Manor Layout* (1927)[968], approached the subject from a different perspective. His study is particularly significant for the present research, as it offers a systematic analysis of Baroque palace gardens, including those in the Royal Valley, and proposes reconstructions of their original layouts.

In 2008, a collaborative volume edited by Aleksandra Kociałkowska was published, focusing on general conservation issues as well as the results of architectural investigations. The book also presented student projects developed during the workshop *Polish-Russian School for the Preservation of Cultural Studzienka 2007*, which centered on Heiligenbrunn Manor. A critical summary of these projects was provided by Bożena Zimnowoda-Krajewska[969], Jan Tajchman, and Anita Jaśkiewicz-Sojak[970]. Beyond the extracurricular school, the publication gathered contributions from numerous scholars. Ulrich Schaff offered valuable insights into the wooden roof construction[971], while stratification plans and sections of Heiligenbrunn Manor were prepared by a team consisting of Bożena Zimnowoda-Krajewska, Ulrich Schaff, Aleksandra Dibowska, Magdalena Grunwald, Małgorzata Nowopolska, and Kamila Rozynek. These plans established the manor's construction history, reconstructed on the basis of detailed architectural investigations.

The most significant contributions to the study of the Wrzeszcz district have been made by Jakub Szczepański, whose extensive research and numerous publications have illuminated its history. As the editor of the 2011 monograph *Wędrówki po Wrzeszczu* (*Journeys around Wrzeszcz*), he provided a comprehensive overview of the district's historical development. The opening chapter[972], authored by Szczepański, offers a concise history of Wrzeszcz from the medieval period to the present (as of 2011) and reflects on its potential for future growth. Within the same volume, Robert Hirsch examined the Abegg Colony[973], a historic workers' housing estate in Wrzeszcz established in the late nineteenth century with the aim of improving living conditions for the city's expanding workforce[974]. Also in *Wędrówki po Wrzeszczu*, Lucyna Nyka and Jakub Szczepański co-authored a study on the district's streams[975]. Since their medieval origins, these waterways have been the district's most valuable asset, as their hydropower drove numerous mills along their course. They also shaped the siting of several

968 Hans Reichow, *Alte bürgerliche Gartenkunst* (PhD diss., Berlin, 1927; Berlin: Verlag der Gartenschönheit).

969 Zimnowoda-Krajewska, Bożena. 2007. "Uwagi Do Projektów Konserwatora Zabytków Architektury." In Problemy Konserwacji i Badań Zabytków Architektury, edited by Aleksandra Kociałkowska, 253–62. Gdańsk: Europejska fundacja ochrony zabytków.

970 Jaśkiewicz-, Anita. 2008. "Dwór Studzienka i Praktyka Konserwatorska." In Problemy Konserwacji i Badań Zabytków Architektury, edited by Aleksandra Kociałkowska, 263–68. Gdańsk: Europejska fundacja ochrony zabytków.

971 Schaff, Urlich. 2008. "Uwagi Do Metod Badań Architektonicznych Konstrukcji Drewnianych Na Przykładzie Osiemnastowiecznej Więźby Mansardowej Dworu Studzienka w Gdańsku." In Problemy Konserwacji i Badań Zabytków Architektury, edited by Aleksandra Kociałkowska, 151–64. Gdańsk: Europejska fundacja ochrony zabytków.

972 Jakub Szczepański, "Siedem i Pół Wieku Wrzeszcza," in *Wędrówki po Wrzeszczu*, ed. Jakub Szczepański and Katarzyna Szczepańska (Gdańsk: Słowo/obraz terytoria, 2011), 8–83.

973 Robert Hirsch, "Kolonie robotnicze Fundacji Abegga we Wrzeszczu. Pamiątka postępowych idei w budownictwie mieszkaniowym XIX wieku," in *Wędrówki po Wrzeszczu*, ed. Jakub Szczepański and Katarzyna Szczepańska (Gdańsk: Słowo/obraz terytoria, 2011), 187–221.

974 The Abegg Colony is largely preserved to this day and is situated north of the main campus of Gdańsk University of Technology.

975 Lucyna Nyka and Jakub Szczepański, "Ukryte potoki Wrzeszcza," in *Wędrówki po Wrzeszczu*, ed. Katarzyna Szczepańska and Jakub Szczepański (Gdańsk: Słowo/obraz terytoria, 2011), 277–92.

manors, providing irrigation for extensive gardens[976]. Another important contribution by Szczepański is the monograph *Architektura zespołu Politechniki Gdańskiej 1904–2018* (*Architecture of the Gdańsk University of Technology Complex 1904–2018*)[977], published in 2019. This study traces the development of the university from its foundation, examining both its architectural evolution and the transformations that have shaped the campus into its present form.

The subject was also explored by Jarosław Wasielewski and Jan Daniluk, who in 2014 published a two-volume album that serves as a valuable resource, assembling a large collection of archival postcards and photographs illustrating the urban transformations of Wrzeszcz[978].

Research on the southern area between Wrzeszcz and the historic city of Gdańsk, where the Young City existed between 1380 and 1455, has been carried out by Piotr Samól. His first article examined the village of "Rutki," considered the predecessor of Heiligenbrunn Manor before its later renaming[979]. He expanded this work in his monograph on *Młode Miasto Gdańsk*[980] (*Young City Gdańsk*, ger. *Jungstadt*), which also analysed the remains of the Church of All God's Angels[981].

Further context is provided by Anna Krüger in her study on cemeteries in the vicinity of manors[982]. She traces the history and transformation of the cemeteries that once lined the Great Alley, the main axis linking Wrzeszcz with the historic centre of Gdańsk. Her research sheds light on the spatial and cultural changes that reshaped this area over time. Other notable works include two doctoral dissertations. Anna Półtorzycka authored dissertation on Gdańsk's Villas in years 1870-1939 [983], which was successfully defended in 2024. Aurelia Bladowska worked on a dissertation concerning the historical architecture of Wrzeszcz between 1871 and 1920[984], focusing on the district's rapid urban development, but the project remained unfinished and unpublished.

History of the *Royal Valley - Heiligenbrunn* area

The valley is closely associated with the district of Wrzeszcz, which was first established in the Middle Ages as a village along the route connecting Gdańsk's Old Town with the Oliwa Monastery. Its location by three streams made it well suited for later expansion.

---

[976] Archival sources demonstrate that the streams did not significantly alter their courses over time, making them stable reference points for geolocating historical maps and thus indispensable for future research.

[977] Jakub Szczepański, *Architektura zespołu Politechniki Gdańskiej 1904–2018* (Gdańsk: Słowo/obraz terytoria, 2019).

[978] Jan Daniluk and Jarosław Wasielewski, *Wrzeszcz na dawnej pocztówce. Spacer pierwszy* (Gdańsk: Wydawnictwo Oskar, 2014); Jan Daniluk, Jarosław Wasielewski, and Krzysztof Grynder, *Wrzeszcz na dawnej pocztówce: Spacer drugi* (Gdańsk: Gdański Kantor Wydawniczy / Wydawnictwo Region, 2019).

[979] Piotr Samól, "Rutki: Wieś patrymonialna Młodego Miasta Gdańska," *Studia z dziejów średniowiecza*, nr 16 (2011): 159–192.

[980] Piotr Samól, *Młode Miasto Gdańsk (1380-1455) i jego patrymonium* (Gdańsk: Wydawnictwo Uniwersytetu Gdańskiego, 2018)

[981] This church serves as a key reference point in the present map analysis.

[982] Anna Krüger, *Cmentarze przy Wielkiej Alei w Gdańsku 1867–1945: Studium z dziejów kultury funeralnej* (Gdańsk: Słowo/obraz terytoria, 2021).

[983] *Anna Półtorzycka, Wille gdańskie. Dom jednorodzinny wyższej klasy średniej w Gdańsku w latach 1870–1939 w świetle dokumentacji projektowych i decyzji administracyjnych (PhD diss., Gdańsk University of Technology, 2024), Politechnika Gdańska, Postępowanie o nadanie stopnia doktora, https://pg.edu.pl/bip/nauka/postepowania/17897-anna-poltorzycka, accessed March 2, 2025.*

[984] Aurelia Marcelina Bladowska, *Architektura gdańskiej dzielnicy Wrzeszcz (Langfuhr), 1871–1920* (PhD diss., University of Gdańsk, not yet defended), https://old.historia.ug.edu.pl/st-tyt_nauk/94712/aurelia_marcelina_bladowska, accessed March 2, 2025.

Wrzeszcz's history begins with the founding of a mill owned by the Cistercians of Oliwa[985]. The village endured frequent destruction by fire during the turbulent medieval period. Another noteworthy settlement was the "Young Town," founded between 1380 and 1455[986], situated between Gdańsk and Wrzeszcz[987]. In 1529, a gallows was erected on Execution Hill (ger. *Galgenberg*), a landmark that later appeared on many maps.

A significant transformation of the area occurred in the 17th century, when overpopulation within Gdańsk's fortified city centre prompted patricians and wealthy merchants to settle along the road to Oliwa. This suburban expansion led to the construction of numerous Baroque manor houses at the foot of the hills, among them *Heiligenbrunn Manor* (pol. *Święta Studzienka – Holy Well)* and *Königstal* (pol. Królewska Dolina - Royal Valley). At the same time, several estates with industrial functions were established, such as *Klein Hammer* (pol. *Kuźniczki)* and the manorial estates (I–XI) in Polanki[988].

One particularly notable residence in Królewska Dolina was built by the merchant Zachariasz Zappio. Initially called *Grüne Brünne* (Green Spring) because of its proximity to *Heiligenbrunn*, the estate was later renamed *Royal Valley* following a visit by King Jan III Sobieski. Another important estate was the *Mon Plaisir* Manor, owned by the Uphagen family, which appears on historical maps and today serves as a valuable reference point for geolocating other historical sites.

Between 1768 and 1770, a monumental public avenue was laid out to connect Wrzeszcz with Gdańsk's city centre. Designed as a landscaped promenade, it was planted with four rows of Dutch linden trees. After the First Partition of Poland in 1772, a border post was erected along the Great Avenue[989], though it was dismantled in 1792 following the Second Partition, when all of Pomerania was incorporated into Prussia.

For many years, the area between Gdańsk and Wrzeszcz remained largely undeveloped because of the protective zone surrounding the Gdańsk fortress. This defensive belt prevented continuous urban growth and instead fostered the emergence of two distinct settlement centres: the fortified city of Danzig itself, and its suburban surroundings, including Wrzeszcz with its manor houses and the area now occupied by Gdańsk University of Technology, the former crop fields.

During the Napoleonic Wars, the Siege of Danzig took place in 1807, when Napoleon's army targeted the city as a key strategic stronghold[990]. The front line passed along the Great Avenue and through Wrzeszcz. In the course of the fighting, the hospital and the Church of All God's Angels were destroyed, together with the remaining traces of the Young City. That same year, the First Free City of Danzig was established.

Further clashes followed in 1813, when Prussian-Russian forces launched a major counter-offensive and recaptured Gdańsk. These events caused extensive damage to Wrzeszcz and likely led to the destruction of the Mon Plaisir (Uphagen) and Königstal (Royal Valley) manor houses. The present form of these manors dates to their reconstruction after the Napoleonic Wars, when they were rebuilt on

[985] Jakub Szczepański, "Siedem i Pół Wieku Wrzeszcza," in *Wędrówki po Wrzeszczu*, ed. Jakub Szczepański and Katarzyna Szczepańska (Gdańsk: Słowo/obraz terytoria, 2011), 12.

[986] Piotr Samól, Młode Miasto Gdańsk (1380-1455) i jego patrymonium (Gdańsk: Wydawnictwo Uniwersytetu Gdańskiego, 2018)

[987] The only surviving trace of this settlement is the archaeological remains of the Church of All God's Angels.

[988] Marcin Gawlicki, Polanki. Podmiejskie rezydencje mieszczan gdańskich (Gdańsk: Wydawnictwo Terytoria, 2019).

[989] This resulted in a rather peculiar way of life, where a merchant owning a manor in Wrzeszcz had to cross the border between Prussia and the Crown twice a day to reach his shop or exchange in the inner city.

[990] Nieuważny, Andrzej. 2022. Klucz Do Wszystkiego. Dzieje Napoleońskiej Twierdzy Gdańsk 1807-1814. Gdańsk: Wydawnictwo Muzeum Gdańska.

the sites of earlier Baroque residences and adapted in a Classicist style consistent with Gdańsk architecture of the period[991].

The subsequent history of the area includes the creation of Jaśkowa Dolina Park, a city-funded project established on the hills flanking the Jaśkowa Dolina stream. Around 1860, a series of cemeteries belonging to individual Gdańsk churches and parishes were laid out along the Great Avenue[992].

By the late 19th century, the landscape of Wrzeszcz and its surroundings changed dramatically. New streets were introduced, and the area saw the rapid development of villas and turn-of-the-century tenement houses. These tenements, often built along Wrzeszcz's main longitudinal axis, displayed eclectic and historicist styles. During this same period, the Abegg Foundation established workers' housing estates near the cemetery, providing much-needed accommodation for the labouring population. To the north of the Royal Valley estate, formerly owned by Zachariasz Zappio, a complex for the blind was constructed. At the same time, medical infrastructure expanded with the building of a large hospital complex to the south, later incorporated into the Medical Academy.

In 1897, the Gdańsk City Council purchased the land designated for the construction of the *Technische Hochschule*. Between 1899 and 1904, the Gdańsk University of Technology was built, marking a major milestone in the city's development. Shortly after its completion, another educational institution was added: the neo-Renaissance Catholic Teacher's Seminary, which survives to this day.

During the Second World War, the area suffered partial destruction, particularly along the main thoroughfare, now Grunwaldzka Street. This resulted from the Soviet advance, when the Red Army broke through to the Baltic at Sopot in March 1945 and attacked Gdańsk from the northwest, entering via Wrzeszcz[993].

After the war, following the change of government and the resettlement of Danzig's population, rebuilding of the area began. One of the most significant decisions was to demolish the partially destroyed northern frontage of Wrzeszcz's main thoroughfare in order to widen the road connecting the district with the city centre. By the late 1940s, the Grunwaldzka residential district was laid out in the socialist realist style, while the area surrounding the Polytechnic also underwent further expansion. In the subsequent decades, the urban fabric continued to evolve, with additional buildings introduced during the modernist period.

The manor houses of Wrzeszcz have also undergone various transformations. The oldest of them, Heiligenbrunn, today stands in a state of permanent ruin. The property was sold by the city to Aleksandra Kociałkowska[994], who sought to restore the manor to its former splendour. To this end, she organised a conference, published the already mentioned book, and attempted to raise the necessary funds. However, following her death in 2022, the manor has remained in ruin. Notably, the northern wing underwent visible changes: it was dismantled and rebuilt using new materials and techniques, whereas drawings published in 2007 still depict it in its original form.

The Mon Plaisir Manor, built in the Baroque period as one of several patrician villas in Wrzeszcz, was destroyed in 1813 during the siege of Gdańsk by Russian forces. It was later rebuilt in the Classical style

[991] The 19th century, following the Napoleonic Wars, was marked by a relatively stagnant phase in the development of both the city centre and its suburbs, with few major new investments being undertaken.

[992] Although later demolished, their presence is still legible in the urban fabric today.

[993] The fighting caused heavy damage to the northern frontage and to vital infrastructure.

See Maciej Żakiewicz, *Gdańsk 1945: Kronika wojennej burzy* (Gdańsk: Oskar, 2011).

[994] Katarzyna Moritz, "Dwór Studzienka we Wrzeszczu. 'Akcja klepsydra,'" *Trojmiasto.pl,* February 9, 2012, accessed March 8, 2025, https://www.trojmiasto.pl/historia/Dwor-Studzienka-we-Wrzeszczu-Akcja-klepsydra-n55277.html?strona=3.

on the same site, incorporating its original cellars. The building has survived to the present day. After the Second World War, it temporarily housed the Swedish consulate. Between 1976 and 2001, its historic interiors served as the venue for civil marriage ceremonies, earning it the nickname *Wedding Palace*. Today, it accommodates the Regional Information and Support Centre for Non-Governmental Organisations and was restored in 2019.

5.4.2. Historical urban development

Archival and historical studies

The author analyzed a wide range of historical and archival sources[995], including maps and etchings from different periods, obtained through archival research, that depicted the Heiligenbrunn area. These sources provided essential insights into the spatial evolution of the site and were integrated into a GIS environment to support detailed mapping.

Fig. 221. Historical sources. Left: Map of the terrain between Wrzeszcz and Gdańsk by Peter Willer, 1691, (Source: BG PAN, C I 54). Right: Friedrich Bernhard Engelhardt, *Map of the Danzig Surroundings,* 1813 (detail of Heiligenbrunn), (Source: Collection of the Royal Castle in Warsaw).

An in-depth study of these materials produced a synthesis of knowledge about spatial changes within the Heiligenbrunn manor area. Identified features included communication routes, some with medieval origins, rivers, streams, ponds, Baroque manor houses belonging to the Heiligenbrunn, Zappio, and Uphagen families, gardens, tree-lined alleys, and the Great Alley. These features were geolocated and cross-checked in ArcGIS, where their accuracy was verified through comparison with present-day geodetic data, archival overlays, and field observations[996]. This process produced a reliable dataset that later formed the basis for virtual reconstruction.

[995] Friedrich Brendt, Map of the Village of Rutki (later *Heiligenbrunn*) and the Church of All God's Angels, ca. 1601, Archiwum Państwowe w Gdańsku (APG), 300, MP/511; Peter Willer, Map of the Area between Wrzeszcz and Gdańsk, 1691, Biblioteka Gdańska PAN (BG PAN), C I 54; Map of the Area between Wrzeszcz and Gdańsk, ca. 1700, BG PAN, C I 54.7.f; Siege of Gdańsk, 1807, APG, 300, MP/3; Friedrich Bernhard Engelhardt, Map of the Danzig Surroundings, 1813; Stadtgeometer Block, Maps of Wrzeszcz, 1896–98, BG PAN, C I 54.12–14; Map of the City of Danzig, 1920, BG PAN, C I 46.1; Geländeplan Freie Stadt Danzig, 1926–33, BG PAN, collection B 550; Map of Wrzeszcz, 1940; Mapa Wrzeszcz, 1947, private collection of Marek Zieliński, online access.

[996] The integration of the material into the GIS environment will be discussed in detail in the following chapter, in order to maintain the structural coherence of the dissertation. It should be noted, however, that the processes of digitalisation, archival research, and interpretive analysis were carried out simultaneously.

Fig. 222. Map of 1885 underlay under the today buildings outline, in ArcGIS, visualizing the differences. Source: author.

Stratification of urban area.

To systematize this diachronic material, a stratification of the urban area was created. Architectural objects were grouped into chronological layers corresponding to major political and social transformations. GIS integration allowed historical cartography to be georeferenced on the basis of present-day geodetic data, enabling precise comparison between historical and current urban forms. This layered approach produced a rigorous cartographic synthesis and provided the methodological foundation for subsequent three-dimensional modelling and immersive reconstruction. The stratified reconstructions, when experienced in virtual reality, not only convey the physical evolution of the district but also enable diachronic comparison across phases, making otherwise invisible historical transformations accessible and comprehensible.

Historical Development

For the development of the reconstruction, the author selected four historical phases, each supported by reliable sources. Earlier archival material from the seventeenth and eighteenth centuries, although valuable, was considered too fragmentary for detailed reconstruction and therefore served only as contextual background. Synthetic interpretive plans were prepared for each phase and translated into virtual reality scenes. Following a author's subtraction method, where each earlier phase was established by systematically removing features introduced in later periods, ensuring chronological consistency and reflecting both archival evidence and the logical sequence of urban development. The phases were established in reverse chronological order:

- 2025 Present day. This phase documents post-war reconstruction and modernization, serving as the reference model, established through urban inventory and aerial LiDAR scanning.

- 1930s. This period reflects the Second Free City of Danzig, illustrating rapid infrastructural growth, densification, and the rise of Gdańsk University of Technology.
- Circa 1895. This phase captures the eve of Wrzeszcz and Heiligenbrunn's industrial expansion, marked by the development of railways, shipyards, aligned with and the process of defortification of Gdańsk.
- Circa 1815. This phase corresponds to the period after the Napoleonic campaign and the recapture of Gdańsk by Prussia, coinciding with the rebuilding of Baroque manor houses. It is extensively documented in military and siege maps.

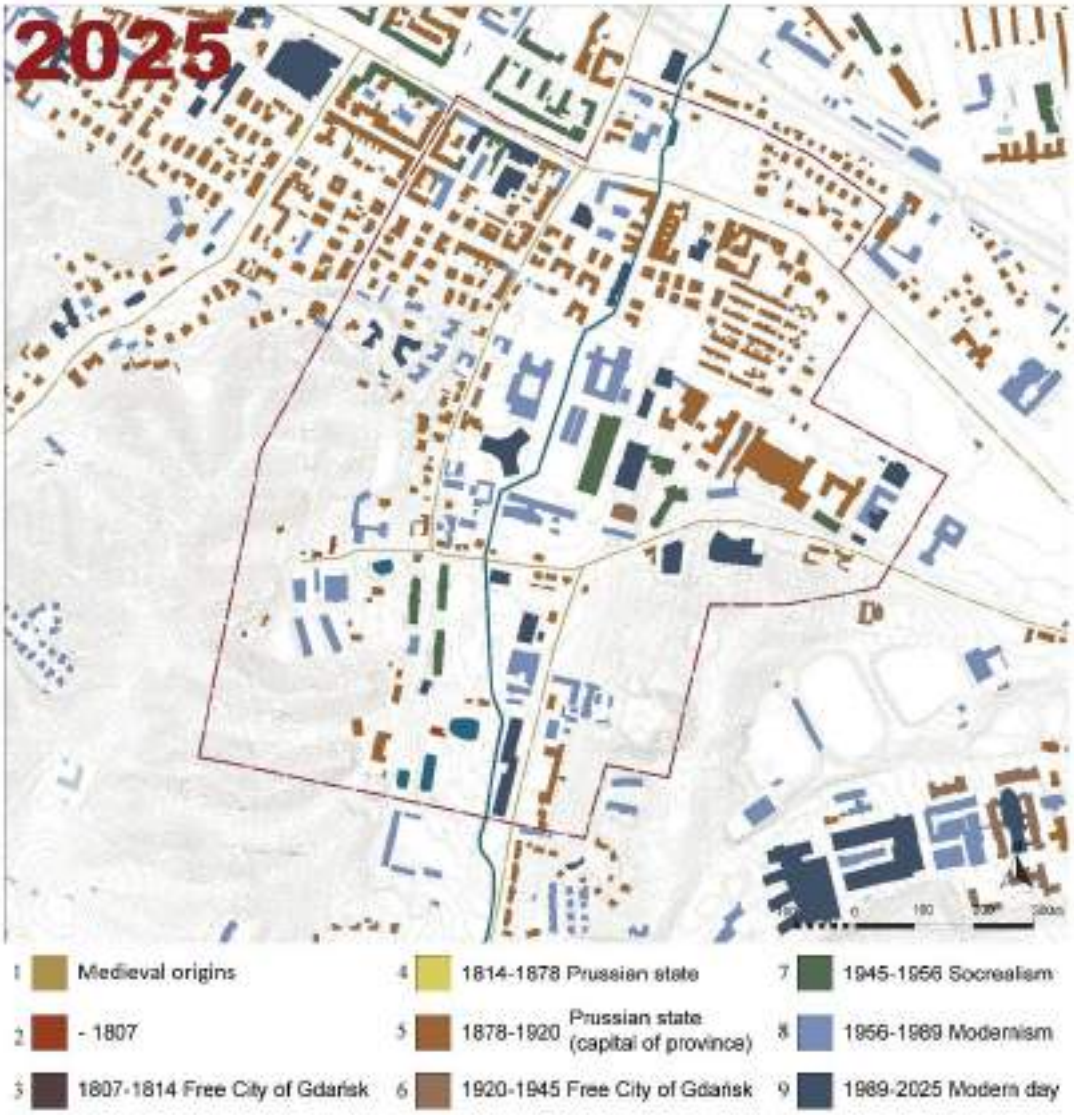


Fig. 223. Urban stratification plan. Source: author.

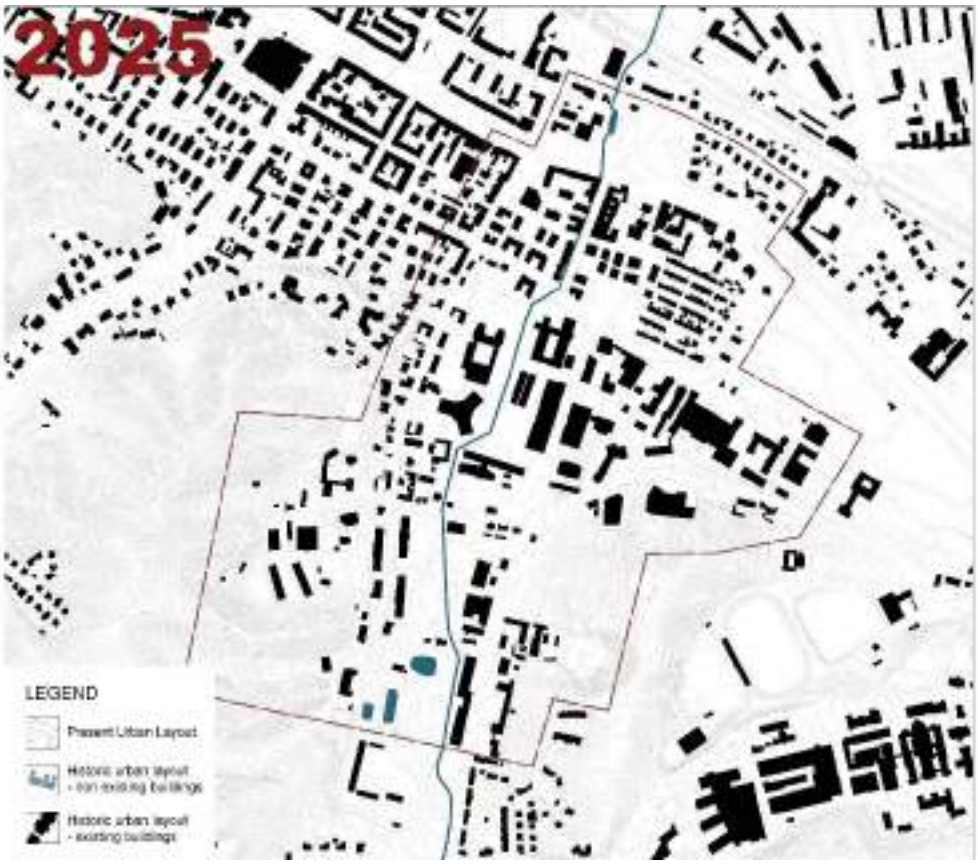


Fig. 224. Heiligenbrunn area in 2025. Source: author.

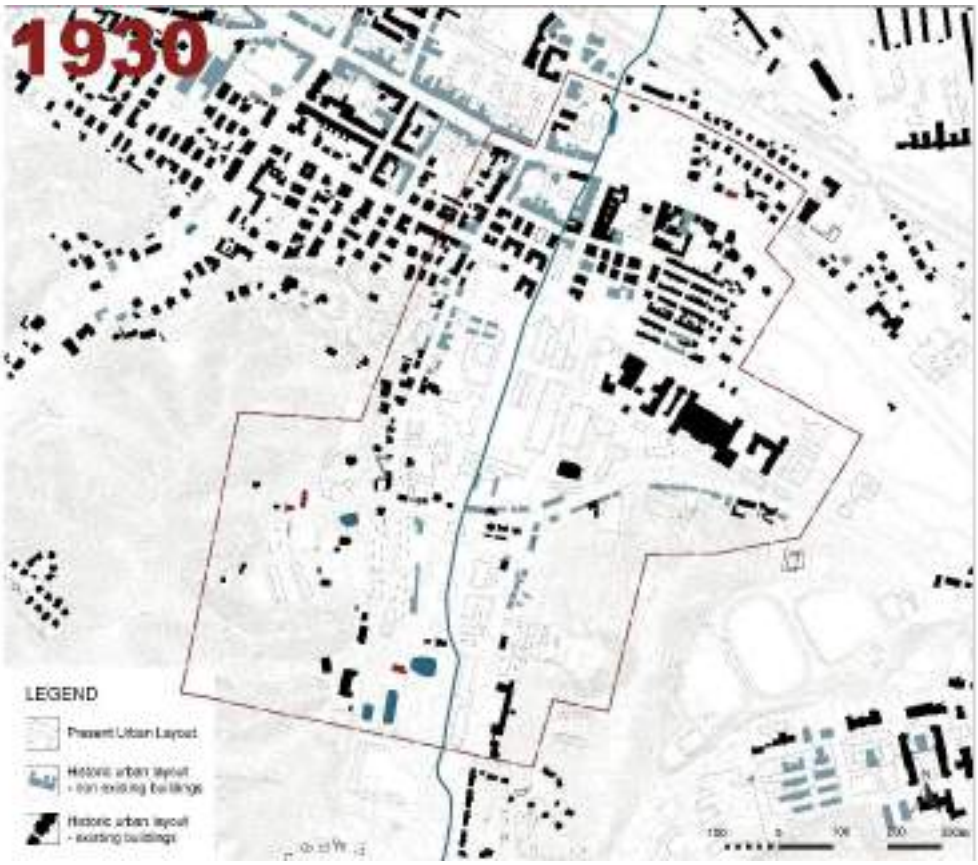


Fig. 225. Heiligenbrunn area in 1930. Source: author.

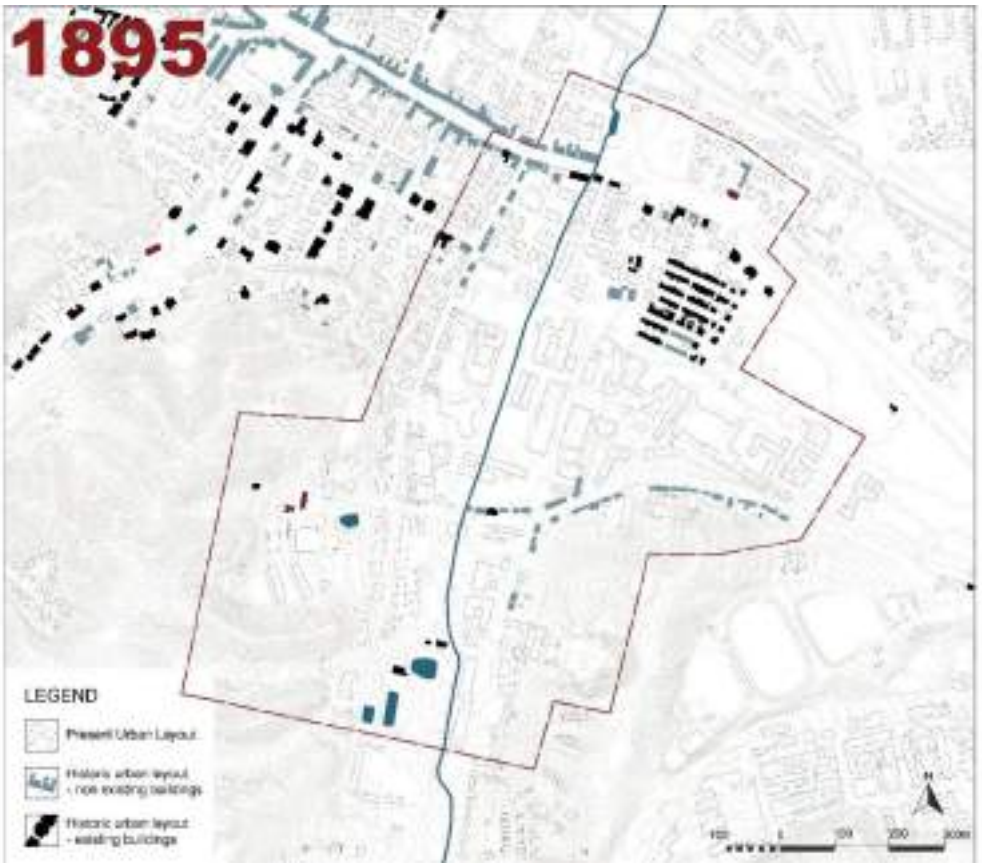


Fig. 226. Heiligenbrunn area in 1895. Source: author.

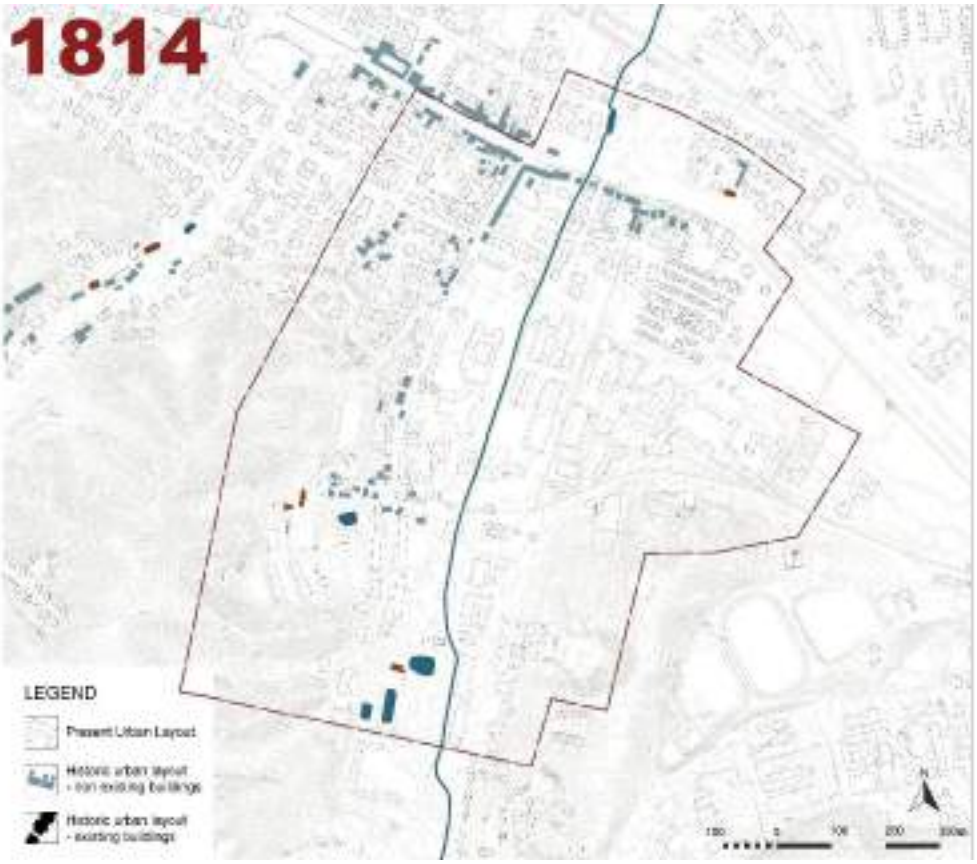


Fig. 227. Heiligenbrunn area in 1814. Source: author.

5.4.3. Digital survey

During the course of the research, the methodological approach evolved in response to the limitations encountered with open-source datasets. The initial workflow, based on aerial LiDAR data, numerical terrain models, and topographical databases, provided a solid geospatial foundation but proved insufficient for generating mesh models of the accuracy required for immersive reconstruction. Attempts to refine the data using ArcGIS and CloudCompare highlighted the critical dependence of the process on point density, which was inadequate in the available open-source resources. Consequently, the methodology was adapted to incorporate drone-based aerial photogrammetry, which offered a higher-resolution alternative. This shift not only ensured greater accuracy in representing the built environment but also enabled the reliable reconstruction of vertical surfaces, thereby aligning the digital models more closely with the aims of the study.

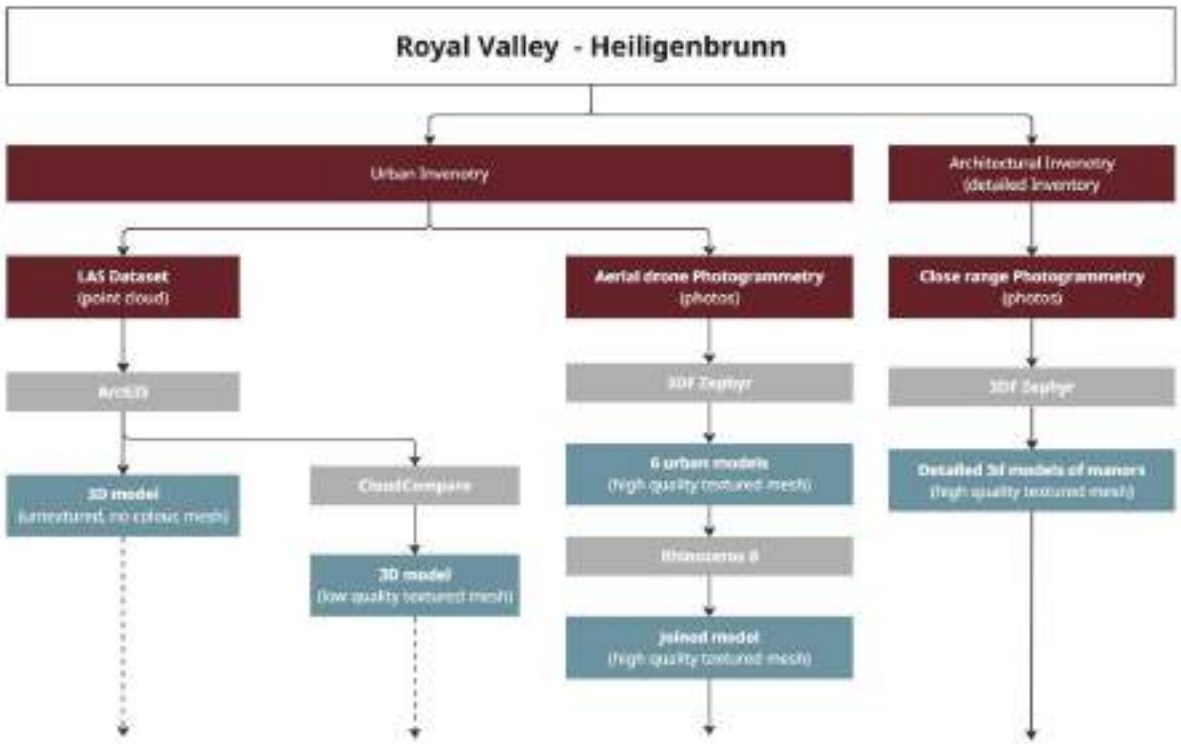


Fig. 228. Digital survey methodological workflow. Source: author.

Detailed inventory

In order to create a detailed digital inventory of not only the wider urban area but also each manor and its immediate surroundings, the author decided to combine urban and architectural inventory approaches. To broaden the scope of this work, the author, together with a group of students from the inventory practice course, prepared inventories of the preserved manors, including Heiligenbrunn and Kings Valley. The aim was to document their current state and to produce detailed digital records using photogrammetry techniques, which would later be integrated into the virtual environment.

Fig. 229. Heiligenbrunn Mannor digital inventory. Source: author.

Fig. 230. *Heiligenbrunn* Manor inventory. Source: author with students from documentation practice.

Fig. 231. Royal Valley *(Königstal)* Manor inventory. Source: author with students from documentation practice.

Open source aerial LIDAR point cloud

To create the virtual reconstruction, as in the previous studies, the objective was to develop a 3D model that accurately reflected the historical state of the area at the selected moment in time[997]. To construct such an extensive environment with the highest possible degree of realism, the author first made use of open-source data from the Polish Geoportal, with the most essential resource being the LiDAR point cloud acquired through aerial surveys[998]. Using ArcGIS, the author imported and unpacked the LAZ data packages, converting them into the LAS format for 3D visualization. This process yielded a highly accurate urban inventory of the research area, which was further refined using ArcGIS filtering tools. These tools allowed for the extraction of points specifically associated with buildings, enabling the isolation of relevant structures and ensuring a more precise representation of the urban environment.

In addition to the aerial LiDAR point cloud, the author imported a numerical terrain model, also produced through aerial scanning and made available by the Geoportal in raster format. This model was used to generate an exact terrain mesh that subsequently served as the foundation for the virtual

[997] The author did not undertake detailed architectural research, as described in the previous case studies, since this was not the primary objective of the present study. Instead, the research focused on a broader spatial context, which made in-depth analysis of individual structures unnecessary.

[998] Upon subsequently encountering a significant problem in converting point clouds into a mesh model, the author was compelled to develop an alternative methodology, employing drones and aerial photogrammetry to produce a high-quality scan. Accordingly, the description will be divided into two parts and presented in detail later.

reconstruction. To supplement this, the Database of Topographical Objects (BDOT10k)[999] was incorporated, providing additional information such as building outlines, the precise locations of watercourses, and other elements of urban infrastructure. By combining these datasets, it was possible to align terrain, built structures, and infrastructural features within a single geospatial framework, creating a coherent basis for 3D modeling.

The integration of these diverse sources also required addressing several challenges, including differences in resolution and accuracy between aerial LiDAR, raster terrain data, and BDOT10k records, as well as the need for manual verification of ambiguous features. Nonetheless, this multi-layered approach ensured both greater accuracy and methodological transparency. Ultimately, the workflow established a robust geospatial foundation for the immersive reconstruction, enabling a historically grounded and technically consistent model that bridged archival cartography, geospatial data, and digital visualization.

Fig. 232. Aerial Lidar point cloud of Gdańsk University of Technology and area of Heiligenbrunn in ArcGIS software. Source: author.

Historical maps implementation into GIS model

Historical maps obtained through archival research were incorporated into the GIS project, georeferenced, and scaled in multiple directions using established reference points[1000]. Key landmarks such as the corners of Baroque manors, major crossroads, and other prominent features served as anchors for precise alignment. This process produced a triangulated geodetic warp, ensuring that the historical maps corresponded accurately to the modern spatial framework. As a result, the maps could be superimposed onto the previously imported digital terrain model, providing three-dimensional spatial context and supporting detailed elevation analysis.

To refine the analysis, contemporary buildings were scaled within the model and positioned in relation to historical subdivisions. This approach, which reverses the conventional direction of such surveys,

[999] Central Office of Geodesy and Cartography. *Database of Topographical Objects (BDOT10k)*. Polish Geoportal. Accessed March 6, 2025. https://www.geoportal.gov.pl/pl/dane/baza-danych-obiektow-topograficznych-bdot10k/.

[1000] The author wishes to express his heartfelt gratitude to his colleague, Joanna Badach, for her guidance with the methodology and for introducing creative solutions in ArcGIS. Her support was essential in achieving the accuracy of these studies and in completing this case study.

offered a more nuanced understanding of the relationship between past and present urban layouts. By overlaying modern structures onto historical maps rather than the reverse, the study revealed insights into both the continuity of spatial patterns and the transformations of the built environment over time. In addition, contemporary structures derived from the imported point cloud were integrated into the model, enabling their precise correlation with historical boundaries and further reinforcing the validity of the analysis[1001].

Fig. 233. Filtered aerial lidar point cloud of Gdańsk University of Technology, projected to the map of 1930 in ArcGIS. Source: author.

Mesh model based on opensource data

Due to the requirements of 3D model visualization, the acquired datasets had to be converted into mesh models. The first method employed by the author involved the use of built-in tools within ArcGIS, the most effective being the Point Cloud to TIN methodology[1002]. In this approach, points from the aerial LiDAR point cloud were projected onto the building outlines, generating a scan-based 3D model of the structures. However, the final results proved unsatisfactory: the walls appeared fragmented and jagged, the geometry was overly simplified, and the models lacked any color information[1003].

[1001] This method, which inverted the typical approach to such surveys, allowed for a more precise understanding of the relationship between past and present urban layouts. By overlaying modern structures onto historical maps, rather than the reverse, the study revealed new insights into the continuity and transformation of the built environment over time.

[1002] The method was largely developed by a colleague from the faculty, Dr. Eng. Arch. Joanna Badach, during the joint implementation of the grant *"Student science groups create innovations: Digital Twin of Gdańsk. Digital Modeling of City Development – from History to the Past"*, funded by the Ministry of Science and Higher Education (MNiSW), agreement number SKN/SP/570294/2023. Within this project, the author was a team member responsible for historical research and the methodology of 3D printing.

See: "Cyfrowy bliźniak Gdańska: Modelowanie cyfrowe rozwoju miasta od historii do przeszłości." *Most Wiedzy*. Accessed May 2, 2025. https://mostwiedzy.pl/pl/project/cyfrowy-blizniak-gdanska-modelowanie-cyfrowe-rozwoju-miasta-od-historii-do-przeszlosci,1035-1.

[1003] Unfortunately, this method of applying a 3D model in a VR simulation was not as effective as intended. It is better suited to generating simplified 3D models that can be prepared for 3D printing, making it particularly useful for producing city models derived from scans.

Fig. 234. Aerial point cloud transferred to mesh model using method Point cloud to TIN, with raster to TIN as ground model. Source: author.

The alternative method, developed by the author, involved filtering the point cloud by classification values[1004] to extract only the buildings (Class 6) using GIS software, resulting in a separate building-only dataset. Due to the lack of satisfactory mesh-generation tools within the GIS environment, this point cloud was exported as a .LAZ file and imported into CloudCompare for further refinement. Within CloudCompare, the data was merged into a single master point cloud, after which Octree[1005] structures and normals[1006] were computed to prepare it for conversion[1007]. The Poisson Reconstruction plugin was then used in an attempt to generate a mesh through triangulation. However, the outcome was far from satisfactory, as the poor quality of the model was primarily caused by the insufficient point density of the open-source dataset.s

Although this method, developed by the author with the invaluable assistance of Joanna Badach, did not initially produce reliable results, it is expected to become effective once denser aerial point cloud datasets are made available. This outcome highlights the critical dependence of immersive VR reconstructions on the quality of base data, underscoring the need for high-resolution surveys to achieve both technical precision and historical authenticity[1008].

[1004] The point cloud provided by the Geoportal is classified according to the Common LiDAR Classification Codes (ASPRS Standard). This means that individual points are assigned specific indices, which makes it possible to filter and isolate particular groups of features. The classifications used are as follows: 0 – Never Classified, 1 – Unclassified, 2 – Ground, 3 – Low Vegetation, 4 – Medium Vegetation, 5 – High Vegetation, 6 – Building, 7 – Low Point (noise), 9 – Water, and 10 – Rail.

[1005] An octree is a spatial data structure used to partition point clouds in three-dimensional space. By organizing the data into a hierarchy of nested cubes, it significantly improves the efficiency of operations such as distance computation, segmentation, normal estimation, and registration.

[1006] Normals in point clouds are vectors perpendicular to the surfaces represented by the points. They define the local orientation of a surface and are essential for processes such as meshing, shading, and accurate 3D reconstruction.

[1007] Meshing is the process of converting a point cloud, which consists of discrete individual points, into a continuous surface representation, typically composed of interconnected polygons (usually triangles) that form a mesh.

[1008] The density of aerial LiDAR point clouds in Poland varies depending on the acquisition campaign and the area of interest. The primary national source of LiDAR data is the ISOK project (Informatyczny System Osłony Kraju), coordinated by the Head Office of Geodesy and Cartography (GUGiK). Standard national coverage (ISOK/LPIS) typically ranges from 4 to 12 points per square metre. In certain cases, such as in Gdańsk, the municipality has commissioned very high-density LiDAR, reaching 20–30 points per square metre, primarily for urban planning and infrastructure development. Even this higher-density open-source data, however, remains insufficient for generating highly accurate mesh models using the method described. With ongoing advancements in remote sensing technology, it is expected that GUGiK will significantly increase data density in future campaigns.

Fig. 235. Left: filtered aerial lidar point cloud of the Wrzeszcz district acquired via Geoportal and processed in ArcGIS. Right: the same point cloud transferred into the mesh model. Source: author.

Mesh model based on drone aerial photogrammetry

Due to the unsatisfactory results of the model described in the previous paragraph, the author decided to employ the established method of drone-based aerial photogrammetry to produce a high-accuracy representation. Given the extensive scope of the digital survey, which encompassed not only the university structures but also the surrounding urban layout and green areas, covering a total area of approximately 850 × 1100 metres, the flight missions had to be divided into subparts. Over the course of two weeks[1009], the author, together with a colleague[1010], conducted approximately eleven separate flights using a DJI Mavic 3 and a DJI Mavic 3 Mini to capture a comprehensive photographic dataset. In total, 19,391 individual images were collected and used to generate six separate models of the area, which were divided into parts due to the limitations of the software[1011].

The separated parts were created with an extension collar to ensure the most accurate representation and were subsequently imported into Rhinoceros 8 software for the merging process. Because the metadata of each photograph contained GPS coordinates, the sub-models were automatically assigned geolocation data, which facilitated their alignment. The merging process required the creation of section planes to define the extent of the separate models and to ensure seamless integration.

In comparison with the open-source aerial LiDAR data described previously, this method produced a far more accurate representation owing to the greater coverage of the built environment. Moreover, the use of a gimbal-mounted camera positioned at an angle of approximately 45 degrees enabled a more precise reconstruction of vertical walls, an aspect that the LiDAR-based method failed to capture effectively.

[1009] The extended duration of the flight missions was primarily due to changing weather conditions, as well as GPS jamming from the Kaliningrad Oblast, a consequence of the ongoing Russian-Ukrainian conflict since 2022, which significantly impacted the flight missions.

[1010] Some of the aerial photographs used in this study were taken by Pauline Bone. The author extends sincere gratitude for her invaluable assistance and dedication during the drone flights, which significantly contributed to the quality of the photogrammetric documentation.

[1011] The limitations arose from the computational capabilities of both the software and the hardware workstation used by the author. As practical experience demonstrated, the 3DF Zephyr software, when paired with the workstation (Intel i9, 16 cores, 32 GHz, 64 GB RAM, RTX 3080 Ti), was unable to process models based on more than 5,500 photos acquired with the DJI Mavic 3 drone. Consequently, the solution was to divide the project into six subparts.

Fig. 236. One of the 3d models showing historical campus of Gdańsk University of Technology, published at the Sketchfab platform[1012]. Source: author and Paulina Bone.

Fig. 237. The six individual aerial photogrammetry scans of the entire area were joined and unified into a single master scan. Source: author.

1012 DALAB_PG, *Politechnika Gdańska*, 3D model, by Szymon Kowalski and Paulina Bone, Sketchfab, published June 3, 2024. https://sketchfab.com/3d-models/politechnika-gdanska-342d4fe2b4da44418091223c7f94a003

5.4.4. Virtual reconstruction

After the partial models were unified in the 3D modelling software *Rhinoceros 8*, it became possible to develop virtual representations for each historical period. Building on the results of earlier urban-historical research, the scan-based model was segmented into individual buildings. The dataset was supplemented with a terrain model and urban structures acquired through aerial laser scanning and subsequently processed in GIS software, to keep the high level of geometric accuracy. This workflow enabled the creation of four distinct historical models, each corresponding to a different stage in the district's development and together providing both a chronological and spatial interpretation of the site's transformation.

Missing structures were reconstructed using archival sources, particularly historical maps and photographs. To ensure geometric accuracy, perspective restitution techniques described in previous case studies were also applied. Several simplifications were introduced to make the modelling process feasible at the urban scale. Vegetation, including rows of trees, surrounding parkland, and other greenery, was omitted in order to emphasise the built fabric. The most significant simplification was the assumption that buildings had remained unchanged over time. Archival inventories demonstrate that this was not the case, as many structures were extended, their façades altered, or replaced entirely. Nevertheless, this generalisation was retained to keep the models simple, methodologically clear, and manageable. More detailed work, such as adding ornamental features or creating retopologies for each building, was deliberately avoided. Although technically possible, such refinements would have added little value at the urban scale and would have overlapped with the objectives of architectural-scale studies[1013].

Urban-scale reconstructions also raise questions of accuracy, since not every part of the district is covered by reliable archival evidence that would permit precise modelling. While the integration of scan data, archival sources, and restitution techniques can produce detailed digital environments, the vast scope of an entire district introduces a level of complexity that risks obscuring the interpretive aims of the project. Each additional building requires segmentation, modelling, and interpretive decision-making, which exponentially increases the time and resources required. A convincing VR simulation would also demand the reconstruction of pavements—which in this case evolved from cobblestones to asphalt—along with urban furniture such as benches and lampposts. Yet the gains in precision remain marginal when measured against the overall scale of the model. From the intended first-person perspective, fine-grained detailing of façades or ornamental features contributes little to historical interpretation. At this stage, the project risks becoming an exercise in exhaustive modelling rather than a focused investigation of transformation over time.

The technical limitations further compounded these issues. Even when reduced photogrammetric scans were employed, the overall data volume exceeded the processing capacity of the author's computer. This problem was most evident during rendering and real-time calculations in the virtual reality environment, which severely constrained workflow efficiency[1014]. Given these methodological

[1013] The officers' villa offers a particularly instructive case, as it provides an almost ideal reference point for both scale and decorative scheme from a comparable period. More broadly, although the method was applied to an entire district, it remained conceptually close to the architectural scale. This is because the first-person perspective used in the visualisations effectively framed the wider district as an enlarged architectural object.

[1014] Professional development teams working on commercial virtual environments often employ advanced optimisation strategies, including level of detail management, mesh decimation, texture baking, or occlusion culling, to render complex urban models efficiently in real time. These techniques require not only substantial computational resources but also specialised expertise in computer graphics and game development, where real-time rendering is the primary field of

and technical challenges, and recognising the financial constraints on acquiring more powerful equipment, the author ultimately judged full-scale urban reconstruction unnecessary and potentially misleading at this stage, and chose instead to present its potential in a separate study.

Fig. 238. Simplified model showing 2025 using segmented building from a scanned photogrammetry model with integration of TIN buildings and a mesh terrain model. Source: author.

Fig. 239. Reconstruction of the 1930 state, with missing buildings in red, based on the previous model. Source: author.

As a pragmatic compromise, a cut-out urban scene was developed, in which a historical engraving was animated within an immersive environment. This shifted the emphasis from a full urban reconstruction

practice. As the author does not possess professional training in game development, and since the workflow was carried out in dedicated architectural software rather than in a game engine, such optimisation methods could not be implemented within the scope of this study, which was conducted on a single workstation. Nevertheless, the author recognises the value of these techniques and intends, in future studies, to explore the creation of optimised immersive environments drawing on such professional practices.

to a pilot, scene-based exploration of historical landscape reconstruction. The focus was placed on simplified modelling, using elements from previously acquired scans combined in a patchwork to create a virtual reconstruction of the valley around 1825[1015]. The author intentionally simplified the geometries of the reconstructed structures[1016], acknowledging the potential inaccuracies of the lithograph[1017].

Fig. 240. Surroundings of Royal Valley and *Heiligenbrunn,* original lithograph by Carl August Helmsauer around 1825.

Fig. 241. Virtual model based on Helmsauer's lithograph. Source: author.

[1015] It should be noted that the source materials contain notable inconsistencies. Some buildings shown on the maps are absent from the lithograph, while certain structures visible in the lithograph do not appear in the cartographic record. These discrepancies stem not only from the limitations of representational techniques and the selective choices made by the authors, but also from the differing dates and processes of production. The creation of a map was a lengthy undertaking, involving field surveys, editing, and corrections, during which the built environment could already have changed. Such factors necessitate critical analysis and caution when attempting to reconstruct the historical landscape.

[1016] Additional elements such as fences or other minor details could have supplemented the view, but modeling them would serve merely as aesthetic embellishment without adding significant research value. For this reason, the author deliberately refrained from reconstructing every minor feature.

[1017] The use of terrain scans and scans of selected structures made it possible to partially approximate the landscape as it might have appeared around 1825. A comparison with the lithograph, however, reveals different proportions in the representation of the view, resulting from both the chosen perspective and the simplifications of the graphic composition. In this framing, particular emphasis was placed on the manor houses, which in the digital reconstruction tends to be visually absorbed into the surrounding landscape.

An intermediate solution was also tested through the superimposition of missing structures directly onto the scan data in virtual reality. This approach conveyed the impression of altered architecture and evolving urban layouts without requiring the exhaustive reconstruction of every element. The model was simulated using the Enscape rendering plugin directly within Rhino modelling software and visualised through a head-mounted display (HMD).

Fig. 242. Immersive simulation of Royal Valley in 1825, using HMD. Source: author.

5.5. Cross-Case Conclusions

The three case studies, St. Nicholas Church, Westerplatte, and Heiligenbrunn, demonstrate how immersive reconstruction can operate at interior, object, and urban scales, offering new opportunities for documentation, interpretation, and conservation practice. Collectively, they confirm that immersive reconstructions, when grounded in rigorous digital survey and historical research, are non-invasive, reversible, and adaptable, providing an ethically responsible alternative to material rebuilding.

5.5.1 Conclusions at the Interior Scale (St. Nicholas Church)

The sacristy case demonstrated the methodological importance of interior-scale immersive reconstruction. Small, enclosed spaces heightened perceptual immersion and made diachronic reconstructions easier to understand, positioning interiors as effective testing grounds for developing immersive virtual reconstruction methods. St. Nicholas showed that, when grounded in invasive architectural investigation, digital reconstruction could both safeguard layered history and authenticity and serve as an interpretive medium that turned investigative challenges into opportunities for historical analysis and presentation.

This case showed that:

- The combination of invasive investigation (plaster removal, brick analysis) with non-invasive digital survey (photogrammetry, TLS) provided a fuller record than either approach alone.
- The sacristy's successive interventions, Gothic, seventeenth-century, and Prussian Neo-Gothic, showed that authenticity in interiors must be read as a palimpsest of values, not a single original state.
- Virtual modelling of multiple diachronic phases (ca. 1348, ca. 1370, ca. 1650, nineteenth century, and post-1904) demonstrated how immersive reconstruction can recreate architectural realities that are no longer accessible in material form.
- Reconstructions revealed both structural vulnerabilities and interpretive risks, confirming that VR can serve as an investigative laboratory rather than only a medium of dissemination.

Interdisciplinary synergy

The investigation combined invasive architectural research, such as plaster removal and brick analysis, with non-invasive digital methods, including photogrammetry and terrestrial laser scanning. This interdisciplinary synergy ensured that both tactile evidence and precise geometric data were collected, enabling a more comprehensive reconstruction than either method could achieve alone.

Layered authenticity

The sacristy embodied successive architectural interventions, from Gothic foundations through seventeenth-century adaptations to Prussian Neo-Gothic restorations. Rather than being treated as obstacles, these layers became analytical anchors, showing that authenticity in interiors must be understood as a palimpsest of values rather than a single "original" state.

Conservation insight through simulation

By modelling multiple historical phases (ca. 1348, ca. 1370, ca. 1650, nineteenth century, and post-1904), the study demonstrated how VR could “restore” architectural realities that were no longer materially accessible. Virtual stratigraphy allowed hypotheses to be tested, scholarly claims to be contested, and uncertainties to be explicitly communicated. The reconstructions also exposed both structural vulnerabilities, such as unrealised vaulting schemes, and interpretive risks, such as Prussian stylistic insertions. VR, therefore, functioned not only as a record and tool of dissemination but also as an investigative laboratory, offering views on scenarios for how interventions altered space and perception.

Taken together, the sacristy case illustrated how immersive reconstruction could operate as a form of immaterial time-travel: rooted in architectural investigation, safeguarding layered history and authenticity, and serving as an interpretive medium that transformed investigative obstacles into opportunities for historical presentation. Yet its immersive power also carried interpretive risks, since compelling visualisations can obscure uncertainty or exaggerate hypothetical elements if not critically framed. This awareness underscored the importance of using immersive tools responsibly within conservation practice.

5.5.2 Conclusions at the Object Scale (Westerplatte)

At the object scale, Westerplatte demonstrated how immersive reconstruction can address contested heritage sites where ruins, memory politics, and authenticity debates intersect. The case highlighted both the risks of material reconstruction and the potential of immersive reconstruction as a transparent and non-invasive alternative.

This case showed that:

- Immersive reconstruction provides a reversible and non-invasive alternative to physical rebuilding, preserving surviving fragments such as the New Barracks while visualising lost forms.
- It enables the representation of multiple temporal phases, including pre-war, wartime destruction, and post-war commemoration, avoiding the contradictions inherent in material reconstructions limited to a single moment.
- The site illustrates the impact of memory politics, where successive interventions such as the 1966 memorial and the post-2019 museum concepts have shaped interpretation. Immersive reconstruction offers a way to present these contested narratives without erasing authentic traces.
- Issues of accuracy and interpretation, such as the veranda and colour scheme of the Officers’ Villa, show that reconstructions are always provisional. In digital form, errors can be revised without damaging the authentic substance.
- Different modes of representation, such as complete versus ghosted reconstructions, highlight the importance of transparency, with restrained models better communicating uncertainty.
- Immersive guides and AR overlays offer educational opportunities for battlefield interpretation, providing a middle ground in the debate over whether to reconstruct the site.
- In alignment with the Venice Charter of 1964, the Nara Document of 1994, the London Charter of 2009, and the Seville Principles of 2011, immersive reconstruction demonstrates how international conservation doctrine can be extended into the virtual domain.

Potential Solution

Despite the fact that the commemorative design from 1966 significantly interfered with the authentic substance of the Westerplatte Peninsula, it now holds considerable value, particularly in documenting the communist period and the political approach to memory policy. To enhance the material substance, it will require approaches such as excavating elements, foundations that have been buried for decades, to increase the amount of preserved material or clarify the layout of Westerplatte, including the removal of self-seeded plants to expose the historic tree alleys from the resort period. To further extend its material value, an immersive reconstruction could broaden the perception of the entire battleground. While the reconstruction will never replace the material substance, it will not harm it either. The described examples of multiple case studies around Westerplatte demonstrate the potential of such reconstructions as an alternative to material rebuilding, as the solution is not tangible and does not interfere with authentic substance.

Alternative for Reconstruction

The destruction of the New Barracks cannot be undone today, as, even after being destroyed in the post-war period, it still contains a great deal of authentic substance. It bears witness to both the 1939 and 1945 warfare, particularly through the bullet holes and its overall structure as a memory carrier. The concept of the museum from around 2019, which proposed the full reconstruction of the barracks, could irreversibly erase and destroy the last elements of the object's authenticity. However, using immersive reconstruction, this rebuilding can be visualised and described without altering or even touching the original substance. This approach, in the spirit of John Ruskin's philosophy of minimal intervention, preserves what remains of the site, while providing visitors with all the necessary information about its scale and helping to clarify its dramatic appearance today.

A Moment in Time

An interesting aspect is the timeline of existence. While the authentic preserved, even partially, object can bear traces of previous phases, it will always be positioned as its present-day appearance. Thanks to immersive reconstruction, it is possible to recreate all of the previous phases based on extensive research. As the examples described in this work, both in Chapter 2 and in the case studies, showed, material reconstruction will need to decide to focus on only one period of time, probably the most flourishing, during the existence of the structure. The preserved substance can show stratifications that reveal a complex history.

The Second World War Museum initially aimed to reconstruct the Westerplatte objects and their appearance just before the fighting, as the outbreak of World War II was seen as the most significant moment. However, this raises a dangerous concern: if the concept were implemented along with the museum's policy, it could create a temporal contradiction at Westerplatte. Two timelines could emerge, one authentic, showing the destruction of the objects, and another reconstructed to reflect their appearance in September 1939. Photographs in the text clearly depict the state of the Officers' Villa after the fighting. This temporal discrepancy could mislead visitors into falsely concluding that the fighting never occurred, due to the lack of material evidence. However, immersive reconstruction is free from these risks, as it does not attempt to alter or enter the physical realm. While the reconstruction can provide a sense of interaction and convey the presence of the object in different time periods, it will always remain a form of simulation, not reality.

The issue of scanning is also crucial here, given the planned changes on the peninsula. Today, it is possible to capture the current state before these changes take place, such as the construction of the

new exposition space, or digitally preserving the bus station, serving as a kind of timestamp on the Westerplatte timeline.

Accuracy of Reconstruction

Despite the fact that Andrzej Ditrich has done an excellent job in developing the models, which deserves recognition, this raises the question of his depiction of the Officers' Villa veranda as a potential error. He drew the different dimensions of the outline and roofing that, as previously mentioned, were not present before the outbreak of the Second World War. Another issue is the case of the colour scheme of the Villa, which is also a matter of interpretation, as mentioned earlier in the text. The author does not intend to criticise his predecessor but rather to highlight the broader issue that such reconstructions can pose. After all, the museum had a narrative of reconstruction for some time, and errors in design can lead to significant mistakes in material reconstruction, which later can affect the perception of visitors. The advantage of immersive reconstruction is that it is non-material and, thanks to simulation, it offers a kind of approximation to a state of belief in authenticity. Moreover, any errors that may arise can be corrected, and the reconstruction can be updated accordingly.

Fig. 243. Comparison of the "complete" reconstruction and the more restrained approach. Left Visualisation: (source: 'Mezzano' company 3D renders based on models by Andrzej Ditrich.) Right: Created by the author.

Digital Reconstruction Limit

Another issue is the general idea of providing as faithful a reconstruction as possible, clarifying all of the materials used and colour schemes. This approach offers the viewer a vivid and clear image of the virtually reconstructed structure. However, in the author's opinion, the use of a translucent, ghosted version is much more appropriate for objects where it is not possible to determine all the required information. This approach leaves space for interpretation by each viewer while delivering the most important information, a synthesis of the knowledge that stays within the boundaries of truth, without fabricating or presuming details in order to create a complete appearance of a structure.

Direct Application for Battlefield Sightseeing

This approach, with the use of digital guides, remote sightseeing, and AR guides, significantly enhances the potential for visiting open-air museums like Westerplatte, where the most valuable objects were either destroyed or dismantled during or after the war. It could offer a solution to the long-standing debate over whether to reconstruct the site. This method serves an educational purpose without affecting the existing relics, providing a middle ground in the dispute over the peninsula's future.

Immersive Reconstruction and Conservation Ethics

Unlike material reconstruction or alteration, immersive reconstruction is non-invasive, reversible, and modifiable. It permits dynamic reconfigurations and multiple hypotheses without endangering the authentic fabric. This property positions immersive reconstruction as a mediator in the long-standing tension between the desire to rebuild and the obligation to preserve authenticity, as the case of Westerplatte presented. For heritage practice, this duality carries both promise and risk. Immersive reconstructions enable unprecedented comprehension of spatial qualities, scale, and atmosphere, fostering historical context and supporting educational storytelling. At the same time, the persuasive realism of immersive reconstruction can obscure its interpretive and hypothetical nature, leading to uncritical acceptance of reconstructions by viewers. Responsible application, therefore, requires transparency, documentation, and reflexivity, ensuring that immersive reconstructions remain interpretive tools crafted in the most accurate manner possible.

5.5.3 Conclusions at the Urban Scale (Heiligenbrunn)

At the urban scale, the Royal Valley in Heiligenbrunn demonstrated how immersive reconstruction can handle complex historical layering across centuries of development, where it is not possible to get back to a previous stage of development with the effect of a palimpsest. The case highlighted the scalability of the methodology, moving beyond individual structures to the interpretation of entire urban fabrics.

This case showed that:

- Archival and cartographic sources can be combined with modern drone surveys and terrestrial scans to create a multi-layered reconstruction of urban evolution.
- The methodology is scalable, applicable not only to isolated objects but also to districts and larger heritage landscapes.
- Immersive reconstructions at the urban level allow stakeholders to perceive continuity, rupture, and transformation in a dynamic, spatially engaging form, extending beyond what traditional maps or drawings can convey in 3 dimensions, with or without immersive visualisation.
- At the urban scale, immersive reconstruction can be constrained by limits of detail and data density; oversimplified models risk reducing authenticity, though future advances in computing power and open-source datasets will allow more accurate large-scale environments.

Complex Historical Layering

The case of Heiligenbrunn illustrated the challenges of interpreting architectural heritage where multiple historical periods coexist in the same spatial fabric. From the early stages of the medieval village, remnants of Baroque manor houses to nineteenth-century expansions and contemporary housing, the district represents a palimpsest of interventions. Immersive reconstruction allowed these layers to be visualised together, presenting a unified spatial history that is difficult to perceive in fragmented archival sources.

Integration of Sources and Scales

This case demonstrated how archival cartography and historical documentation can be effectively integrated with modern drone-based photogrammetry and aerial scanning in a GIS environment. The combination of sources produced a reconstruction that was not only geometrically accurate but also historically meaningful. By merging small-scale architectural surveys with large-scale aerial

perspectives, immersive reconstruction proved capable of bridging scales, from single buildings to entire districts.

Urban Interpretation and Public Value

Unlike material reconstruction, which would be unfeasible at the scale of a district, immersive reconstruction provided a feasible but simplified interpretation of urban transformations across centuries. For stakeholders, including planners, researchers, and the general public, the ability to navigate an urban environment through different historical layers in three dimensions offered new insights into continuity, transformation, and loss. This capacity to move between temporal phases in immersive form extends far beyond the static representations of maps or drawings, offering a dynamic, spatial understanding of urban heritage.

Limitations of urban scale

The urban-scale reconstructions carried out in the *Kings Valley – Heiligenbrunn* manors area demonstrate the promise of extending architectural methodologies into broader spatial contexts. Yet they also reveal inherent challenges. Because immersive simulations are ultimately experienced from the perspective of a person moving within the environment, oversimplified urban models cannot provide sufficient detail for accurate interpretation. In this sense, district-scale reconstructions are essentially an extension of architectural-scale approaches, demanding the same attention to precision but applied to a much larger canvas. At present, compromises must be made between scale and detail, as computational capacity and dataset resolution set practical limits. Nevertheless, rapid advancements in computing power, combined with the increasing availability of high-quality open-source data, suggest that in the near future it will be possible to construct larger, more detailed, and more reliable immersive environments, bridging the gap between architectural accuracy and urban comprehensiveness.

5.5.4 Cross-Case Conclusions and Methodological Implications

Across the three scales, several methodological and theoretical insights converge.

Across the three scales, several methodological and theoretical insights converge.

- The iterative interaction between digital inventory and 3D modelling proved central. Scanning techniques such as close-range and aerial photogrammetry, terrestrial and mobile LiDAR, and aerial LiDAR complement and overlap to create comprehensive datasets. Their costs, expertise requirements, and accessibility varied, but together they provided a powerful platform for architectural investigation, enhancing both precision and interpretation.
- Immersive reconstructions, when responsibly applied, were non-invasive, reversible, and modifiable. They preserved surviving substance, conveyed uncertainties, and allowed multiple hypotheses to coexist, aligning with principles set out in the Venice Charter (1964), the Nara Document (1994), the London Charter (2009), and the Seville Principles (2011).
- The multiple immersive visualisation possibilities of the digital reconstruction model, including HMD-based VR and CAVE systems, can be flexibly combined, as they all derive from the same 3D modelling foundation. This interoperability allows the same dataset to be presented through different levels of immersion and interaction, adaptable to both individual and collective experiences, as well as to diverse research, conservation, and educational purposes. Moreover, such models remain open to later extension, alteration, and correction, ensuring

that new findings or interpretations can be seamlessly incorporated without compromising the integrity of the overall reconstruction.

- Immersive reconstruction served both as an epistemological tool for testing historical hypotheses and as a medium of public engagement, making heritage accessible across audiences and contexts.
- The digital reconstruction models can also serve as a foundation for game development, as discussed in Chapter 4, where immersive environments are adapted into interactive experiences that enhance engagement, education, and dissemination of heritage, and can be further enriched with storytelling and narrative.
- The high realism of immersive environments can blur the boundary between interpretation and fact, as in the Westerplatte models, where conjectural elements risk being perceived as authentic.
- Digital obsolescence threatens the long-term sustainability of 3D data, while unequal access to advanced technologies such as HMDs or CAVE systems may restrict wider public engagement.
- A gradual shift from conventional 2D drawings to 3D models as standard practice in conservation appears inevitable. As tools become more accessible, digital workflows are likely to be embraced by conservation offices, provided accuracy and transparency are maintained. This promises higher precision and new interpretive opportunities without compromising authenticity.

Comparative Synthesis Across Scales

Viewed side by side, the three case studies demonstrated the scalability and complementarity of immersive reconstruction. At the interior scale, St. Nicholas showed how diachronic reconstructions could recreate architectural realities no longer materially accessible. At the object scale, Westerplatte demonstrated how immersive reconstruction could mediate contested authenticity and memory politics while avoiding destructive rebuilding. At the urban scale, Heiligenbrunn illustrated the potential to integrate complex historical layering across centuries. Together, these cases showed how one methodological framework could operate from the micro-scale to the macro-scale of urban transformation while addressing distinct conservation dilemmas.

In the author's view, however, the architectural scale represents the most effective point of application: it makes optimal use of available digitisation tools, produces models of significant value, and provides a robust foundation for subsequent simulations.

Stakeholder Reflections

The case studies also revealed the value of immersive reconstruction for diverse stakeholders. For conservators, it offered rigorous and transparent documentation. For researchers, it served as an epistemological tool for testing spatial hypotheses against archival and archaeological evidence. For the public, it provided engaging and accessible interpretations, whether on-site through AR or remotely through immersive guides. For policymakers and heritage managers, it created a neutral platform for negotiating contested narratives, as illustrated by Westerplatte, by making interpretive choices explicit rather than material.

Theoretical Resonance

These conclusions also resonate with theoretical debates developed in earlier chapters. The reflection on authenticity and reconstruction in Chapter 2 found practical expression in the immaterial and

reversible strategies tested here. Similarly, the exploration of illusion and immersion in Chapter 3 was reinterpreted through contemporary digital technologies, where immersive reconstruction inherited and extended earlier traditions of perspectival and panoramic manipulation. In this sense, the case studies closed the loop between the philosophical and historical foundations of immersion and their twenty-first-century application in heritage conservation.

Original Contribution

This chapter, therefore, makes an original contribution to the field of conservation by demonstrating:

- In addition to addressing the scientific aims of the thesis, it presents new findings within the case studies, including the author's own syntheses and original discoveries.
- Immersive reconstruction can be systematically integrated into conservation methodology across interior, object, and urban scales.
- Immersive reconstruction provides an ethical digital alternative to rebuilding to material rebuilding, extending conservation doctrine into the digital domain.
- Virtual reality functions not only as a visualisation tool but also as an epistemological and ethical instrument, serving conservation research, public engagement, and memory politics.
- Virtual reconstruction expands rather than replaces material conservation, creating a hybrid future in which digital models coexist with preserved ruins and fragments.
- VR reconstructions operate as epistemological instruments, enabling the study of transformation, decay, and multiple historical phases in ways that material reconstructions cannot.
- Digital immersion represents the latest stage in a long cultural lineage, from illusionistic art and Renaissance perspective to Baroque quadratura and nineteenth-century panoramas.

These reflections conclude the comparative analysis of the three case studies. They not only synthesise methodological and ethical outcomes but also establish a foundation for the broader theoretical and doctrinal conclusions of this dissertation.

CHAPTER 6

SUMMARY

VIRTUAL REALITY TECHNOLOGY IN ARCHITECTURAL HERITAGE AND ITS IMPACT ON CONSERVATION

6. Summary and final conclusions

This final chapter synthesises the main findings of the dissertation. It restates the research problem, highlights theoretical and methodological contributions, reviews the case studies, and verifies the research questions and theses. The chapter concludes with reflections on the implications of immersive virtual reconstructions for conservation practice.

Restating the Research Problem

At the heart of architectural conservation lies a persistent tension: the desire to reconstruct lost monuments as symbols of continuity, identity, and resilience, versus the obligation to preserve the authenticity of surviving fabric. Conservation doctrine, articulated in the Venice Charter (1964) and subsequent charters, emphasises irreversibility and authenticity, while cultural expectations often demand visible rebuilding. This contradiction has shaped practice from antiquity through Romantic ruin-cult, post-war reconstructions and rebuilding, and postmodern reconstructions.

In the twenty-first century, digital technologies have emerged as potential mediators of this conflict. Photogrammetry, LiDAR, drones, and immersive visualisation offer non-material, reversible means of engagement. Virtual reality (VR), in particular, enables reconstructions that visualise multiple phases and hypotheses without physically altering remains. This dissertation asked whether VR can serve as an academically rigorous, ethically responsible, and technologically robust alternative to material reconstruction.

Theoretical and Methodological Contributions

Two genealogies informed this work. The first traced shifts in conservation doctrine, from antiquity's continuity of function, through Renaissance and Baroque practices, nineteenth-century dualism of Restauration-Conservation, unification of those thoughts, to the doctrines and post-war varying approaches to postmodern reinterpretation and monuments building. The second followed the history of illusion and immersion, from Pompeian wall painting and Renaissance perspective to Baroque trompe l'oeil, panoramas, and cinema, showing VR as the latest stage in a lineage of immersive strategies that blur boundaries between reality and representation.

Methodologically, the dissertation developed an interdisciplinary framework integrating archival research, architectural investigation, digital survey (photogrammetry, LiDAR, drones), 3D reconstruction, and immersive VR. Its iterative loop between digital inventory and reconstruction allowed survey data to inform hypotheses and reconstructions to clarify spatial interpretation. Aligned with the London Charter (2009) and Seville Principles (2011), the framework emphasised transparency, documentation, and paradata, ensuring that VR outputs remain interpretive rather than illusory.

Case Studies

Three case studies in Gdańsk tested this framework across different scales. At St. Nicholas Church, VR visualisations at the interior level presented architectural changes over time, allowing interventions to be modelled and revised without risk to the Gothic fabric. At Westerplatte, a contested ruin where physical rebuilding would compromise the war-damaged authenticity, VR provided authenticity-preserving alternatives, including layered simulations, scan-based guides, full architectural reconstructions, and "ghosted" models for uncertain elements. In the Królewska Dolina urban district, archival and survey data were combined to reconstruct centuries of transformation, with VR enabling diachronic interpretation and exemplifying transparency by visualising overlapping historical layers otherwise obscured in the present fabric. Taken together, these examples demonstrate VR's

adaptability across interior, architectural, and urban contexts, and show how conservation doctrine can be effectively operationalised in the digital domain.

Research questions answered

The research questions outlined in the introduction were divided into two main questions, each supported by a series of subsidiary questions designed to deepen and specify the investigation. The following section verifies these questions against the findings of the dissertation.

(MQ1) How can virtual reality visualisation be effectively implemented in scan-based digital reconstructions of architectural heritage?

Immersive virtual reconstructions can be effectively implemented in scan-based digital heritage through an integrated workflow developed and tested in this dissertation. The process begins with precise survey data from terrestrial laser scanning and photogrammetry (SQ3), which are combined in complementary ways to achieve both high metric precision and flexible accessibility. These datasets are structured into digital inventories and enriched with historical and architectural research to avoid speculative reconstructions detached from scientific methodology. The inventories are then adapted for real-time use in immersive environments such as VR headsets, CAVE systems, or online platforms. In this process, significant challenges arise (SQ4): large point clouds and meshes must be simplified and optimised without losing essential accuracy, while file size, hardware limitations, texture resolution, and software interoperability remain persistent barriers. Equally critical is the interpretive side, where scans capture only the present state of structures and require careful integration of historical evidence; without transparent paradata, reconstructions risk being mistaken for fact. The findings further show that implementation depends on scale (SQ5): at the interior level, reconstructions clarify subtle stratifications; at the building level, they restore the legibility of destroyed or fragmented structures; and at the urban level, they reveal long-term transformations. Finally, risks identified in this workflow (SQ6) include oversimplification of complex data, technical obsolescence, and the danger of compelling VR models overshadowing authentic remains. Taken together, these results confirm that effective implementation of VR in heritage reconstruction depends on technical optimisation, methodological transparency, scale sensitivity, and a strong grounding in architectural and historical research.

(MQ2) What impact might this have on conservation theory and the reconstruction practice?

Immersive virtual reconstructions impact conservation theory by extending the principles of authenticity, reversibility, and transparency into the digital domain, providing a credible, non-invasive alternative to contested rebuilding. They serve not as speculative replacements but as interpretive tools that enable layered readings of heritage, situating viewers in digitally crafted spaces that visualise past states of architecture. The analysis of conservation doctrine (SQ1) shows that reconstruction and authenticity remain contested and fluid: despite codification efforts such as the Venice Charter, practice varies from outright rejection of reconstruction to its continuation under cultural or social pressures. Historical antecedents (SQ2) demonstrate that illusion and immersion have long been central to artistic practice, from Roman wall painting and Renaissance perspective to Baroque quadratura and nineteenth-century panoramas, establishing VR as the latest step in this lineage. Case studies show how impact differs by scale (SQ5): interiors highlight stratigraphy and authenticity, buildings restore legibility of destroyed structures, and urban reconstructions clarify diachronic transformations. Yet these benefits are tempered by risks (SQ6): persuasive realism may blur fact and interpretation, technical simplification and data obsolescence threaten sustainability, and ethically, VR reconstructions risk overshadowing authentic remains. Together, these findings show that immersive VR enriches

rather than undermines conservation doctrine, reframing reconstruction as an immaterial and ethical practice that balances preservation of fabric with the need for interpretation and access.

Thesis Verification

Beyond answering the research questions, the dissertation also set out to test two theses formulated in the introduction. These have been verified through the research undertaken, and the results confirm their validity. Because the dissertation is structured around case studies, the supporting evidence is dispersed across several chapters rather than concentrated in a single section. The following overview demonstrates how each thesis has been substantiated.

> **Thesis 1. When grounded in rigorous interdisciplinary research, immersive virtual reconstructions can convey historical states of heritage in an immaterial form, offering reversible and modifiable simulations that preserve the integrity of authentic remains. This makes them an ethically preferable approach in contested heritage contexts, where material reconstructions risk distortion through conjecture or political pressures.**

Chapter 2, *Concept of Reconstruction*, sets the context by presenting the author's research on historical and ethical debates surrounding authenticity, reconstruction, and conservation doctrine, as well as diverse reconstruction practices. Particular attention is given to post-war reconstructions, analysed within a wide historical framework that highlights different approaches to restraint in rebuilding and the safeguarding of authentic material.

Building on this theoretical context, the three case studies presented in Chapter 5 provide concrete demonstrations of the principle at different scales. Chapter 5.2 analyses the sacristy of St. Nicholas, where immersive simulation clarified multiple architectural changes and stratifications. Chapter 5.3, dedicated to Westerplatte, demonstrates how immersive reconstructions can be applied in a context marked by contested memory politics and strong social and political pressure to rebuild. Chapter 5.4, on the *Heiligenbrunn – Royal Valley* area, presents the case of layered urban transformation, where digital reconstruction visualised historical development without compromising surviving remains. Finally, Chapter 5.5 provides additional comparative reflection, reinforcing the findings of the earlier case studies, which critically show how VR can provide a responsible alternative to material intervention.

By enabling reversible and non-invasive simulations, immersive VR reconstructions allow contested histories to be presented without compromising the integrity of authentic remains. The combined results of Chapters 5.2, 5.3, 5.4, and 5.5 demonstrate that immersive reconstructions can balance scholarly interpretation with conservation ethics, thereby confirming the validity of this thesis.

> **Thesis 2. Remote sensing and digital inventory tools enable the transformation of heritage from the material to the virtual domain, providing a basis for immersive simulations that function both as instruments of scholarly interpretation and as platforms for public engagement through accessible, shared, and interactive experiences**

Remote sensing and digital inventory tools enable the transformation of heritage from the material to the virtual domain, establishing the foundation for immersive simulations that serve both as instruments of scholarly interpretation and as platforms for public engagement. Chapter 4.2, *Technological Foundations*, presents workflows that integrate terrestrial laser scanning, photogrammetry, drone surveys, and potential HBIM processes, demonstrating how interdisciplinary and integrated approaches produce accurate and verifiable digital inventories by combining architectural research, historical sources, and complementary digital methods.

The case studies in Chapter 5 apply this methodology at three scales: the interior of the sacristy at St. Nicholas (5.2.3–5.2.4), architectural structures at Westerplatte, including Guardhouse No. 1 and the New Barracks (5.3.3–5.3.5), and the *Royal Valley* district in Gdańsk (5.4.3-5.4.4). These examples show the adaptability of the survey approach, demonstrating how digital inventories provide both the foundation for immersive simulations and a resource for conservation, monitoring, and future research. Chapters 3 and 4 situate these practices within a broader historical and methodological framework. Chapter 3 traces immersive strategies from a Renaissance perspective and Baroque quadratura to nineteenth-century panoramas, positioning VR as part of a longer tradition of interpretive tools, while Chapter 4.1.4, *Immersive Virtual Reconstructions*, shows how simulations synthesise historical sources, architectural analysis, and survey data, extending the methodological framework developed in Chapter 4.2.

The reconstructions developed in the case studies demonstrate the dual role of immersive simulations. They clarify architectural hypotheses and stratified histories, while also enabling dissemination through CAVE systems, HMDs, and online platforms such as Sketchfab. In doing so, they bridge research and public engagement, demonstrate applicability across scales, and outline a framework for future uses of immersive technologies in conservation and education. The validity of this thesis is confirmed by both the methodological framework and the applied case studies.

Final Conclusion

The theoretical analyses and case studies confirm the validity of the theses outlined in the introduction. Immersive virtual reconstructions, when grounded in interdisciplinary research, preserve authenticity while offering an ethically responsible alternative to material rebuilding. Remote sensing and digital inventory tools provide the systematic and high-precision basis for such simulations, while immersive reconstructions serve both as instruments of scholarly interpretation and as platforms for public engagement, demonstrating their dual potential in contemporary conservation practice.

The verification of both the main and subsidiary research questions shows that immersive virtual reconstructions can be effectively implemented and critically assessed within conservation practice when anchored in integrated survey and architectural research. They enrich conservation theory by reframing reconstruction as an immaterial and transparent practice, provide methodological frameworks that ensure precision and interpretive depth, and expand opportunities for public education and interpretation. At the same time, the risks identified in this research underline the need for transparency, critical reflection, and doctrinal grounding to ensure that digital reconstructions support rather than undermine the protection of authenticity and the integrity of heritage.

The conclusion is clear: VR marks a new chapter in conservation: it is not merely a representational tool but a new medium. When grounded in rigorous historical research and precise digital documentation, VR provides an academically credible, ethically preferable in endangered cases, and practically scalable alternative to material rebuilding. VR does not replace conservation doctrine; it extends it into the digital age. By synthesising art-historical insights, conservation doctrine, and digital technologies, the research advances a paradigm shift in heritage practice: from irreversible material reconstruction toward reversible, immaterial simulation. This constitutes its central contribution and establishes a foundation for future applications of immersive technologies in architectural conservation worldwide. Heritage practice is increasingly moving towards 3D digital inventories and immersive interpretation, and museums, battlefields, and urban sites are likely to adopt VR and XR tools more widely. Yet vigilance is essential: seamless illusions risk creating hyperreal pasts, and long-term digital preservation remains uncertain. Paradata, transparency, and ethical reflexivity must therefore remain central to ensure that immersive reconstructions support conservation aims rather than spectacle.

Bibliography

Literature

1. Acampa, Giovanna, and Mariolina Grasso. “Heritage Evaluation: Restoration Plan through HBIM and MCDA.” *IOP Conference Series: Materials Science and Engineering* 949, no. 1 (2020): 012061. https://doi.org/10.1088/1757-899X/949/1/012061.
2. Acampa, Giovanna, Fabiana Forte, and Pierfrancesco De Paola. “B.I.M. Models and Evaluations.” In *Values and Functions for Future Cities*, edited by Giulio Mondini, Alessandra Oppio, Stefano Stanghellini, Marta Bottero, and Francesca Abastante, 351–63. Green Energy and Technology series, volume 123. Cham: Springer International Publishing, 2020. https://doi.org/10.1007/978-3-030-23786-8_20
3. Ackerman, James S. *The Architecture of Michelangelo*. 2nd ed. Chicago: University of Chicago Press, 1986.
4. Aiken, John A. “The Perspective Construction of Masaccio’s *Trinity* Fresco and Medieval Astronomical Graphics.” *Artibus et Historiae* 16, no. 31 (1995): 171–84. https://doi.org/10.2307/1483503.
5. Alberti, Leon Battista. *On the Art of Building in Ten Books*. Translated by Joseph Rykwert, Neil Leach, and Robert Tavernor. Cambridge, MA: MIT Press, 1991.
6. Alberti, Leon Battista. *On Painting: A New Translation and Critical Edition*. Edited and translated by Rocco Sinisgalli. Cambridge: Cambridge University Press, 2011.
7. Alexander, Edward P., and Mary Alexander. *Museums in Motion: An Introduction to the History and Functions of Museums*. 2nd ed. Lanham, MD: AltaMira Press, 2007.
8. Alshawabkeh, Yahya, Mohammad El-Khalili, Eyad Almasri, Fadi Bala’awi, and Amaal Al-Massarweh. “Heritage Documentation Using Laser Scanner and Photogrammetry: The Case Study of Qasr Al-Abidit, Jordan.” *Digital Applications in Archaeology and Cultural Heritage* 16 (2020): e00133. https://doi.org/10.1016/j.daach.2019.e00133.
9. Amoruso, Giuseppe, Alberto Sdegno, and Andrea Manti. “Surveying and 3D Modelling of the Andrea Palladio’s Teatro Olimpico in Vicenza: First Studies on Geometric Analysis and Perspectives.” In *Graphic Imprints*, 427–38. Cham: Springer International Publishing, 2019.
10. Andersen, Kirsti. *The Geometry of an Art: The History of the Mathematical Theory of Perspective from Alberti to Monge*. Sources and Studies in the History of Mathematics and Physical Sciences. New York: Springer, 2007. https://doi.org/10.1007/978-0-387-48946-9
11. Anthes, Christoph, Rubén Jesús García-Hernández, Markus Wiedemann, and Dieter Kranzlmüller. “State of the Art of Virtual Reality Technology.” In *2016 IEEE Aerospace Conference* (Big Sky, MT, March 5–12, 2016), 1–19. Piscataway, NJ: IEEE, 2016. https://doi.org/10.1109/AERO.2016.7500674.
12. Aparicio Secanellas, Sofía, Juan Carlos Liébana Gallego, Guillermo Anaya Catalán, Rodrigo Martín Navarro, Javier Ortega Heras, Miguel Ángel García Izquierdo, Margarita González Hernández, and José Javier Anaya Velayos. “An Ultrasonic Tomography System for the Inspection of Columns in Architectural Heritage.” *Sensors* 22, no. 17 (2022): 6646. https://doi.org/10.3390/s22176646.
13. Apollonio, Fabrizio I. “A Review of 3D Documentation of Heritage Structures.” *Journal of Cultural Heritage* 23 (2017): 171–88.
14. Archer, William C. “The Paintings in the Alae of the Casa Dei Vettii and a Definition of the Fourth Pompeian Style.” *American Journal of Archaeology* 94, no. 1 (1990): 95–123.
15. Asbagh, Narmin Babazadeh. “Theories of Conservation and Scientific Restoration from Gustavo Giovannoni’s Point of View.” In the *5th International Conference of Contemporary Affairs in Architecture and Urbanism*. Famagusta: Eastern Mediterranean University, Faculty of Architecture, Alanya Hamdullah Emin Paşa University, 2022.
16. Aukstakalnis, Steve. *Practical Augmented Reality: A Guide to the Technologies, Applications, and Human Factors for AR and VR*. Boston: Addison-Wesley Educational, 2016.
17. Azuma, Ronald, Yohan Baillot, Reinhold Behringer, Steven Feiner, Simon Julier, and Blair MacIntyre. “Recent Advances in Augmented Reality.” *IEEE Computer Graphics and Applications* 21, no. 6 (2001): 34–47. https://doi.org/10.1109/38.963459.
18. Baetjer, Katharine, and Joseph Gluckstein Links. *Canaletto*. New York: The Metropolitan Museum of Art, 1989.
19. Baldini, Umberto, and Ornella Casazza. *The Brancacci Chapel*. Milan: Mondadori Electa, 1994.
20. Barazzetti, Luigi; FabrRizio Banfi; Raffaella Brumana; Daniela Oreni; Mattia Previtali; and Fabio Roncoroni. “HBIM and Augmented Information: Towards a Wider User Community of Image and Range-Based Reconstructions.” *ISPRS International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XL-5/W7 (2015): 35–42. https://doi.org/10.5194/isprsarchives-xl-5-w7-35-2015.
21. Bartel, Kazimierz. *Perspektywa Malarska : Zasady, Zarys Historyczny, Estetyka. Vo.l1*. Lwów-Warszawa: Książnica-Atlas, 1928.

22. Bartel, Kazimierz. *Perspektywa malarska: Zasady, zarys historyczny, estetyka*. Vol. 2. Warszawa: Polskie Wydawnictwo Naukowe, 1958.
23. Bartoszewski, Władysław. *Powstanie Warszawskie*. Warszawa: Świat Książki, 2009.
24. Basso, Alessandro. "Advantages, Critics and Paradoxes of Virtual Reality Applied to Digital Systems of Architectural Prefiguration, the Phenomenon of Virtual Migration." *Proceedings* 1, no. 9 (2017): 915. https://doi.org/10.3390/proceedings1090915.
25. Baudrillard, Jean. *Simulacra and Simulation*. Translated by Sheila Faria Glaser. Ann Arbor: University of Michigan Press, 1994.
26. Bekele, Mafkereseb Kassahun, Roberto Pierdicca, Emanuele Frontoni, Eva Savina Malinverni, and James Gain. "A Survey of Augmented, Virtual, and Mixed Reality for Cultural Heritage." *Journal on Computing and Cultural Heritage* 11, no. 2 (2018): 1–36. https://doi.org/10.1145/3145534
27. Benton, Janetta Rebold. *Materials, Methods, and Masterpieces of Medieval Art*. Praeger Series on the Middle Ages. Illustrated ed. Santa Barbara, CA: Praeger, 2009.
28. Berryman, Donna R. "Augmented Reality: A Review." *Medical Reference Services Quarterly* 31, no. 2 (2012): 212–18. https://doi.org/10.1080/02763869.2012.670604.
29. Bersani, Danilo, Michela Berzioli, Simone Caglio, Antonella Casoli, Pier Paolo Lottici, Laura Medeghini, Gianluca Poldi, and Paolo Zannini. "An Integrated Multi-Analytical Approach to the Study of the Dome Wall Paintings by Correggio in Parma Cathedral." *Microchemical Journal* 114 (2014): 80–88. https://doi.org/10.1016/j.microc.2013.11.014.
30. Bieber, Margarete. *Laocoon: The Influence of the Group since Its Rediscovery*. New York: Columbia University Press, 1942.
31. Biegański, Piotr. "Odbudowa Starego Miasta w Warszawie jako dzielnicy mieszkaniowej." In *Stare Miasto w Warszawie. Odbudowa*, edited by Zofia Szanajca-Kossakowska, 7–18. Warsaw: Architektura i Budownictwo, 1956.
32. Blunt, Anthony, ed. *Baroque and Rococo: Architecture and Decoration*. Ware, England: Wordsworth Editions, 1988.
33. Blunt, Anthony. *Borromini*. Cambridge, MA: Belknap Press of Harvard University Press, 1990.
34. Błyskosz, Tomasz. "Westerplatte – przekształcenia pola bitwy po 1945 r. (do początku XXI w.)." In *Materialne pozostałości konfliktów i zbrodni XX wieku w świetle najnowszych badań archeologicznych*, edited by Hanna Mik and Wirginia Węglińska, 342–62. Gdańsk: Muzeum II Wojny Światowej w Gdańsku, 2019.
35. Boisserée, Sulpiz. "Architecture of Cologne's Cathedral" (1823). In *Wokół problemów konserwacji i ochrony zabytków w XIX wieku*, edited by Piotr Kosiewski and Jarosław Krawczyk, 269–86. Warszawa: Muzeum Pałac w Wilanowie, 2011.
36. Boito, Camilo. *Questioni pratiche di belle arti: Restauri, concorsi, legislazione, professione, insegnamento.* Milano: Ulrico Hoepli, 1893.
37. Bolesław, Bierut. *Sześcioletni Plan Odbudowy Warszawy*. Warszawa: Książka i Wiedza, 1950.
38. Booher, C. Richard. Review of *Rethinking Lessing's Laocoon: Antiquity, the Enlightenment, and the "Limits" of Painting and Poetry*, edited by Avi Lifschitz and Michael Squire. Oxford: Oxford University Press, 2017. In *Classical World* 112, no. 3 (2019): 240–41.
39. Bottomore, Stephen. "The Panicking Audience?: Early Cinema and the 'Train Effect.'" *Historical Journal of Film, Radio and Television* 19, no. 2 (1999): 177–216. https://doi.org/10.1080/014396899100271.
40. Bown, Johnathan, Elisa White, and Akshya Boopalan. "Looking for the Ultimate Display." In *Boundaries of Self and Reality Online*, edited by Jayne Gackenbach and Johnathan Bown, 239–59. San Diego: Elsevier, 2017.
41. Bradbury, Ray. "The Veldt." *The Saturday Evening Post*, September 23, 1950.
42. Brandauer, Isabelle, Stollwagner Architekten, and Philipp Josef Pamer. *Das Tirol Panorama: Der Bergisel und das Kaiserjägermuseum. Rund um den Mythos Tirol*. Innsbruck: Edition Alpina, 2011.
43. Brooks, Kevin R. "Depth Perception and the History of Three-Dimensional Art: Who Produced the First Stereoscopic Images?" *i-Perception* 8, no. 1 (2017): 1–16. https://doi.org/10.1177/2041669516680114.
44. Bruno, Fabio; Stefano Bruno; Giovanna De Sensi; Maria-Laura Luchi; Stefania Mancuso; and Maurizio Muzzupappa. "From 3D Reconstruction to Virtual Reality: A Complete Methodology for Digital Archaeological Exhibition." *Journal of Cultural Heritage* 11, no. 1 (2010): 42–49. https://doi.org/10.1016/j.culher.2009.02.006
45. Bruno, Nazarena, and Riccardo Roncella. "HBIM for Conservation: A New Proposal for Information Modeling." *Remote Sensing* 11, no. 15 (2019): 1751. https://doi.org/10.3390/rs11151751.
46. Brykowska, Maria. *Metody pomiarów i badań zabytków architektury*. Warszawa: Oficyna Wydawnicza Politechniki Warszawskiej, 2003.
47. Bryman, Alan. *The Disneyization of Society*. Thousand Oaks, CA: SAGE Publications, 2004.
48. Buck, Stephanie, and Peter Hohenstatt. *Masters of Italian Art: Raphael*. Potsdam: Ullmann Publishing, 2013.
49. Bugalski, Łukasz. "Kwestia odbudowy zabytkowych zespołów staromiejskich na Ziemiach Odzyskanych." *Przegląd Zachodni* 3 (2014): 212–34.

50. Bugalski, Łukasz. *Zachodni front śródmieścia Gdańska: studium urbanistyczno-konserwatorskie*. Gdańsk: Słowo/obraz terytoria, 2023.
51. Bugalski, Łukasz, and Piotr Lorens. "Post-Second World War Reconstruction of Polish Cities: The Interplay between Politics and Paradigms." *Urban Planning* 8, no. 1 (2023). https://doi.org/10.17645/up.v8i1.6116.
52. Bukal, Grzegorz. "Konserwacja Zamku w Malborku jako przykład kształtowania się doktryny konserwatorskiej." *Ochrona Zabytków*, no. 3 (2008): 91–102.
53. Burckhardt, Jakob. "Cologne and the Rhineland in the 13th Century" (1843). In *Wokół problemów konserwacji i ochrony zabytków w XIX wieku*, edited by Piotr Kosiewski and Jarosław Krawczyk, 287–94. Warszawa: Muzeum Pałac w Wilanowie, 2011.
54. Braun, Georg, and Frans Hogenberg. *Civitates Orbis Terrarum*. Cologne, 1575.
55. Camesasca, Ettore. *Mantegna*. New York: Riverside Book Company, 1992.
56. Campana, Stefano, and Fabio Remondino, eds. *3D Recording and Modelling in Archaeology and Cultural Heritage: Theory and Best Practices*. BAR International Series S2598. Oxford: BAR Publishing, 2016.
57. Camprag, Nebojsa. "Museumification of Historical Centres: The Case of Frankfurt Altstadt Reconstruction." In *Tourism in the City*, edited by Cecilia Pasquinelli and Nicola Bellini, 165–78. Berlin: Springer, 2017.
58. Carbonara, Giovanni. *Avvicinamento al restauro: teoria, storia, monumenti*. Napoli: Liguori, 1997.
59. Cartwright-Punnett, Lynn. *How Spain Sees Its Past: The Monumentalization of the Spanish Civil War*. Undergraduate honors thesis, Wesleyan University, Middletown, CT, May 1, 2007.
60. Champion, Erik. *Critical Gaming: Interactive History and Virtual Heritage*. London: Routledge, 2024.
61. Chomętowska, Zofia, and Maria Chrząszczowa. *Kronikarki. Fotografie Warszawy 1945-1946*. Edited by Karolina Lewandowska. Warszawa: Archeologia Fotografii, 2011.
62. Cigola, Michela. *L'abbazia benedettina di Montecassino: La storia attraverso le testimonianze grafiche di rilievo e di progetto.* Cassino: Ciolfi Editore, 2005.
63. Clarke, John R. *The Houses of Roman Italy, 100 B.C.–A.D. 250: Ritual, Space, and Decoration*. Berkeley: University of California Press, 1991.
64. Clout, Hugh. "The Reconstruction of Upper Normandy: A Tale of Two Cities." *Planning Perspectives* 14, no. 2 (1999): 183–207. https://doi.org/10.1080/026654399364292.
65. Clout, Hugh. "The Great Reconstruction of Towns and Cities in France 1918–35." *Planning Perspectives* 20, no. 1 (2005): 1–33.
66. Collins, Brian, Dave Williams, Robert Haak, Martin Trux, Herbert Herz, Luc Genevriez, Pascal Nicot, Pierrick Brault, Xavier Coyere, Burkhard Krause, Jens Kluckow, and Armin Paffenholz. "The Dresden Frauenkirche: Rebuilding the Past." In *Computer Applications and Quantitative Methods in Archaeology 1993*, edited by J. Wilcock and K. Lockyear, 19–24. Oxford: Tempus Reparatum, 1994.
67. Çöltekin, Arzu, Ian Lochhead, Marguerite Madden, Sidonie Christophe, Alexandre Devaux, Christopher Pettit, Oliver Lock, et al. "Extended Reality in Spatial Sciences: A Review of Research Challenges and Future Directions." *ISPRS International Journal of Geo-Information* 9, no. 7 (2020): 439. https://doi.org/10.3390/ijgi9070439.
68. Costanzo, Antonio, Mario Minasi, Giuseppe Casula, Massimo Musacchio, and Maria Fabrizia Buongiorno. "Combined Use of Terrestrial Laser Scanning and IR Thermography Applied to a Historical Building." *Sensors* 15, no. 1 (2015): 194–213. https://doi.org/10.3390/s150100194.
69. Cozzolino, Marilena, Elisa Di Giovanni, Paolo Mauriello, Salvatore Piro, and Daniela Zamuner. "Geophysical Methods for Cultural Heritage." In *Geophysical Methods for Cultural Heritage Management*, 9–66. Cham: Springer International Publishing, 2018. https://doi.org/10.1007/978-3-319-74790-3_3.
70. Cruz-Neira, Carolina, Daniel J. Sandin, Thomas A. DeFanti, Robert V. Kenyon, and John C. Hart. "The CAVE: Audio Visual Experience Automatic Virtual Environment." *Communications of the ACM* 35, no. 6 (1992): 64–72. https://doi.org/10.1145/129888.129892.
71. Dąbrowski, Franciszek. *Wspomnienia z obrony Westerplatte*. Gdańsk: Gdańskie Towarzystwo Naukowe, 1957.
72. Dakouri-Hild, Anastasia, and Bernard Frischer, eds. *Beyond Illustration: 2D and 3D Digital Technologies as Tools for Discovery in Archaeology*. BAR International Series S1805. Oxford: BAR Publishing, 2008.
73. Daniluk, Jan, and Jarosław Wasielewski. *Wrzeszcz na dawnej pocztówce. Spacer pierwszy*. Gdańsk: Wydawnictwo Oskar, 2014.
74. Daniluk, Jan, Jarosław Wasielewski, and Krzysztof Grynder. *Wrzeszcz na dawnej pocztówce: Spacer drugi*. Gdańsk: Gdański Kantor Wydawniczy / Wydawnictwo Region, 2019.
75. Darecka, Katarzyna. *Drzwi i wrota w Gdańsku. Od średniowiecza do współczesności*. Gdańsk: Muzeum Gdańska, 2024.
76. Dargacz, Janusz. *Od Sopotu po Stogi. Początki kąpielisk morskich w okolicach Gdańska (1800–1870)*. Monografie Muzeum Gdańska, t. 3. Gdańsk: Muzeum Gdańska, 2020.

77. Davies, Norman. *Rising '44: The Battle for Warsaw*. London, England: Pan Books, 2018.
78. Décultot, Élisabeth. "Winckelmann's Model of Art Historiography and Its Reception in the Late 18th and 19th Century." In *Doing Humanities in Nineteenth-Century Germany*, 85–109. Leiden: Brill, 2019. https://doi.org/10.1163/9789004416840_006.
79. Dehio, Georg. *Handbuch der deutschen Kunstdenkmäler.* Berlin: Ernst Wasmuth, 1905.
80. Dehio, Georg, and Gustav Theodor Friedrich von Bezold. *Die Kirchliche Baukunst des Abendlandes*. Stuttgart: Cotta'sche Buchhandlung, 1901.
81. Deisch, Matthäus. *50 Prospecte von Danzig*. Gdansk, 1765.
82. Deleuze, Gilles. *Difference and Repetition*. Translated by Paul Patton. New York: Columbia University Press, 1994.
83. Descartes, René. *Meditations on First Philosophy: With Selections from the Objections and Replies*. Edited by John Cottingham. Cambridge: Cambridge University Press, 2013.
84. Dhaou, Dorra, Saoussen Ben Jabra, and Ezzeddine Zagrouba. "A Review on Anaglyph 3D Image and Video Watermarking." *3D Research* 10, no. 2 (2019): 1–12. https://doi.org/10.1007/s13319-019-0223-1
85. Ditrich, Andrzej. "Rekonstrukcje komputerowe historycznych budowli na terenie byłej Wojskowej Składnicy Tranzytowej na Westerplatte." In *Materialne pozostałości konfliktów i zbrodni XX wieku w świetle najnowszych badań archeologicznych*, edited by Hanna Mik and Wirginia Węglińska, 363–92. Gdańsk: Muzeum II Wojny Światowej, 2019.
86. Dixon, Wheeler Winston, and Gwendolyn Audrey Foster. *A Short History of Film*. 2nd ed. New Brunswick, NJ: Rutgers University Press, 2013.
87. Doğan, Huriye Armağan. "A Critique on Authenticity and Integrity in Reconstruction: Perception of Architectural Heritage and Cities of Postwar Era from Europe." *Art History & Criticism* 18, no. 1 (2022): 174–86. https://doi.org/10.2478/mik-2022-0010.
88. Dolata, Bolesław, and Jurga Tadeusz. *Walki Zbrojne Na Ziemiach Polskich 1939-1945. Wybrane Miejsca Bitew, Walk i Akcji Bojowych*. Edited by Jan Brodala. Warszawa: Rada Ochrony Pomników Walki i Męczeństwa, 1970.
89. Dore, Conor; Murphy, Maurice; McCarthy, Serena; Brechin, Fiona; Casidy, Clare; and Dirix, Evelien. "Structural Simulations and Conservation Analysis – Historic Building Information Model (HBIM)." *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XL-5/W4 (2015): 351–357. https://doi.org/10.5194/isprsarchives-XL-5-W4-351-2015.
90. Doria, Elisabetta, Silvia La Placa, and Jolanta Sroczynska. "Digital Methodologies for Architectural Heritage Preservation: Integrating Photogrammetry, Mobile Laser Scanning, and Immersive Technologies." *Rivista Tema* 11, no. 2 (2025).
91. Drzycimski, Andrzej. *Westerplatte 1939: historia i legenda: przed szturmem*. Gdańsk: Słowo/obraz terytoria, 2009.
92. Drzycimski, Andrzej. *Reduta w budowie*. Gdańsk: Fundacja Gdańska, 2014.
93. Drzycimski, Andrzej. *Reduta wojenna*. Gdańsk: Fundacja Gdańska, 2014.
94. Drzycimski, Andrzej. *Westerplatte: kulisy niemieckiej wojny propagandowej*. Gdańsk: Muzeum Gdańska, 2019.
95. Dubois, Eric. "A Projection Method to Generate Anaglyph Stereo Images." In *Proceedings of the IEEE International Conference on Acoustics, Speech, and Signal Processing* (Cat. No. 01CH37221), vol. 3. Salt Lake City, UT: IEEE, 2001. 1661–64. https://doi.org/10.1109/ICASSP.2001.941256
96. Dylla, Karl, Bernard Frischer, Pascal Müller, Andreas Ulmer, and Simon Haegler. "Rome Reborn 2.0: A Case Study of Virtual City Reconstruction Using Procedural Modeling Techniques." In *Making History Interactive. Computer Applications and Quantitative Methods in Archaeology (CAA)*, Proceedings of the 37th International Conference, Williamsburg, Virginia, March 22–26, 2009, edited by Bernard Frischer, Jane Webb Crawford, and David Koller, 62–66. BAR International Series S2079. Oxford: Archaeopress, 2010.
97. Dziewanowski, Adam, Filip Kuczma, and Wojciech Samól. "Badania archeologiczne pola bitwy na Westerplatte." In *Materialne pozostałości konfliktów i zbrodni XX wieku w świetle najnowszych badań archeologicznych*, edited by Hanna Mik and Wirginia Węglińska, 235–75. Gdańsk: Muzeum II Wojny Światowej, 2019.
98. Dziewanowski, Adam, Piotr Kalka, Filip Kuczma, and Wojciech Samól. "Badania archeologiczne pola bitwy na Westerplatte. Wyniki prac prowadzonych w latach 2018–2019 na obszarze kasyna podoficerskiego Wojskowej Składnicy Tranzytowej." *Wojna i Pamięć: Czasopismo Muzeum II Wojny Światowej w Gdańsku* no. 4 (2022): 154–93.
99. Economou, Maria. "Evaluating the Use of Virtual Reality and Multimedia Applications for Presenting the Past." In *Handbook of Research on Technologies and Cultural Heritage: Applications and Environments*, edited by Georgios Styliaras, Dimitrios Koukopoulos, and Fotis Lazarinis, 223–39. New York: IGI Global, 2011. https://doi.org/10.4018/978-1-60960-044-0.ch011
100. Economou, Maria, and Laia Pujol-Tost. "Educational Tool or Expensive Toy? Evaluating VR Evaluation and Its Relevance for Virtual Heritage." In *New Heritage: New Media and Cultural Heritage*, edited by Yehuda E. Kalay, Thomas Kvan, and Janice Affleck, 242–260. London: Routledge, 2007.
101. Edgerton, Samuel Y. *Renaissance Rediscovery of Linear Perspective*. New York: Joanna Cotler Books, 1976.
102. Edgerton, Samuel Y. "The Mirror, the Window, and the Telescope: How Renaissance Linear Perspective Changed Our Vision of the Universe." *Nexus Network Journal* 12, no. 1 (2010): 149–52.

103. Eimerl, Sarel. *The World of Giotto: c. 1267–1337*. Time-Life Library of Art. New York: Time, Inc., 1967.
104. Ellis, Markman. "'Spectacles within doors': Panoramas of London in the 1790s." *Romanticism* 14, no. 2 (2008): 133–48. https://doi.org/10.3366/E1354991X0800024X.
105. Elsner, Jas. "From the Culture of Spolia to the Cult of Relics: The Arch of Constantine and the Genesis of Late Antique Forms." *Papers of the British School at Rome* 68 (2000): 149–84. https://doi.org/10.1017/S0068246200003901
106. Elżanowski, Jerzy, and Carmen M. Enss. "Cartographies of Catastrophe: Mapping World War II Destruction in Germany and Poland." *Urban History* 49, no. 3 (2022): 589–611. https://doi.org/10.1017/s0963926820000772.
107. Faisal, Aldo. "Computer Science: Visionary of Virtual Reality." *Nature* 551, no. 7680 (2017): 298–99.
108. Farthing, Stephen. *Historia sztuki*. Warszawa: Arkady, 2019.
109. Fasolo, Marco, and Matteo Flavio Mancini. "The 'Architectural' Projects for the Church of St. Ignatius by Andrea Pozzo." *Diségno*, no. 4 (2019): 79–90. https://doi.org/10.26375/disegno.4.2019.09.
110. Feilden, Bernard M. *Conservation of Historic Buildings*. 3rd ed. Oxford: Architectural Press, 2003.
111. Fesenko, Galyna. "Rebuilding the Architectural Heritage: Reflections on the Case of Post-War Warsaw." In *Theory and Practice of Modern Science*, 186–89. 2023.
112. Field, D. M. *Leonardo Da Vinci*. London: Grange Books, 2007.
113. Flisowski, Zbigniew. *Westerplatte*. Warszawa: Wydawnictwo Ministerstwa Obrony Narodowej, 1965.
114. Foss, Pedar, and John J. Dobbins, eds. *The World of Pompeii*. London: Routledge, 2009.
115. Fratadocchi, Tommaso Breccia. *La ricostruzione dell'abbazia di Montecassino*. Rome: Gangemi Editore, 2014.
116. Friedrich, Jacek. *Odbudowa Glownego Miasta w Gdansku w latach 1945-1960*. Gdańsk: Słowo/obraz terytoria, 2015.
117. Frischer, Bernard, Diane Favro, Dean Abernathy, and Monica De Simone. "The Digital Roman Forum Project of the UCLA Cultural Virtual Reality Laboratory." *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XXXIV-5/W10 (2003).
118. Frischer, Bernard D., Dean Abernathy, Gabriele Guidi, Joel Myers, Cassie Thibodeau, Antonio Salvemini, Pascal Müller, H. Peter Hofstee, and Barry Minor. "Rome Reborn." *ACM SIGGRAPH 2008 New Tech Demos*. New York: ACM, 2008. https://doi.org/10.1145/1401615.1401649
119. Frischer, Bernard, and David Massey. "3D Urban Models as Tools for Research and Discovery: Two Case Studies of the Rostra in the Roman Forum Utilizing Rome Reborn." In *Critical Archaeology in the Digital Age*, edited by Kevin Garstki, 23–48. Cotsen Digital Archaeology Series 2. Los Angeles: Cotsen Institute of Archaeology Press, 2022.
120. Frodl, Walter. *Pojęcia i kryteria wartościowania zabytków.* Warsaw: Biblioteka Muzealnictwa i Ochrony Zabytków, 1966.
121. Frodl, Walter. "Wartościowanie zabytków: Pojęcia i kryteria." In *Konserwacja i rewaloryzacja architektury w środowisku kulturowym*, edited by Edmund Małachowicz, 553–60. Wrocław: Oficyna Wydawnicza Politechniki Wrocławskiej, 2007.
122. Fudala, Tomasz. *Spór o odbudowę Warszawy: od gruzów do reprywatyzacji*. Warszawa: Muzuem Sztuki Nowoczesnej, 2016.
123. Galouye, Daniel F. *Simulakron 3*. Translated by Radosław Januszewski. Poznań: Dom Wydawniczy Rebis, 2003.
124. Gasha, Anna. "Fragmented Memory: The Scattering of the Urakami Cathedral Ruins among Nagasaki's Memorial Landscape." In *Shadows of Nagasaki*, 215–42. New York: Fordham University Press, 2024.
125. Gawlicki, Marcin. *Zabytkowa architekturą Gdańska w latach 1945-1951: kształtowanie koncepcji, konserwacji i odbudowy*. Gdańsk: Słowo/obraz terytoria, 2012.
126. Gębczyńska-Janowicz, Agnieszka. "Virtual Reality Technology in Architectural Education." *World Transactions on Engineering and Technology Education* 18 (2020): 24–28.
127. George, Andrew. *Babylonian Topographical Texts*. Leuven: Peeters Publishers, 1992.
133. George, Andrew. *House Most High: The Temples of Ancient Mesopotamia*. Winona Lake, IN: Eisenbrauns, 1993.
134. Gibson, William. *Neuromancer*. London: Gollancz, 2016.
135. Gilbert, Felix. "Jacob Burckhardt's Student Years: The Road to Cultural History." *Journal of the History of Ideas* 47, no. 2 (1986): 249–74. https://doi.org/10.2307/2709813.
136. Giovannoni, Gustavo. *Questioni di architettura nella storia e nella vita.* Rome: Biblioteca d'Arte Editrice, 1929.
137. Glaser, Stephanie A. "'Deutsche Baukunst', 'Architecture Française': The Use of the Gothic Cathedral in the Creation of National Memory in Nineteenth-Century Germany and France." In *Orientations*, edited by Claus Clüver, Véronique Plesch, and Leo H. Hoek, 77–91. Leiden: Brill, 2005.
138. Goethe, Johann Wolfgang. "On German Architecture" (1772). In *Zabytek i historia – wokół problemów konserwacji i ochrony zabytków w XIX wieku*, edited by Piotr Kosiewski and Jarosław Krawczyk, 241–50. Warszawa: Muzeum Pałac w Wilanowie, 2011.
139. Górnikiewicz, Stanisława. *Lwy z Westerplatte*. Gdańsk: Wydawnictwo Morskie, 1983.
140. Górski, Jan, ed. *Odbudowa Warszawy w latach 1944–1949: Wybór dokumentów i materiałów.* Warsaw: Państwowe Wydawnictwo Naukowe, 1977.
141. Graham, Zachary. "When I Paint My Masterpiece: Giotto's Last Judgement and Its Twelfth-Century Cultural Foundations." *Armstrong Undergraduate Journal of History* 11, no. 2 (2021): 50–70. https://doi.org/10.20429/aujh.2021.110204.

142. Guarnieri, Alberto, Nicola Milan, and Antonio Vettore. “Monitoring of Complex Structure for Structural Control Using Terrestrial Laser Scanning (TLS) and Photogrammetry.” *International Journal of Architectural Heritage* 7, no. 1 (2013): 54–67.
143. Guidi, Gabriele, Bernard Frischer, Michele Russo, Alessandro Spinetti, Luca Carosso, and Laura Loredana Micoli. “Three-Dimensional Acquisition of Large and Detailed Cultural Heritage Objects.” *Machine Vision and Applications* 17, no. 6 (2006): 349–360. https://doi.org/10.1007/s00138-006-0029-z.
144. Guranowska-Gruszecka, Krystyna. “Shaping of the Centre of Warsaw – History of Activities and Views, Visions of Future.” *Space & Form / Przestrzeń i Forma* 30 (2017): 9–46.
145. Halkes, Petra. “The Mesdag Panorama: Sheltering the All-Embracing View.” *Art History* 22, no. 1 (1999): 83–98. https://doi.org/10.1111/1467-8365.00140.
146. Halm, Philipp Maria. “The Town Hall in Bamberg and Its Fresco Decoration.” *Die Denkmalpflege* 5, no. 3 (February 25, 1903): 19–21.
147. Hansen, Astrid. “Die Frankfurter Altstadtdebatte zur Rekonstruktion eines ‚gefühlten Denkmals‘.” *Die Denkmalpflege* 66, no. 1 (2008): 5–17. https://doi.org/10.1515/dkp-2008-660105.
148. Hartt, Frederick, and David Wilkins. *History of Italian Renaissance Art*. 7th ed. Upper Saddle River, NJ: Pearson, 2011.
149. Hibbard, Howard. *Bernini*. Harmondsworth, England: Penguin Books, 1965.
150. Hirsch, Robert. “Kolonie robotnicze Fundacji Abegga we Wrzeszczu. Pamiątka postępowych idei w budownictwie mieszkaniowym XIX wieku.” In *Wędrówki po Wrzeszczu*, edited by Jakub Szczepański and Katarzyna Szczepańska, 187–221. Gdańsk: Słowo/obraz terytoria, 2011.
151. Hirsch, Robert, Krzysztof Krzempek, and Piotr Popiński. *Gdańsk Dwa Oblicza Miasta*. Gdańsk: Holm, 1997.
152. Hirsch, Robert. *Seizing the Light: A Social & Aesthetic History of Photography*. 3rd ed. New York: Routledge, 2017.
153. Hovan George, A. S., Fernando Maschio, A. Shaji George, T. Baskar, and Digvijay Pandey. “Metaverse: The Next Stage of Human Culture and the Internet.” *International Journal of Advanced Research Trends in Engineering and Technology* 8, no. 12 (2021): 1–10. https://doi.org/10.5281/zenodo.6548172
154. Howard, Richard Thomas. *Ruined and Rebuilt: The Story of Coventry Cathedral 1939-1962*. Coventry: The Council of Coventry Cathedral, 1962.
155. Howard, Seymour. “On the Reconstruction of the Vatican Laocoon Group.” *American Journal of Archaeology* 63, no. 4 (1959): 365–69. https://doi.org/10.2307/501788
156. Huffman, Kristin L., and Andrea Giordano. “Visualizing Venice to Visualizing Cities – Advanced Technologies for Historical Cities Visualization.” In *Communications in Computer and Information Science*, 171–87. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-93186-5_8.
157. Huffman, Kristin L., Andrea Giordano, and Caroline Bruzelius, eds. *Visualizing Venice: Mapping and Modeling Time and Change in a City*. London & New York: Routledge, 2017. https://doi.org/10.4324/9781315100685..
158. Hugo, Victor. “War on the Demolishers!” (1832). In *Wokół problemów konserwacji i ochrony zabytków w XIX wieku*, edited by Jarosław Krawczyk and Piotr Kosiewski, 85–98. Warszawa: Muzeum Pałac w Wilanowie, 2011.
159. Hugo, Victor. *Guerre aux démolisseurs*. *Revue des Deux Mondes*, 1st ser., 8, no. 4 (September 1, 1832): 751–58. https://fr.wikisource.org/wiki/Guerre_aux_d%C3%A9molisseurs.
160. Hyde, Andrew. *After the Battle: Then & Now – Pearl Harbour*. Edited by Winston Ramsey. London: Battle of Britain Prints, 1982.
161. Hyde, Ralph. *Panoramania!: The Art and Entertainment of the “All-Embracing” View*. London: Trefoil, 1988.
162. ICOMOS. *International Charter for the Conservation and Restoration of Monuments and Sites (the Venice Charter 1964).* Venice: ICOMOS, 1964.
163. Ippolito, Alfonso, Cristiana Bartolomei, Davide Mezzino, Martina Attenni, and Rawan Darwa. “Digital Documentation Strategies for the Knowledge of the Basilica of Santa Maria in Trastevere.” *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XLVIII-M-2-2023 (2023): 735–42. https://doi.org/10.5194/isprs-archives-XLVIII-M-2-2023-735-2023
164. Jacobus, Laura. *Giotto and the Arena Chapel: Art, Architecture & Experience*. Illustrated ed. *Studies in Medieval and Early Renaissance Art History*. Turnhout: Harvey Miller Publishers, 2008.
165. Jałowiecki, Mieczysław. *Wolne Miasto*. Edited and arranged by Michał Jałowiecki. Warszawa: Czytelnik, 2002.
166. Jankowski, Stanisław. “Warsaw: Destruction, Secret Town Planning, 1939–44, and Postwar Reconstruction.” In *Rebuilding Europe’s Bombed Cities*, edited by Jeffry M. Diefendorf, 77–93. London: Palgrave Macmillan UK, 1990.
167. Anita Jaśkiewicz-Sojak, “Dwór Studzienka i praktyka konserwatorska,” in *Problemy konserwacji i badań zabytków architektury*, ed. Aleksandra Kociałkowska (Gdańsk: Europejska Fundacja Ochrony Zabytków, 2008), 263–68.
168. Jiménez-Desmond, David, Juan S. Pozo-Antonio, and Alessandra Arizzi. “The Fresco Wall Painting Techniques in the Mediterranean Area from Antiquity to the Present: A Review.” *Journal of Cultural Heritage* 66 (2024): 166–86. https://doi.org/10.1016/j.culher.2023.11.018.
169. Jokilehto, Jukka. “Considerations on Authenticity and Integrity in World Heritage Context.” *City & Time* 1 (2006): 1–16.
170. Jokilehto, Jukka. *A History of Architectural Conservation*. 2nd ed. New York: Routledge, 2017.

171. Jones, Mark Wilson. “Genesis and Mimesis: The Design of the Arch of Constantine in Rome.” *Journal of the Society of Architectural Historians* 59, no. 1 (2000): 50–77. https://doi.org/10.2307/991562
172. Jones, Roger, and Nicholas Penny. *Raphael*. New Haven, CT: Yale University Press, 1987.
173. Kalawsky, Roy S. *The Science of Virtual Reality and Virtual Environments: A Technical, Scientific, and Engineering Reference on Virtual Environments*. Wokingham, England; Reading, MA: Addison-Wesley, 1993.
174. Kant, Immanuel. *Krytyka czystego rozumu*. Translated by Romuald Ingarden. Warsaw: Państwowe Wydawnictwo Naukowe, 1957.
175. Kiessling, Paula, and Waldemar Kiessling. *Lüftmalerei*. München: Verlag Bruckmann, 1959.
176. Kilarski, Jan. *Gdańsk*. Poznań: Wydawnictwo Polskie R. Wagner, 1937.
177. Kilarski, Maciej. *Odbudowa i konserwacja zespołu zamkowego w Malborku w latach 1945–2000.* Malbork: Muzeum Zamkowe w Malborku, 2007.
178. King, R. Duane. “A Brief History of Stereoscopy.” *Wiley Interdisciplinary Reviews: Computational Statistics* 5, no. 4 (2013): 334–40. https://doi.org/10.1002/wics.1264
179. Kingsland, Kaitlyn. “Comparative Analysis of Digital Photogrammetry Software for Cultural Heritage.” *Digital Applications in Archaeology and Cultural Heritage* 18 (2020): e00157. https://doi.org/10.1016/j.daach.2020.e00157.
180. Kinney, Dale. “Roman Architectural Spolia.” *Proceedings of the American Philosophical Society* 145, no. 2 (2001): 138–61.
181. Kinney, Dale. “Spolia: *Damnatio* and *Renovatio Memoriae*.” *Memoirs of the American Academy in Rome* 42 (1997): 117–48. https://doi.org/10.2307/4238749
182. Kinney, Dale. “Liturgy, Space, and Community in the Basilica Julii (Santa Maria in Trastevere).” *Acta ad archaeologiam et artium historiam pertinentia* 31 (2019): 81–100. https://doi.org/10.5617/acta.7801
183. Kleinbauer, W. Eugene. “Charlemagne’s Palace Chapel at Aachen and Its Copies.” *Gesta* 4 (1965): 2–11. https://doi.org/10.2307/766678
184. Kloeppel, Otto. *Das Stadtbild von Danzig in drei Jahrhunderten seiner großen Geschichte*. Danzig: A. W. Kafemann, 1937.
185. Knapp, Andrew. “The Destruction and Liberation of Le Havre in Modern Memory.” *War in History* 14, no. 4 (2007): 476–98. https://doi.org/10.1177/0968344507081551.
186. Koller, David, Bernard Frischer, and Greg Humphreys. “Research Challenges for Digital Archives of 3D Cultural Heritage Models.” *Journal on Computing and Cultural Heritage* 2, no. 3 (2009): 1–17. https://doi.org/10.1145/1658346.1658347.
187. Kowalski, Janusz, Massalski Ryszard, and Stankiewicz Jerzy. “Rozwój Urbanistyczny i Architektoniczny Gdańska.” In *Gdańsk Jego Dzieje i Kultura*, edited by Franciszek Mamuszka, 215–47. Warszawa: Arkady, 1969.
188. Kowalski, Szymon, Piotr Samól, Jakub Szczepański, and Witold Dłubakowski. “Teaching Architectural History through Virtual Reality.” *World Transactions on Engineering and Technology Education* 18, no. 2 (2020): 297–302.
189. Kowalski, Szymon, Piotr Samól, and Robert Hirsch. “Virtual Reality Tools in Teaching the Conservation and History of Polish Architecture.” *World Transactions on Engineering and Technology Education* 18, no. 4 (2020): 399–404.
190. Kowalski, Szymon, Piotr Samól, and Jakub Szczepański. “Physical Models in the Education of Architectural History.” *World Transactions on Engineering and Technology Education* 20, no. 4 (2022): 251–57.
191. Kowalski, Szymon, Silvia La Placa, and Alberto Pettineo. “From Archives Sources to Virtual 3D Reconstruction of Military Heritage – The Case Study of Port Battery, Gdańsk.” *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XLVIII-M-2-2023 (2023): 885–893. https://doi.org/10.5194/isprs-archives-XLVIII-M-2-2023-885-2023.
192. Kowalski, Szymon, Jacek Lebiedź, Sandro Parrinello, and Francesca Picchio. “New Skills for Architects: 3D Scanning for an Immersive Experience in Architectural Education.” *Global Journal of Engineering Education* 26, no. 2 (2024): 115–121.
193. Kowalski, Szymon, and Wojciech Samól. “Architektura oraz historia tzw. nowych koszar na Westerplatte w latach 1933–2023.” *Przegląd Historyczno-Wojskowy* 25, no. 2 (2024): 92–138. https://doi.org/10.32089/WBH.PHW.
194. Kozakiewicz, Stefan, and Helena Kozakiewicz. *Bernardo Bellotto zwany Canaletto*. Warszawa: Arkady, 1980.
195. Krawczyk, Janusz. “Kompromis i metoda: Wybrane aspekty teorii konserwatorskich Aloisa Riegla i Cesare Brandiego.” *Ochrona Zabytków*, no. 2 (2010): 64–74.
196. Krawczyk, Janusz. *Nazwać, żeby ocalić. Klasycy myśli konserwatorskiej wobec reliktów przeszłości*. Toruń: Wydawnictwo Naukowe Uniwersytetu Mikołaja Kopernika, 2020.
197. Krevelen, Rick van. “Augmented Reality: Technologies, Applications, and Limitations.” VU University Amsterdam, 2007. https://doi.org/10.13140/RG.2.1.1874.7929.
198. Krueger, Myron W. “VIDEOPLACE: A Report from the ARTIFICIAL REALITY Laboratory.” *Leonardo* 18, no. 3 (1985): 145–151.
199. Krueger, Myron W., Thomas Gionfriddo, and Katrin Hinrichsen. “VIDEOPLACE—An Artificial Reality.” In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI ’85)*, 35–40. New York: Association for Computing Machinery, 1985. https://doi.org/10.1145/317456.317463.
200. Krüger, Anna. *Cmentarze przy Wielkiej Alei w Gdańsku 1867–1945: Studium z dziejów kultury funeralnej*. Gdańsk: Słowo/obraz terytoria, 2021.
201. Krzyżanowski, Lech. “Gdańsk.” In *Zabytki urbanistyki i architektury w Polsce: Odbudowa i konserwacja*, edited by Wiktor Zin. Warszawa: Arkady, 1986.

202. Kuczma, Filip, Wojciech Samól, and Karol Szejko. *Westerplatte w 7 Odsłonach: Prezentacja Zabytków Pierwszego Etapu Badań Archeologicznych Na Westerplatte*. Gdańsk: Muzuem II Wojny Światowej, 2019.
203. Kuiper, Kathleen, ed. *The 100 Most Influential Painters & Sculptors of the Renaissance*. New York: Rosen Education Service, 2010.
204. Kuleto, Valentin, Milena P. Ilić, Marko Ranković, Mladen Radaković, and Aleksandar Simović. "Augmented and Virtual Reality in the Metaverse Context: The Impact on the Future of Work, Education, and Social Interaction." In *The Metaverse as a Virtual Form of Existence: Emerging Trends and Design Practices*, edited by Dalibor Radovanović, 3–24. Cham: Springer Nature Switzerland, 2024.
205. La Placa, Silvia, Andrea Bongini, Szymon Kowalski, and Jakub Szczepański. *The Canal System, Stone Sluice, Locks and Defence: Gdańsk Urban Fortifications. Report of Achieved Research Experiences for the Development of the H2020 Prometheus Project*. Pavia: Pavia University Press, forthcoming.
206. Laborde, Alexandre de. *Les monuments de la France classés chronologiquement et considérés sous le rapport des faits historiques et de l'étude des arts*. Paris: Pierre Didot l'aîné, 1816.
207. Landrieu, Jérôme, Christian Père, Jacques Rollier, Stéphane Castandet, and Grégory Schotte. "Digital Rebirth of the Greatest Church of Cluny Maior Ecclesia: From Optronic Surveys to Real Time Use of the Digital Model." *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XXXVIII-5/W16 (2012): 31–37. https://doi.org/10.5194/isprsarchives-XXXVIII-5-W16-31-2011.
208. Lebiedź, Jacek, and Mariusz Szwoch. "Virtual Sightseeing in Immersive 3D Visualization Lab." *Proceedings of the 2016 Federated Conference on Computer Science and Information Systems* (FedCSIS 2016), *Annals of Computer Science and Information Systems* 8 (2016): 1641–45. DOI: https://doi.org/10.15439/2016F227.
209. Lejnieks, Jānis. "Rebranding the Soviet Regime's Built Cultural Heritage and the Need for Collective Memory." In *The 6th Baltic Sea Region Cultural Heritage Forum: From Postwar to Postmodern – 20th Century Built Cultural Heritage*, edited by Maria Rossipal, 58–63. Stockholm: Swedish National Heritage Board, 2017.
210. Lem, Stanisław. *Summa Technologiae*. Kraków: Wydawnictwo Literackie, 1964.
211. Lercari, Nicola. "Terrestrial Laser Scanning in the Age of Sensing." In *Digital Methods and Remote Sensing in Archaeology*, edited by Maurizio Forte and Stefano Campana, 3–33. Cham: Springer International Publishing, 2016.
212. Lercari, Nicola. "Monitoring Earthen Archaeological Heritage Using Multi-Temporal Terrestrial Laser Scanning and Surface Change Detection." *Journal of Cultural Heritage* 39 (2019): 152–165. https://doi.org/10.1016/j.culher.2019.04.005.
213. Lévy, Pierre. *Becoming Virtual: Reality in the Digital Age*. Boulder, CO: Perseus Books, 1998.
214. Lifschitz, Avi, and Michael Squire, eds. *Rethinking Lessing's Laocoon*. Oxford: Oxford University Press, 2017.
215. Lightbown, Ronald. *Andrea Mantegna: With a Complete Catalogue of the Paintings, Drawings, and Prints*. Berkeley: University of California Press, 1992.
216. Ling, Roger. *Pompeii: History, Life & Afterlife*. Stroud: Tempus, 2005.
217. Liu, Junshan, Salman Azhar, Danielle Willkens, and Botao Li. "Static Terrestrial Laser Scanning (TLS) for Heritage Building Information Modeling (HBIM): A Systematic Review." *Virtual Worlds* 2, no. 2 (2023): 90–114. https://doi.org/10.3390/virtualworlds2020006.
218. Liu, Junshan, Danielle Willkens, and Russell Gentry. "Developing a Practice-Based Guide to Terrestrial Laser Scanning (TLS) for Heritage Documentation." *Heritage* 8, no. 8 (2025): 313. https://doi.org/10.3390/heritage8080313.
219. Logothetis, Simos, Athina Delinasiou, and Efstratios Stylianidis. "Building Information Modelling for Cultural Heritage: A Review." *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences* II-5/W3 (2015): 177–183. https://doi.org/10.5194/isprsannals-II-5-W3-177-2015
220. López-Menchero Bendicho, Víctor Manuel, and Alfredo Grande. "Hacia una Carta Internacional de Arqueología Virtual: El Borrador SEAV." *Virtual Archaeology Review* 2, no. 4 (2011): 71–75.
221. Lorens, Piotr. *Tematyzacja przestrzeni publicznej miasta*. Gdańsk: Wydawnictwo Politechniki Gdańskiej, 2006.
222. Lorens, Piotr, and Justyna Martyniuk-Pęczek. "Od *City Beautiful Movement* do nowego urbanizmu." In *Wybrane teorie współczesnej urbanistyki*, edited by Izabela Mironowicz and Piotr Lorens. Gdańsk: Wydawnictwo Politechniki Gdańskiej, 2013.
223. Lowenthal, David. *The Past Is a Foreign Country*. Cambridge: Cambridge University Press, 1985.
224. Nyka, Lucyna, and Jakub Szczepański. "Ukryte potoki Wrzeszcza." In *Wędrówki po Wrzeszczu*, edited by Katarzyna Szczepańska and Jakub Szczepański, 277–92. Gdańsk: Słowo/obraz terytoria, 2011.
225. Lubocka-Hoffmann, Maria. "Powojenna odbudowa miast w Polsce a retrowersja Starego Miasta w Elblągu." *Ochrona Zabytków* 1 (2019): 35–71.
226. Ludwig, Bogna. *"Zastosowanie iluzji perspektywicznej w monumentalnych dekoracjach wnętrz śląskich świątyń w okresie późnego baroku." Architectus* 2, no. 16 (2004): 3–27.
227. Lumini, Andrea. "The Integrated Digital Survey of the Florence Air Warfare School. HBIM-Based Protocols for Documentation and Information Management." *DISEGNARECON* 16, no. 30 (2023): 1–15. https://doi.org/10.20365/disegnarecon.30.2023.11.

228. Lupiano, Vincent Depaul. *Massacre at Oradour-Sur-Glane: Nazi Gold and the Murder of an Entire French Town by SS Division Das Reich*. Lanham, MD: Lyons Press, 2024.
229. Łużyniecka, Ewa. "Próba odtworzenia przeobrażeń rozplanowania klasztoru dominikanów w Gdańsku." In *Architektura romańska w Polsce. Nowe odkrycia i interpretacje*, edited by Tomasz Janiak and Dariusz Stryniak, 145–172. Gniezno: Muzeum Początków Państwa Polskiego w Gnieźnie, 2013.
230. Łużyniecka, Ewa. *Kościół Dominikanów w Gdańsku: Architektura i jej przeobrażenia*. Wrocław: Oficyna Wydawnicza Politechniki Wrocławskiej, 2022.
231. Lyotard, Jean-François. *Kondycja ponowoczesna: raport o stanie wiedzy*. Warszawa: Aletheia, 1997.
232. Ma, Lai. *"Video Game as an Immersive Interactive Virtual Interpretation of Historic Heritages, Taking Assassin's Creed as an Example."* Master's thesis, Columbia University, 2021. https://doi.org/10.7916/D8-4VNQ-D355.
233. Prarat, Maciej, and Ulrich Schaaf. "Inwentaryzacja Pomiarowo-Rysunkowa Zabytków Architektury Drewnianej w Procesie Konserwatorskim – Problemy i Propozycja Standaryzacji." *Budownictwo i Architektura* 14, no. 4 (2015): 99–110.
234. Macur, Andrzej. *Gdańsk Kazimierza Macura*. Gdańsk: Słowo/obraz terytoria, 2016.
235. Macur, Andrzej. *Pól wieku z zabytkami*. Gdańsk: Słowo/obraz terytoria, 2018.
236. Magagnato, Licisco. "The Genesis of the Teatro Olimpico." *Journal of the Warburg and Courtauld Institutes* 14, no. 3–4 (1951): 209–20. https://doi.org/10.2307/750339.
237. Małachowicz, Edmund. *Konserwacja i rewaloryzacja architektury w środowisku kulturowym*. Wrocław: Oficyna Wydawnicza Politechniki Wrocławskiej, 2007.
238. Margry, Karel. "The Capture of Le Havre." *After the Battle*, no. 139 (2008): 2–31.
239. Marquardt, Janet T. *From Martyr to Monument: The Abbey of Cluny as Cultural Patrimony.* Newcastle upon Tyne, UK: Cambridge Scholars Publishing, 2007.
240. Massumi, Brian. "Envisioning the Virtual." In *The Oxford Handbook of Virtuality*, edited by Mark Grimshaw-Aagaard, 55–70. Oxford: Oxford University Press, 2013.
241. Mateus, Luis, José Fernández, Vasco Ferreira, Clara Oliveira, João Aguiar, Ana S. Gago, Pedro Pacheco, and José Pernão. "Terrestrial Laser Scanning and Digital Photogrammetry for Heritage Conservation: Case Study of the Historical Walls of Lagos, Portugal." *ISPRS International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XLII-2/W11 (2019): 843–847. https://doi.org/10.5194/isprs-archives-XLII-2-W11-843-2019.
242. Maxwell, James Clerk. "Experiments on Colour, as Perceived by the Eye, with Remarks on Colour-Blindness." *Transactions of the Royal Society of Edinburgh* 21, no. 2 (1855): 275–98.
243. McCarthy, John. "Reconstruction, Regeneration and Re-Imaging: Case of Rotterdam." *Cities* 15, no. 5 (1998): 337–44. https://doi.org/10.1016/S0264-2751(98)00029-8.
244. McClelland, Gwyn. "Remembering the Ruins of the Urakami Cathedral: Providence or Fifth Persecution?" *Journal of Religion in Japan* 5, no. 1 (2016): 47–69. https://doi.org/10.1163/22118349-00501007.
245. Mierzwiński, Mariusz. *Katalog rysunków architektonicznych dawnego Zarządu Odbudowy Zamku w Malborku: (1817–1945).* Malbork: Muzeum Zamkowe w Malborku, 2019.
246. Milgram, Paul, and Fumio Kishino. "Taxonomy of Mixed Reality Visual Displays." *IEICE Transactions on Information and Systems* E77-D, no. 12 (1994): 1321–29.
247. Miller, Angela L. "The Panorama, the Cinema, and the Emergence of the Spectacular." *Wide Angle* 18, no. 2 (1996): 34–69. https://doi.org/10.1353/wan.1996.0010.
248. Miśniakiewicz, Elżbieta, and Wojciech Skowroński. *Rysunek techniczny budowlany*. Warszawa: Arkady, 2013.
249. Mérimée, Prosper. "Studies in Art in the Middle Ages" (1832). In *Wokół problemów konserwacji i ochrony zabytków w XIX wieku*, edited by Jarosław Krawczyk and Piotr Kosiewski, 113–22. Warszawa: Muzeum Pałac w Wilanowie, 2011.
250. Monge, Gaspard. *Géométrie descriptive: leçons données aux écoles normales, l'an 3 de la République*. Paris: Bachelier, 1799.
251. Montalembert, Charles de. "Vandalism and Catholicism in Art" (1832). In *Wokół problemów konserwacji i ochrony zabytków w XIX wieku*, edited by Jarosław Krawczyk and Piotr Kosiewski, 99–112. Warszawa: Muzeum Pałac w Wilanowie, 2011.
252. Murat, Zeynep. "Wall Paintings through the Ages: The Medieval Period (Italy, Twelfth to Fifteenth Century)." *Archaeological and Anthropological Sciences* 13, no. 11 (2021): article 191. https://doi.org/10.1007/s12520-021-01410-4.
253. von Mücke, Dorothea E. "Beyond the Paradigm of Representation: Goethe on Architecture." *Grey Room* 35 (2009): 6–27. https://doi.org/10.1162/grey.2009.1.35.6
254. Murphy, Maurice, Eugene McGovern, and Sara Pavia. "Historic Building Information Modelling (HBIM)." *Structural Survey* 27, no. 4 (2009): 311–327. https://doi.org/10.1108/02630800910985108.
255. Nasrallah, Laura Salah. "Empire and Apocalypse in Thessaloniki: Interpreting the Early Christian Rotunda." *Journal of Early Christian Studies* 13, no. 4 (2005): 465–508.
256. Nawrowski, Mieczysław. *Die baugeschichtliche Entwickelung der Dominikanerkirche St. Nikolaus in Danzig*. Danzig, 1917.
257. Nevejan, Marie, and Gisèle Gantois. "Restoring Broken Journeys in the Framework of Urban Reconstruction after a Disaster: The Ypres Case." *Architecture_MPS* 29, no. 1 (2024): Article 3. DOI: 10.14324/111.444.amps.2024v29i1.003.
258. Newhall, Beaumont. *The History of Photography: From 1839 to the Present*. 5th ed. New York: Museum of Modern Art, 1984.

259. Nieuważny, Andrzej. *Klucz Do Wszystkiego. Dzieje Napoleońskiej Twierdzy Gdańsk 1807-1814*. Gdańsk: Wydawnictwo Muzeum Gdańska, 2022.
260. Nisch, Gunther. "Hospitals in Medieval Documents of the Cistercian Monastery Chorin." In *Festschrift für Gunther Nisch*, 45–52. 2018.
261. Nowak, Romuald, and Beata Stragierowicz. *Panorama Racławicka*. Wrocław: Muzeum Narodowe we Wrocławiu, 2021.
262. Oettermann, Stephan. *The Panorama: History of a Mass Medium*. Translated by Deborah Lucas Schneider. New York: Zone Books, 1997.
263. Oleksijczuk, Denise Blake. *The First Panoramas: Visions of British Imperialism*. Minneapolis: University of Minnesota Press, 2011.
264. Omilanowska, Małgorzata. "Odbudowa Kalisza po zniszczeniach 1914 roku." *Biuletyn Historii Sztuki: Kwartalnik Instytutu Sztuki Polskiej Akademii Nauk* 78, no. 4 (2016): 663–86.
265. Omilanowska, Małgorzata. "Architectural Reconstructions in Post-War Poland." *Architectura* 46, no. 1 (2016): 28–48.
266. Omilanowska, Małgorzata, and Edmund Kizik. "Wędrująca kamienica: Kilka uwag o translokacji i zreplikowaniu kamienicy gotyckiej przy ulicy Chlebnickiej w Gdańsku w świetle dokumentów." In *Budowanie nad Bałtykiem: Studia z architektury i sztuki Gdańska, Pomorza i Żmudzi*, edited by Małgorzata Omilanowska, 52–63. Gdańsk: Słowo/obraz terytoria, 2017.
267. Omilanowska, Małgorzata. "Architektura rekonstrukcyjna pomiędzy polityką historyczną a komercją." In *Historia jako pokusa. Spojrzenie przez pryzmat Westerplatte*, edited by Janusz Marszalec, 107–26. Gdańsk: Wydawnictwo Muzeum Gdańska, 2021.
268. Opaska, Janusz. "U źródeł ochrony zabytków: rozwój systemowego konserwatorstwa w Niemczech w początkach XIX." *Ochrona Zabytków* 1, no. 4 (2010): 199–210.
269. Ossowski, Waldemar. "Westerplatte – obraz przemian po II wojnie." In *Historia jako pokusa. Spojrzenie przez pryzmat Westerplatte*, edited by Janusz Marszalec, 127–46. Gdańsk: Wydawnictwo Muzeum Gdańska, 2021.
270. Otto, Franciszek and Edward Otto. *Podręcznik geometrii wykreślnej*. Warszawa: Wydawnictwo Naukowe PWN, 1998.
271. Paul, Jürgen. "The Rebirth of Historic Dresden." In *Debating German Cultural Identity since 1989*, edited by Anne Fuchs, Kathleen James-Chakraborty, and Linda Shortt, 117–28. *Studies in German Literature, Linguistics, and Culture*. Rochester, NY: Camden House, 2011.
272. Papadopoulou, Georgia, Peter Thompson, and Eleni Vassiliou. "The Origins of Entasis: Illusion, Aesthetics or Engineering?." *Spatial Vision* 20, no. 6 (2007): 531–43. https://doi.org/10.1163/156856807782758359.
273. Pieraccini, Massimiliano, Gabriele Guidi, and Carlo Atzeni. "3D Digitizing of Cultural Heritage." *Journal of Cultural Heritage* 2, no. 1 (2001): 63–70. https://doi.org/10.1016/S1296-2074(01)01108-6.
274. Piethe, Marcel, Michael Lissok, Franziska Siedler, and Stefanie Wagner. *Enthusiastischer Weltverschönerer – Karl Friedrich Schinkel: Sonderheft 2019*. Berlin: Ammian Verlag, 2019.
275. Piovesan, Rebecca, Ruth Siddall, Claudio Mazzoli, and Luca Nodari. "The Temple of Venus (Pompeii): A Study of the Pigments and Painting Techniques." *Journal of Archaeological Science* 38, no. 10 (2011): 2633–43.
276. Piranesi, Giovanni Battista. *Vedute di Roma*. Paris: Firmin-Didot, 1839.
274. Piwocki, Ksawery. "Uwagi o odbudowie zabytków." *Biuletyn Historii Sztuki i Kultury* 8, nos. 1–2 (1946): 53–59.
275. Plunz, Richard. "Reflections on Leuven as Martyred City and the Realignment of Propinquity." In *Revival after the Great War*, 55–64. Leuven: Leuven University Press, 2020.
276. Portoghesi, Paolo. *Rome Baroque: The History of an Architectonic Culture*. Cambridge, MA: MIT Press, 1970.
277. Pospieszny, Kazimierz. *Domus Malbork. Zamek krzyżacki w typie regularnym.* Toruń: Wydawnictwo Uniwersytetu Mikołaja Kopernika, 2014.
278. Pozzo, Andrea. *Perspectiva pictorum et architectorum. Pars prima*. Rome: Joannis Jacobi Komarek Bohemi, 1693.
279. Pozzo, Andrea. *Perspectiva pictorum et architectorum. Pars secunda*. Rome: Joannis Jacobi Komarek Bohemi, 1700.
280. Prien, Roland. "The Copy of an Empire? Charlemagne, the Carolingian Renaissance and Early-Medieval Perceptions of Late Antiquity." In *The Transformative Power of the Copy: A Transcultural and Interdisciplinary Approach*, edited by Corinna Forberg and Philipp Wolfgang Stockhammer, 309–29. Heidelberg: Heidelberg University Publishing, 2017. https://doi.org/10.17885/heiup.195.260
281. Pritchard, Douglas, Joerg Sperner, Sophie Hoepner, and Ruth Tenschert. "Terrestrial Laser Scanning for Heritage Conservation: The Cologne Cathedral Documentation Project." *ISPRS Annals of Photogrammetry, Remote Sensing and Spatial Information Sciences* IV-2/W2 (2017): 213–220. https://doi.org/10.5194/isprs-annals-IV-2-W2-213-2017.
282. Rabiega, Mateusz. "Problem odbudowy centrum Kalisza po 1914 roku z punktu widzenia niemieckiego konserwatora zabytków Juliusa Kohtego." *Zeszyty Kaliskiego Towarzystwa Przyjaciół Nauk* 21 (2021): 105–21. https://doi.org/10.4467/26578646ZKNT.21.005.17589
283. Ranisch, Bartel. *Beschreibung aller Kirchen-Gebäude der Stadt Dantzig*. Gdańsk: Jan Zachariasz Stolle, 1695.
284. Rauschnabel, Philipp A., Reto Felix, Chris Hinsch, Hamza Shahab, and Florian Alt. "What Is XR? Towards a Framework for Augmented and Virtual Reality." *Computers in Human Behavior* 133 (2022): 107289. https://doi.org/10.1016/j.chb.2022.107289
285. Reichow, Hans. *Alte bürgerliche Gartenkunst*. PhD diss., Berlin, 1927. Berlin: Verlag der Gartenschönheit.

286. Remondino, Fabio, and Stefano Campana, eds. *3D Recording and Modelling in Archaeology and Cultural Heritage: Theory and Best Practices*. BAR International Series no. S2598. Oxford: Archaeopress/BAR Publishing, 2014. ISBN 978-1-4073-1230-9.
287. Rennie, Kriston R. *The Destruction and Recovery of Monte Cassino, 529–1964*. *Italy in Late Antiquity and the Early Middle Ages*. Amsterdam: Amsterdam University Press, 2021.
288. Rheingold, Howard. *Virtual Reality: The Revolutionary Technology of Computer-Generated Artificial Worlds—and How It Promises to Transform Society*. New York: Simon & Schuster, 1992.
289. Migliari, Riccardo, and Jessica Romor. "Theories and Experiments on the 'Veduta Vincolata.'" *Journal for Geometry and Graphics* 19, no. 1 (2015): 57–77.
290. Richter, Gisela. *Perspective in Greek and Roman Art*. London, England: Phaidon Press, 1970.
291. Riegl, Alois. "Nowoczesny kult zabytków. Jego istota i powstanie." In *Alois Riegl, Georg Dehio i kult zabytków*, edited by Ryszard Kasperowicz, 31–90. Warsaw: Muzeum Pałacu w Wilanowie, 2012.
292. Robertson, Martin. "The Boscoreale Figure-Paintings." *The Journal of Roman Studies* 45 (1955): 58–67.
293. Robins, Gay. *The Art of Ancient Egypt, Revised Edition*. 2nd ed. Cambridge, MA: Harvard University Press, 2008.
294. Rollason, David. "Charlemagne's Palace." *Archaeological Journal* 172, no. 2 (2015): 443–48. https://doi.org/10.1080/00665983.2015.1040262
295. Ruskin, John. *The Seven Lamps of Architecture.* London: Smith, Elder & Co., 1849.
296. Ruskin, John. *The Stones of Venice.* London: Smith, Elder & Co., 1851.
297. Rut, Sławomir, Wojciech Samól, and Jarosław Tuliszka. *Westerplatczycy – lista 1939: skład załogi Wojskowej Składnicy Tranzytowej na Westerplatte w Wolnym Mieście Gdańsku 1 września 1939 r.* Gdańsk: Muzeum II Wojny Światowej, 2023.
298. Rymaszewski, Bohdan. *Polska ochrona zabytków*. Warszawa: Wydawnictwo Naukowe Scholar, 2005.
299. Salonia, Paolo, Serena Scolastico, Andrea Pozzi, Andrea Marcolongo, and Tommaso Leti Messina. "Multi-Scale Cultural Heritage Survey: Quick Digital Photogrammetric Systems." *Journal of Cultural Heritage* 10, Supplement 1 (2009): e59–e64. https://doi.org/10.1016/j.culher.2009.09.004.
300. Samól, Piotr. "Rutki: wieś patrymonialna Młodego Miasta Gdańska." *Studia z dziejów średniowiecza*, no. 16 (2011): 159–92.
301. Samól, Piotr. *Młode Miasto Gdańsk (1380-1455) i jego patrymonium*. Gdańsk: Wydawnictwo Uniwersytetu Gdańskiego, 2018
302. Samól, Piotr. *Architektura kościołów dominikańskich w średniowiecznych Prusach*. Gdańsk: Wydawnictwo Słowo/Obraz Terytoria, 2022.
303. Samól, Piotr. "O odkrywaniu historii budowlanej kościoła św. Mikołaja w Gdańsku. Architektura świątyni dominikanów w świetle badań architektonicznych, archeologicznych i konserwatorskich." In *Dominikanie w Gdańsku. 800 lat zakonu dominikanów w Polsce*, edited by Anna Frąckowska and Katarzyna Darecka, 65–75. Gdańsk: Muzeum Gdańska, 2021.
304. Samól, Wojciech. "Stan osobowy Wartowni nr 5 a pochówki przy Willi Oficerskiej na Westerplatte we wrześniu 1939 r. w świetle źródeł archiwalnych, wspomnień i relacji." *Wojna i Pamięć: Czasopismo Muzeum II Wojny Światowej w Gdańsku* (2020): 46–99.
305. Samól, Wojciech, Szymon Kowalski, Arkadiusz Woźniakowski, and Piotr Samól. "Where the Second World War in Europe Broke Out: The Landscape History of Westerplatte, Gdańsk/Danzig." *Land* 12, no. 3 (2023): 596. https://doi.org/10.3390/land12030596.
306. Schaff, Ulrich. "Uwagi do metod badań architektonicznych konstrukcji drewnianych na przykładzie osiemnastowiecznej więźby mansardowej Dworu Studzienka w Gdańsku." In *Problemy konserwacji i badań zabytków architektury*, edited by Aleksandra Kociałkowska, 151–64. Gdańsk: Europejska Fundacja Ochrony Zabytków, 2008.
307. Schinkel, Karl Friedrich. "Memorandum to the Prussian Authorities" (1815). In *Wokół problemów konserwacji i ochrony zabytków w XIX wieku*, edited by Piotr Kosiewski and Jarosław Krawczyk, 263–68. Warszawa: Muzeum Pałac w Wilanowie, 2011.
308. Schlegel, Friedrich. "Letters from Travels in the Netherlands, the Rhineland, Switzerland and Parts of France" (1806). In *Wokół problemów konserwacji i ochrony zabytków w XIX wieku*, edited by Piotr Kosiewski and Jarosław Krawczyk, 251–62. Warszawa: Muzeum Pałac w Wilanowie, 2011.
309. Sempoliński Leonard, and Emila Borecka. *Warszawa 1945*. Warszawa: Państwowe Wydawnictwo Naukowe, 1985.
310. Sharma, Alisha, Ryan Nett, and Jonathan Ventura. 2020. "Unsupervised Learning of Depth and Ego-Motion from Cylindrical Panoramic Video with Applications for Virtual Reality." *International Journal of Semantic Computing* 14 (3): 333–56.
311. Silver, Minna, Gabriele Fangi, and Ahmet Denker. *Reviving Palmyra in Multiple Dimensions: Images, Ruins and Cultural Memory*. Caithness, UK: Whittles Publishing, 2018.
312. Skalimowski, Andrzej. "„Budowniczy Stolicy''. Warszawski Mecenat Bolesława Bieruta w Latach 1945-1955." *Pamięć i Sprawiedliwość* 2, no. 24 (2014): 75–94.
313. Snodin, Michael. *Karl Friedrich Schinkel: A Universal Man*. New Haven, CT: Yale University Press, 1991.
314. Speicher, Maximilian, Brian D. Hall, and Michael Nebeling. "What Is Mixed Reality?" In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, 1–15. New York: ACM, 2019. https://doi.org/10.1145/3290605.3300767.

315. Stankiewicz, Jerzy, and Bohdan Szermer. *Gdańsk: rozwój urbanistyczny i architektoniczny oraz powstanie zespołu Gdańsk–Sopot–Gdynia.* Warsaw: Arkady, 1959.
316. Stovel, Herb. "Origins and Influence of the Nara Document on Authenticity." *APT Bulletin* 39, no. 2/3 (2008): 9–17.
317. Stephenson, Neal. *Snow Crash*. New York: Bantam Books, 1992.
318. Sylaiou, Styliani; Fotis Liarokapis; Kostas Kotsakis; and Petros Patias. "Virtual Museums, a Survey and Some Issues for Consideration." *Journal of Cultural Heritage* 10, no. 4 (2009): 520–28. https://doi.org/10.1016/j.culher.2009.03.003
319. Suh, Ayoung, and Jane Prophet. "The State of Immersive Technology Research: A Literature Analysis." *Computers in Human Behavior* 86 (September 2018): 77–90. https://doi.org/10.1016/j.chb.2018.04.019
320. Sullivan, Elaine A., and Lisa M. Snyder. "Digital Karnak: An Experiment in Publication and Peer Review of Interactive, Three-Dimensional Content." *Journal of the Society of Architectural Historians* 76, no. 4 (2017): 464–482. https://doi.org/10.1525/jsah.2017.76.4.464.
321. Sutherland, Ivan E. "A Head-Mounted Three Dimensional Display." In *Proceedings of the Fall Joint Computer Conference (AFIPS)*, 757–64. 1968.
322. Szczepański, Jakub. 2011. "Siedem i Pół Wieku Wrzeszcza." In *Wędrówki po Wrzeszczu*, edited by Jakub Szczepański and Katarzyna Szczepańska, 8–83. Gdańsk: Słowo/obraz terytoria.
323. Szczepański, Jakub. *Architektura zespołu Politechniki Gdańskiej 1904–2018*. Gdańsk: Słowo/obraz terytoria, 2019.
324. Szermer, Bohdan. *Gdańsk - Przeszłość i Współczesność*. Warszawa: Interpress, 1971.
325. Szmygin, Bogusław. "Ochrona zabytkowych ruin – założenia do teorii i praktyki." In *Historyczne ruiny: Ochrona, użytkowanie, zarządzanie*, edited by Bogusław Szmygin, 191–200. Warszawa: Polski Komitet Narodowy Międzynarodowej Rady Ochrony Zabytków ICOMOS, 2018.
326. Szumigała, Paweł Piotr, and Karolina Olenia Szumigała. "Forgotten Academic Modernism in the Reconstruction of Downtown Le Havre by Auguste Perret." *Teka Komisji Architektury, Urbanistyki i Studiów Krajobrazowych* 17, no. 1 (2021). https://doi.org/10.35784/teka.2651.
327. Szyszka, Maciej. "Badania ratunkowe w piwnicach Hali Targowej w Gdańsku." In *Dominikanie. Gdańsk – Polska – Europa*, edited by Andrzej Gołębnik, Marcin Grubka OP, and Dariusz Aleksander Dekański OP, 485–499. Gdańsk–Pelplin: Dominikańskie Centrum św. Jacka w Gdańsku, 2003.
328. Szyszka, Maciej. "Romański kościół pw. św. Mikołaja i trzynastowieczny zespół podominikański w świetle badań archeologicznych na stanowisku 5 w Gdańsku." In *Architektura romańska w Polsce. Nowe odkrycia i interpretacje*, edited by Tomasz Janiak and Dariusz Stryniak, 610–640. Gniezno: Muzeum Początków Państwa Polskiego w Gnieźnie, 2009.
329. *The Royal Castle in Poznań: History and Restitution*. Edited by Włodzimierz Łęcki, Jacek Wiesiołowski, Hanna Kóćka-Krenz, and Andrzej Zarzycki. Poznań: Bogucki Scientific Publishers, 2014.
330. Toman, Rolf. *Baroque*. Königswinter, Germany: Könemann, 1998.
331. Torbus, Tomasz. *Rekonstrukcje, dekonstrukcje, (nad)interpretacje: studia o losach architektury środkowoeuropejskich miast i rezydencji w aspekcie politycznym (XIX-XXI wiek)*. Gdańsk: Słowo/obraz terytoria, 2019.
332. Trojanowska, Izabella. *Wspomnienia z Odbudowy Głównego Miasta*. Gdańsk: Marpress, 1997.
333. Trojanowska, Monika. "The New Approach to Commemorating Open-Air War Sites on the Example of the Museum of Westerplatte and the 1939 War in Gdańsk, Poland." *Muzeológia a kultúrne dedičstvo* 11, no. 3 (2023): 37–51. https://doi.org/10.46284/mkd.2023.11.3.3.
334. Tyler, Christopher W. "Perspective as a Geometric Tool That Launched the Renaissance." In *Human Vision and Electronic Imaging V*, edited by Bernice E. Rogowitz and Thrasyvoulos N. Pappas, vol. 3959, *Proceedings of SPIE*, 492–97. Bellingham, WA: SPIE, 2000.
335. Uricchio, William. "A 'Proper Point of View': The Panorama and Some of Its Early Media Iterations." *Early Popular Visual Culture* 9, no. 3 (2011): 225–38. https://doi.org/10.1080/17460654.2011.601165.
336. Van Assche, Kristof, and Monica Gruezmacher. "Remembering Ypres: Post-War Reconstruction, Land and the Legacies of Shock and Conflict." *Land* 12, no. 1 (2023): 21. https://doi.org/10.3390/land12010021.
337. Vasarainen, Minna, Sami Paavola, and Liubov Vetoshkina. "A Systematic Literature Review on Extended Reality: Virtual, Augmented and Mixed Reality in Working Life." *International Journal of Virtual Reality* 21, no. 2 (2021): 1–28.
338. Vasari, Giorgio. *Żywoty najsławniejszych malarzy, rzeźbiarzy i architektów*. Warszawa: Państwowe Wydawnictwo Naukowe, 1985.
339. Vaughan, William. *Romantic Art.* Cary, NC: Oxford University Press, 1978.
340. Venugopal, Jothi Prakash, Arul Antran Vijay Subramanian, and Jegathesh Peatchimuthu. "The Realm of Metaverse: A Survey." *Computer Animation and Virtual Worlds* 34, no. 5 (2023): e2150. https://doi.org/10.1002/cav.2150.
341. Velenis, Georgios. "Some Observations on the Original Form of the Rotunda in Thessaloniki." *Balkan Studies* 15 (1974): 298–307.
342. Viollet-le-Duc, Eugène-Emmanuel. *Dictionnaire raisonné de l'architecture française du XIe au XVIe siècle*. 10 vols. Paris: B. Bance, 1854–1868.
343. Viollet-le-Duc, Eugène. *La cité de Carcassonne*. Paris: A. Morel, 1888.

344. Wainwright, Andrew Martin. “Teaching Historical Theory through Video Games.” *The History Teacher* 47, no. 4 (2014): 579–612. https://www.jstor.org/stable/43264296.
345. Watkin, David. *Historia architektury zachodniej*. Warszawa: Arkady, 2001.
346. Westbrook, Nigel, Kenneth Rainsbury Dark, and Rene van Meeuwen. “Constructing Melchior Lorichs’s Panorama of Constantinople.” *Journal of the Society of Architectural Historians* 69, no. 1 (2010): 62–87. https://doi.org/10.1525/jsah.2010.69.1.62.
347. Westbrook, Nigel B., and Rene van Meeuwen. “Reconstructing Sixteenth-Century Istanbul: The Use of Digital Modelling as an Heuristic Tool in Architectural History Research.” *Architectural Theory Review* 18, no. 1 (2013): 62–82. https://doi.org/10.1080/13264826.2013.792852.
348. Wheatstone, Charles. “Contributions to the Physiology of Vision.—Part the First. On Some Remarkable and Hitherto Unobserved Phenomena of Binocular Vision.” *Proceedings of the Royal Society of London* 4 (1843): 76–77. https://doi.org/10.1098/rspl.1837.0035.
349. Wilkinson, Richard H. *Symbol and Magic in Egyptian Art*. London, England: Thames & Hudson, 1994.
350. Williams, Robert. *Raphael and the Redefinition of Art in Renaissance Italy*. Cambridge: Cambridge University Press, 2017.
351. Winckelmann, Johann Joachim. “Sendschreiben von den Herculanischen Entdeckungen an den Reichsgrafen von Brühl.” In *Kleine Schriften und Briefe*, edited by Wilhelm Senff, 242–62. Weimar: H. Böhlaus Nachfolger, 1960.
352. Winckelmann, Johann Joachim. *History of the Art of Antiquity*. Translated by Harry Francis Mallgrave. Santa Monica, CA: Getty Publications, 2006.
353. Winter, Tim. “Angkor Meets Tomb Raider: Setting the Scene.” *International Journal of Heritage Studies* 8, no. 4 (2002): 323–336. https://doi.org/10.1080/1352725022000037218.
354. Witkowski, Rafał. *Westerplatte. Historia i dzień dzisiejszy*. Gdańsk: Wydawnictwo Morskie, 1977.
355. Wittman, Richard. “Luigi Poletti and the Challenge of Rebuilding San Paolo.” In *Rebuilding St. Paul’s Outside the Walls*, edited by Richard Wittman, 207–45. Cambridge: Cambridge University Press, 2024.
358. Witwicki, Michał. “Kryteria oceny wartości zabytkowej obiektów architektury jako podstawa wpisu do rejestru zabytków.” *Ochrona Zabytków*, no. 1 (2007): 77–98.
359. Wójtowicz-Podhorski, Mariusz. *Westerplatte 1939*. Gdańsk: AJ-Press, 2009.
360. Woods, Andrew J., and Chris R. Harris. “Comparing Levels of Crosstalk with Red/Cyan, Blue/Yellow, and Green/Magenta Anaglyph 3D Glasses.” In *Proceedings of SPIE Stereoscopic Displays and Applications XXI*, vol. 7253, 0Q1–0Q12. Bellingham, WA: SPIE, 2010. doi:10.1117/12.840835.
361. Woźniakowski, Arkadiusz. “Historia i materialne relikty fortyfikacji Westerplatte sprzed 1920 r.” In *Materialne pozostałości konfliktów i zbrodni XX wieku w świetle najnowszych badań archeologicznych*, edited by Hanna Mik and Wirginia Węglińska, 276–303. Gdańsk: Muzeum II Wojny Światowej, 2019.
362. Wüstenhagen, Elisabeth. “Undoing Trauma: Reconstructing the Church.” *Future Anterior: Journal of Historic Preservation, History, Theory, and Criticism* 3, no. 1 (2006): 12–23.
363. Yang, Xiucheng, Pierre Grussenmeyer, Mathieu Koehl, Hélène Macher, Arnadi Murtiyoso, and Tania Landes. “Review of Built Heritage Modelling: Integration of HBIM and Other Information Techniques.” *Journal of Cultural Heritage* 46 (2020): 350–360. https://doi.org/10.1016/j.culher.2020.05.008.
364. Yastikli, Naci. “Documentation of Cultural Heritage Using Digital Photogrammetry and Laser Scanning.” *Journal of Cultural Heritage* 8, no. 4 (2007): 423–27. https://doi.org/10.1016/j.culher.2007.06.003.
365. Yilmaz, Hüseyin Murat, Mustafa Yakar, S. Ali Güleç, and Orhan Nuri Dülgerler. “Importance of Digital Close-Range Photogrammetry in Documentation of Cultural Heritage.” *Journal of Cultural Heritage* 8, no. 4 (2007): 428–433. https://doi.org/10.1016/j.culher.2007.07.004.
366. Zachwatowicz, Jan. “Mury obronne Warszawy i prace nad ich odsłoną.” *Biuletyn Historii Sztuki i Kultury* 2 (1937): 279–87.
367. Zachwatowicz, Jan. “Program i zasady konserwacji architektury.” *Biuletyn Historii Sztuki i Kultury* 8, nos. 1–2 (1946): 48–52.
368. Zachwatowicz, Jan. “Stare Miasto Warszawa wraca do życia.” *Ochrona Zabytków* 6, nos. 2–3 (1953): 73–77.
369. Zachwatowicz, Jan. *Ochrona zabytków w Polsce*. Warszawa: Polonia, 1965.
370. Zachwatowicz, Jan. “Odbudowa Zamku Królewskiego w Warszawie: Prace Komisji Architektoniczno-Konserwatorskiej Obywatelskiego Komitetu Odbudowy Zamku Królewskiego w Warszawie.” *Ochrona Zabytków* 26, no. 1 (1973): 13–20.
371. Zachwatowicz, Jan. “Problemy restytucji Zamku Królewskiego w Warszawie.” *Ochrona Zabytków* 32, no. 1 (1979): 3–18.
372. Zachwatowicz, Jan. “O polskiej szkole odbudowy i konserwacji zabytków.” *Ochrona Zabytków* 34, nos. 1–2 (1981): 4–10.
373. Zadrożniak, Aleksandra. “Biuro Odbudowy Stolicy – od początków działalności do programu ‘Pamięć Świata’ UNESCO.” *Kronika Warszawy*, no. 2 (2011): 85–91.
374. Zajączkowski, Krzysztof. *Westerplatte jako miejsce pamięci 1945–1989*. Warszawa: Wydawnictwo IPN, 2015.
375. Żakiewicz, Maciej. *Gdansk 1945 Kronika wojennej burzy*. Gdańsk: Oskar, 2011.
376. Zaloga, Steven. *Rangers Lead the Way: Pointe-du-Hoc, D-Day 1944*. London: Osprey Publishing, 2009.

377. Zanker, Paul. *Pompeii: Public and Private Life*. Translated by Deborah Lucas Schneider. Cambridge, MA: Harvard University Press, 1999.
378. Zbierski, Andrzej. "Dotychczasowe wyniki badań archeologicznych w kościołach św. Mikołaja i św. Katarzyny w Gdańsku." *Rocznik Gdański*, no. 15–16 (1956/1957): 53–77.
379. Żemła, Michał, and Matylda Siwek. "Between Authenticity of Walls and Authenticity of Tourists' Experiences: The Tale of Three Polish Castles." *Cogent Arts & Humanities* 7, no. 1 (2020): art. 1763893. https://doi.org/10.1080/23311983.2020.1763893.
380. Ziejka, Franciszek. *Panorama Racławicka*. Warsaw, Poland: Krajowa Agencja Wydawnicza, 1984.
381. Zielińska, Monika, and Magdalena Rucka. "Assessment of Wooden Beams from Historical Buildings Using Ultrasonic Transmission Tomography." *International Journal of Architectural Heritage: Conservation, Analysis, and Restoration* 17, no. 1 (2023): 249–261. https://doi.org/10.1080/15583058.2022.2086505.
382. Zill, Rüdiger. "'A True Witness of Transience': Berlin's Kaiser-Wilhelm-Gedächtniskirche and the Symbolic Use of Architectural Fragments in Modernity." *European Review of History / Revue européenne d'histoire* 18, no. 5–6 (2011): 811–27. https://doi.org/10.1080/13507486.2011.618332.
383. Zimnowoda-Krajewska, Bożena. "Uwagi do projektów konserwatora zabytków architektury." In *Problemy konserwacji i badań zabytków architektury*, edited by Aleksandra Kociałkowska, 253–62. Gdańsk: Europejska Fundacja Ochrony Zabytków, 2007.
384. Zone, Ray. *Stereoscopic Cinema and the Origins of 3-D Film, 1838–1952*. Lexington: University Press of Kentucky, 2007.
385. Zukin, Sharon. *Naked City: The Death and Life of Authentic Urban Places*. New York, NY: Oxford University Press, 2010.

Charters

386. *The Athens Charter for the Restoration of Historic Monuments.* Adopted at the First International Congress of Architects and Technicians of Historic Monuments, Athens, 1931. Accessed June 28, 2025. https://civvih.icomos.org/wp-content/uploads/2022/03/The-Athens-Charter_1931.pdf.
387. *Charte ICOMOS pour l'interprétation et la présentation des sites culturels patrimoniaux.* Ratifiée par la 16e Assemblée générale de l'ICOMOS (Québec, Canada), le 4 octobre 2008. ICOMOS. Accessed June 29, 2025. https://admin.icomos.org/wp-content/uploads/2025/03/interpretation_FREN.pdf.
388. *Declaration of Amsterdam.* Adopted at the Congress on the European Architectural Heritage, Amsterdam, October 1975. Accessed June 28, 2025. https://civvih.icomos.org/wp-content/uploads/2022/03/Declaration-of-Amsterdam_25_10_1975.pdf.
389. *Hague Convention for the Protection of Cultural Property in the Event of Armed Conflict.* Adopted at The Hague, 14 May 1954; entered into force 7 August 1956. Accessed June 28, 2025. https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU19570460212.
390. *International Charter for the Conservation and Restoration of Monuments and Sites (The Venice Charter, 1964).* IInd International Congress of Architects and Technicians of Historic Monuments, Venice; adopted by ICOMOS in 1965. Accessed June 28, 2025. https://admin.icomos.org/wp-content/uploads/2025/03/Venice_Charter_EN.pdf.
391. *The London Charter for the Computer-based Visualisation of Cultural Heritage.* Accessed March 22, 2022. http://www.londoncharter.org.
392. *Nara Document on Authenticity.* 1994. Accessed June 28, 2025. https://whc.unesco.org/document/116018.
393. *Principles for the Recording of Monuments, Groups of Buildings and Sites.* Ratified by the 11th ICOMOS General Assembly, Sofia, October 1996. Accessed June 28, 2025. https://admin.icomos.org/wp-content/uploads/2025/03/archives-eng.pdf.
394. *The Seville Principles: International Principles of Virtual Archaeology.* Adopted at the XVI International Congress of Classical Archaeology, Seville, 2011. Accessed June 28, 2025. https://icomos.es/wp-content/uploads/2020/06/Seville-Principles-IN-ES-FR.pdf.

Digital & Online Sources

395. Adobe. "Substance 3D." Accessed March 12, 2023. https://www.adobe.com/pl/products/substance3d
396. Alexander, Harriet. "Berlin Begins Reconstruction of King Frederick the Great's Palace." *The Telegraph,* June 12, 2013. Accessed August 9, 2025. https://www.telegraph.co.uk/news/worldnews/europe/germany/10117103/Berlin-begins-reconstruction-of-King-Frederick-the-Greats-palace.html

397. "Album: Powojenna Warszawa." *Fototeka 1944.pl.* Accessed July 11, 2025. https://www.1944.pl/fototeka/kolekcja/maciej-czaplinski-album-powojenna-warszawa-pa,163,strona,4.html
398. ArchiMemory. "Mieczysław Nawrowski – architekt." Accessed February 2, 2025. https://www.archimemory.pl/pokaz/mieczyslaw_nawrowski,26179
399. Architektura i Biznes. "Wyniki konkursu na opracowanie architektoniczno-budowlanej koncepcji projektowej Muzeum Westerplatte i Wojny 1939 – Oddziału Muzeum II Wojny Światowej w Gdańsku." October 2023. Accessed December 24, 2024. https://www.architekturaibiznes.pl/konkurs-wyniki/wyniki-konkursu-na-muzeum-ii-wojny-swiatowej-w-gdansku,30523.html
400. Berliner Schloss – Humboldt Forum. *Baugeschichte. Das historische Schloss.* Accessed August 9, 2025. https://berliner-schloss.de/das-historische-schloss/baugeschichte
401. Berliner Schloss – Humboldt Forum. *Die Schloss-Simulation 1993 / 1994. Das historische Schloss.* Accessed August 9, 2025. https://berliner-schloss.de/das-historische-schloss/die-schloss-simulation-1993-1994
402. Biasco, Paul. "When It Comes to Building Anew, Frankfurt Looks to the Past." *Architectural Digest,* January 2, 2019. Accessed August 9, 2025. https://www.architecturaldigest.com/story/when-it-comes-to-building-anew-frankfurt-looks-to-the-past
403. Blin, Sylvie. "The Panorama of Rome by Louis Le Masson." *La Gazette Drouot,* July 15, 2025. Accessed September 9, 2025. https://www.gazette-drouot.com/en/article/the-panorama-of-rome-by-louis-le-masson/90233
404. "Blisko 14 mln zł odszkodowania dla Gdańska za przejęcie Westerplatte." *Trojmiasto.pl.* Accessed December 23, 2024. https://www.trojmiasto.pl/wiadomosci/Blisko-14-mln-zl-odszkodowania-dla-Gdanska-za-przejecie-Westerplatte-n189799.html
405. Boissoneault, Lorraine. "The Debate Over Rebuilding That Ensued When a Beloved French Cathedral Was Shelled During WWI." *Smithsonian Magazine,* April 19, 2019. Accessed June 29, 2025. https://www.smithsonianmag.com/history/debate-over-rebuilding-ensued-when-beloved-french-cathedral-was-shelled-during-wwi-180971999
406. "Budowa Muzeum Westerplatte i Wojny 1939 – założenia programowe." *Ministerstwo Kultury i Dziedzictwa Narodowego,* August 25, 2020. Accessed December 23, 2024. https://www.gov.pl/web/kultura/budowa-muzeum-westerplatte-i-wojny-1939--zalozenia-programowe
407. British Museum. "Object: Section of the Rotunda, Leicester Square, in Which Is Exhibited the Panorama." Museum Number P. 1875-0710-4485. *British Museum Collection Online.* Accessed September 28, 2024. https://www.britishmuseum.org/collection/object/P_1875-0710-4485
408. Cambridge English Dictionary. "Inventory." Accessed July 1, 2025. https://dictionary.cambridge.org/us/dictionary/english/inventory
409. Cambridge English Dictionary. "Mimesis." Accessed May 20, 2025. https://dictionary.cambridge.org/dictionary/english/mimesis?topic=representation-in-art-and-in-general
410. Cambridge English Dictionary. "Survey." Accessed July 1, 2025. https://dictionary.cambridge.org/us/dictionary/english/survey
411. Cambridge English Dictionary. "Virtual Reality." Accessed May 20, 2025. https://dictionary.cambridge.org/dictionary/english/virtual-reality
412. Central Office of Geodesy and Cartography. "Database of Topographical Objects (BDOT10k)." Polish Geoportal. Accessed March 6, 2025. https://www.geoportal.gov.pl/pl/dane/baza-danych-obiektow-topograficznych-bdot10k
413. "Cistercian Monastery, Chorin." *Europäische Route der Backsteingotik.* Accessed March 21, 2023. https://www.eurob.org/item/chorin_cistercian-monastery/?lang=en
414. Cubiculum (bedroom) from the Villa of P. Fannius Synistor at Boscoreale. Roman late Republic fresco (ca. 50–40 BCE). *The Metropolitan Museum of Art.* Accessed April 20, 2022. https://www.metmuseum.org/art/collection/search/247017
415. "Culture.pl. Warszawa 1945: Przewodnik po mieście ruin." Accessed July 11, 2025. https://culture.pl/pl/superartykul/warszawa-1945-przewodnik-po-miescie-ruin
416. "Cyfrowy bliźniak Gdańska: Modelowanie cyfrowe rozwoju miasta od historii do przeszłości." *Most Wiedzy.* Accessed May 2, 2025. https://mostwiedzy.pl/pl/project/cyfrowy-blizniak-gdanska-modelowanie-cyfrowe-rozwoju-miasta-od-historii-do-przeszlosci,1035-1
417. Digital Camera Museum. "Sony ProMavica MVC-2010 (1990)." Accessed September 9, 2025. https://www.digitalkameramuseum.de/en/esvc/item/sony-promavica-mvc-2010
418. Dominikanie Gdańsk. "Wirtualna rekonstrukcja zakrystii." August 9, 2022. Accessed March 3, 2025. https://gdansk.dominikanie.pl/2022/08/wirtualna-rekonstrukcja-zachrystii
419. DomRömer GmbH. *Übersichtskarte* (interactive map of the Dom-Römer quarter). Accessed August 9, 2025. https://www.domroemer.de/ubersichtskarte

420. "Domgrabung." *Kölner Dom.* Accessed March 21, 2023. https://www.koelner-dom.de/erleben/domgrabung
421. "Dyrektor MIIWŚ: jesteśmy zdeterminowani, aby na Westerplatte powstało muzeum." *Dzieje.pl,* April 25, 2018. Accessed December 23, 2024. https://dzieje.pl/aktualnosci/dyrektor-miiws-jestesmy-zdeterminowani-aby-na-westerplatte-powstalo-muzeum
422. Edoardo Tresoldi. Official website. Accessed July 3, 2025. https://www.edoardotresoldi.com
423. Encyklopedia Gdańska. "Lelewicz Kazimierz, fotografik." *Gedanopedia* (Fundacja Gdańska / Muzeum Gdańska). Accessed July 13, 2025. https://gdansk.gedanopedia.pl/gdansk/?title=LELEWICZ_KAZIMIERZ,_fotografik
424. Encyclopaedia Britannica. "Virtual Reality." Accessed May 20, 2025. https://www.britannica.com/technology/virtual-reality
425. Encyclopaedia Britannica. s.v. "Daguerreotype." *Britannica.com.* Last updated August 12, 2025. Accessed June 24, 2024. https://www.britannica.com/technology/photography/Daguerreotype
426. Enthusiastischer Weltverschönerer · Karl-Friedrich Schinkel. *Die Mark Brandenburg.* Accessed June 9, 2023. https://www.die-mark-brandenburg.de/p/enthusiastischer-weltverschoenerer-karl-friedrich-schinkel
427. Epic Games Developer Documentation. "LiDAR Point Cloud Plugin Overview in Unreal Engine." Accessed December 27, 2024. https://dev.epicgames.com/documentation/en-us/unreal-engine/lidar-point-cloud-plugin-overview-in-unreal-engine
428. Epic Games Developer Documentation. "nDisplay Overview for Unreal Engine." Accessed December 27, 2024. https://dev.epicgames.com/documentation/en-us/unreal-engine/ndisplay-overview-for-unreal-engine
429. Faculty of Electronics, Telecommunications and Informatics, Gdańsk University of Technology. "Immersive 3D Visualization Lab." Accessed July 1, 2025. https://eti.pg.edu.pl/lzwp/o-laboratorium
430. "Gdańsk: radni protestują ws. wywłaszczenia Westerplatte." *Interia.pl.* Accessed December 23, 2024. https://wydarzenia.interia.pl/pomorskie/news-gdansk-radni-protestuja-ws-wywlaszczenia-westerplatte,nId,3018266
431. "Google Arts & Culture. Między zniszczeniem a odbudową – Gdańsk na fotografii Kazimierza Lelewicza." *Muzeum Gdańska.* Accessed July 13, 2025. https://artsandculture.google.com/story/mi%C4%99dzy-zniszczeniem-a-odbudow%C4%85-%E2%80%93-gda%C5%84sk-na-fotografii-kazimierza-lelewicza/9QUBrz3ybHcAzg?hl=pl
432. "Google Arts & Culture. Warszawa 1945." Accessed July 11, 2025. https://artsandculture.google.com/story/yQWhS5Gh6u2hLw?hl=pl
433. Goode, Lauren. "Microsoft's HoloLens 2 Puts a Full-Fledged Computer on Your Face." *WIRED,* February 24, 2019. Accessed September 13, 2025. https://www.wired.com/story/microsoft-hololens-2-headset
434. Heilig, Morton L. "Experience Theater." U.S. Patent 3,628,829, filed July 8, 1969; issued December 21, 1971. https://patents.google.com/patent/US3628829A/en
435. Hiroshima Peace Memorial Museum. *Hiroshima Peace Memorial Museum.* Accessed October 19, 2024. https://hpmmuseum.jp/?lang=eng
436. "Historia półwyspu Westerplatte." *Muzeum II Wojny Światowej,* April 1, 2020. Accessed January 24, 2025. https://muzeum1939.pl/historia-polwyspu-westerplatte-m2wswirtualnie/aktualnosci/3298.html
437. "Historycy z całego świata przeciwni łączeniu Muzeum II WS – oświadczenie." *Trojmiasto.wyborcza.pl.* Accessed December 23, 2024. https://trojmiasto.wyborcza.pl/trojmiasto/7,35612,21641103,historycy-z-calego-swiata-przeciwni-laczeniu-muzeum-ii-ws-oswiadczenie.html?disableRedirects=true
438. "Istorinė raida." *Nacionalinis muziejus Lietuvos Didžiosios Kunigaikštystės valdovų rūmai.* Accessed August 7, 2025. https://www.valdovurumai.lt/lt/rumu-istorija/i/142/istorine-raida
439. "Jak może wyglądać Westerplatte? Zobacz trzy koncepcje. WIZUALIZACJE." *Gdańsk.pl,* July 12, 2018. Accessed December 22, 2024. https://www.gdansk.pl/wiadomosci/Jak-moze-wygladac-Westerplatte-Idee-architektoniczne-i-dyskusja-historykow-w-Dworze-Artusa,a,119656
440. Karl Friedrich Schinkel und Chorin. *Kloster Chorin.* Accessed June 12, 2023. https://www.kloster-chorin.org/ausstellung-karl-friedrich-schinkel
441. "Katastrofa budowlana wisi nad kościołem w sercu Gdańska. Startuje akcja ratownicza." *Trojmiasto.wyborcza.pl.* Accessed January 12, 2024. https://trojmiasto.wyborcza.pl/trojmiasto/7,35612,24114753,katastrofa-budowlana-wisi-nad-kosciolem-w-sercu-gdanska-startuje.html
442. Kloster Chorin. "Geschichte." Accessed March 21, 2023. https://www.kloster-chorin.org/geschichte
443. "Kościół św. Mikołaja. Pękające sklepienie naprawione, ale na całkowite otwarcie trzeba poczekać." *Gdansk.pl,* December 21, 2021. Accessed January 12, 2024. https://www.gdansk.pl/wiadomosci/Kosciol-sw-Mikolaja-w-Gdansku-koniec-remontu-nawy-poludniowej-sklepienia-naprawione,a,210932
444. "Kościół św. Mikołaja znów otwarty dla wiernych i zwiedzających." *Trojmiasto.wyborcza.pl.* Accessed January 12, 2024. https://trojmiasto.wyborcza.pl/trojmiasto/7,35612,26088693,kosciol-sw-mikolaja-znowu-otwarty-dla-wiernych-i-zwierdzajacych.html

445. "Konserwator: inne zabytki zagrożone jak kościół św. Mikołaja." *Trojmiasto.pl,* October 31, 2018. Accessed January 12, 2024. https://www.trojmiasto.pl/wiadomosci/Konserwator-inne-zabytki-zagrozone-jak-kosciol-sw-Mikolaja-n128856.html
446. "LiDAR Point Cloud Plugin Overview in Unreal Engine." *Epic Games Developer Documentation.* Accessed December 27, 2024. https://dev.epicgames.com/documentation/en-us/unreal-engine/lidar-point-cloud-plugin-overview-in-unreal-engine
447. Lillie, Amanda. "Place Making," introduction to *Building the Picture: Architecture in Italian Renaissance Painting. National Gallery.* Accessed October 18, 2023. https://www.nationalgallery.org.uk/research/research-resources/exhibition-catalogues/building-the-picture/place-making/introduction
448. Maier, Andreas. "Erinnerung: Fachwerk für alle!" *Die Zeit,* May 18, 2006. Accessed August 9, 2025. https://www.zeit.de/2006/21/Archi_Frankfurt_xml/komplettansicht
449. "Media.gdansk.pl. Westerplatte: oświadczenie Muzeum Gdańska w sprawie rzekomej prywatyzacji." Accessed December 23, 2024. https://media.gdansk.pl/komunikaty/445507/westerplatte-oswiadczenie-muzeum-gdanska-w-sprawie-rzekomej-prywatyzac
450. Mennenga, Menno Egbert. *Kloster Chorin 3D: Monastery Chorin 3D – at the Time of the Cistercians.* Android app. Google Play Store. Accessed July 1, 2025. https://play.google.com/store/apps/details?id=com.reunion.klosterchorin
451. Meta Quest. *Medal of Honor: Above and Beyond.* Accessed July 1, 2025. https://www.meta.com/pl-pl/experiences/medal-of-honor-above-and-beyond/3647259232032222
452. Microsoft Learn. "What Is Mixed Reality?" *Microsoft Learn,* January 25, 2023. Accessed September 13, 2024. https://learn.microsoft.com/en-us/windows/mixed-reality/discover/mixed-reality
453. Moakley, Paul. "Street View and Beyond: Google's Influence on Photography." *TIME,* October 24, 2012. Accessed September 11, 2024. https://time.com/55683/street-view-and-beyond-googles-influence-on-photography
454. Moritz, Katarzyna. "Kościół św. Mikołaja stoi na kamiennych ławach. To zaskoczenie." *Trojmiasto.pl,* July 16, 2019. Accessed January 12, 2024. https://www.trojmiasto.pl/wiadomosci/Kosciol-sw-Mikolaja-stoi-na-kamiennych-lawach-n136321.html
455. Moritz, Katarzyna. "Sklepienia i filary w kościele św. Mikołaja przestały się ruszać." *Trojmiasto.pl,* December 9, 2018. Accessed January 12, 2024. https://www.trojmiasto.pl/wiadomosci/Sklepienia-i-filary-w-kosciele-sw-Mikolaja-przestaly-sie-ruszac-n129985.html
456. Most Wiedzy – Gdańsk University of Technology. "Technologia wirtualnej rzeczywistości w dziedzictwie architektonicznym i jej wpływ na konserwację zabytków." Accessed July 1, 2025. https://mostwiedzy.pl/pl/project/technologia-wirtualnej-rzeczywistosci-w-dziedzictwie-architektonicznym-i-jej-wplyw-na-podejscie-do-k,1206-1
457. Muzeum Gdańska. "Wartownia nr 1 na Westerplatte." Accessed December 22, 2024. https://muzeumgdansk.pl/oddzialy-muzeum/wartownia-nr-1-na-westerplatte
458. "Muzeum II Wojny twierdzi, że po wyroku NSA nadal jest posiadaczem terenu." *Trojmiasto.wyborcza.pl.* Accessed December 23, 2024. https://trojmiasto.wyborcza.pl/trojmiasto/7,35612,27583465,muzeum-ii-wojny-twierdzi-ze-po-wyroku-nsa-nadal-jest-posiadaczem.html
459. Muzeum II Wojny Światowej w Gdańsku. "Badania archeologiczne na Westerplatte." Accessed December 23, 2024. https://muzeum1939.pl/badania-archeologiczne-Westerplatte
460. Muzeum II Wojny Światowej w Gdańsku. "Etap VII – Badania archeologiczne na Westerplatte." Accessed December 28, 2024. https://muzeum1939.pl/etapVII-badania-Westerplatte
461. Muzeum II Wojny Światowej w Gdańsku. "Polish Army Soldiers' Cemetery at Westerplatte." Accessed December 23, 2024. https://muzeum1939.pl/cmentarz-zolnierzy-wojska-polskiego-na-westerplatte
462. Muzeum II Wojny Światowej w Gdańsku. "Poznaj obrońców." Accessed December 23, 2024. https://muzeum1939.pl/node/5954
463. Muzeum II Wojny Światowej w Gdańsku. "Przesunięcie Wartowni nr 1." Accessed December 22, 2024. https://muzeum1939.pl/przesuniecie-wartowni-nr-1/timeline/217.html
464. Muzeum II Wojny Światowej. "Wystawa 1945–2022. Dzieje krzyża na Westerplatte." Accessed December 19, 2024. https://muzeum1939.pl/wystawa-19452022-dzieje-krzyza-na-westerplatte/aktualnosci/4805.html
465. Muzeum II Wojny Światowej w Gdańsku. *Recording of the Full Conference Program* (YouTube video). "Prezentacja założeń programowych dla inwestycji Muzeum Westerplatte i Wojny 1939." Accessed December 23, 2024. https://www.youtube.com/watch?v=RQ_1hNy63ao
466. Muzeum II Wojny Światowej w Gdańsku. "Muzeum II Wojny Światowej." *Culture.pl.* Added October 8, 2010. Accessed December 23, 2024. https://culture.pl/pl/miejsce/muzeum-ii-wojny-swiatowej
467. Muzeum Narodowe w Poznaniu. "Muzeum Sztuk Użytkowych w Zamku Królewskim." Accessed November 30, 2024. https://mnp.art.pl/wp-content/uploads/2022/10/Muzeum-Sztuk-Uz%CC%87ytkowych-w-Zamku-Kro%CC%81lewskim.jpg

468. Museum Panorama Mesdag. “Home.” *Panorama Mesdag.* Accessed March 21, 2024. https://panorama-mesdag.nl/en Museum-Panorama “Battle of Borodino.” *Музей-панорама «Бородинская битва».* Accessed March 21, 2024. https://1812panorama.ru/visitors/museum-panorama
469. Museo Correr and Ca’ Rezzonico – Museum of the 18th Century Venice. “Canaletto’s Secret: How Canaletto’s ‘photographic’ paintings are being used to fight the ‘acqua alta’ in Venice.” *Google Arts & Culture.* Accessed September 9, 2025. https://artsandculture.google.com/story/canaletto-s-secret-museo-correr/3QVhioQYNBkoJA?hl=en
470. Museo della Civiltà Romana. “Plastico di Roma Imperiale.” *Museo della Civiltà Romana.* Accessed July 2, 2025. https://www.museociviltaromana.it/it/percorso/plastico-di-roma-imperiale
471. Museum Virtuell GmbH. *Kloster Chorin* (virtual tour). Accessed July 1, 2025. https://visit.museum-virtuell.com/de/tour/chorin
472. National Park Service. “Cyclorama Painting.” *Gettysburg National Military Park.* Accessed September 21, 2024. https://www.nps.gov/gett/learn/historyculture/cyclorama.htm
473. National Science and Media Museum. “A Short History of Colour Photography.” *Objects and Stories* (blog). Published July 7, 2020. Accessed March 21, 2024. https://www.scienceandmediamuseum.org.uk/objects-and-stories/history-colour-photography
474. “nDisplay Overview for Unreal Engine.” *Epic Games Developer Documentation.* Accessed December 27, 2024. https://dev.epicgames.com/documentation/en-us/unreal-engine/ndisplay-overview-for-unreal-engine
475. NOMA (New Orleans Museum of Art). “Stereoscopes: Nineteenth-Century Virtual Reality Devices.” *Arts Quarterly,* October 19, 2017. Accessed August 19, 2024. https://noma.org/stereoscopes-first-virtual-reality-devices
476. Nietopiel, Aleksandra. “Sklepienia w Mikołaju już po remoncie. Rusztowanie zostaje.” *Trojmiasto.pl,* December 22, 2022. Accessed January 12, 2024. https://www.trojmiasto.pl/wiadomosci/Sklepienia-w-Mikolaju-juz-po-remoncie-Rusztowanie-zostaje-n173856.html
477. Ochotorena, Juan Miguel. “The Hidden Scars of the Spanish Civil War in Madrid.” *SAH Blog* (Society of Architectural Historians), April 5, 2022. Accessed June 29, 2025. https://www.sah.org/publications/sah-blog/blog-detail/sah-blog/2022/04/05/the-hidden-scars-of-the-spanish-civil-war-in-madrid
478. Omilanowska, Małgorzata. “Co dalej z Westerplatte? Odpowiada prof. Małgorzata Omilanowska.” *Gdańsk.pl,* April 26, 2018; updated May 1, 2018. Accessed December 22, 2024. https://www.gdansk.pl/przerobka/co-dalej-z-westerplatte-odpowiada-prof-malgorzata-omilanowska,a,107688
479. Omilanowska, Małgorzata. “Omilanowska o rewitalizacji Westerplatte: to skrajna niekompetencja.” *Trojmiasto.wyborcza.pl.* Accessed December 22, 2024. https://trojmiasto.wyborcza.pl/trojmiasto/7,35612,23327590,omilanowska-o-rewitalizacji-westerplatte-to-skrajna-niekompetencja.html
480. “Oficjalnie: PiS znacjonalizował Westerplatte. Gdańsk stracił teren.” *Trojmiasto.wyborcza.pl.* Accessed December 23, 2024. https://trojmiasto.wyborcza.pl/trojmiasto/7,35612,26191279,oficjalnie-pis-znacjonalizowal-westerplatte-gdansk-stracil.html
481. PAR. “Lokalny biznesmen i polityk przegrywa proces z historykiem. Poszło o wywiad na Slazag.pl.” *Press.pl,* December 2, 2024. Accessed June 8, 2025. https://www.press.pl/tresc/84847,lokalny-biznesman-i-polityk-przegrywa-proces-z-historykiem_-poszlo-o-wywiad-na-slazag_pl
482. Politechnika Gdańska. “Prof. Adalbert Matthaei (historia budownictwa i historia sztuki).” Accessed February 2, 2025. https://pg.edu.pl/uczelnia/ludzie-pg/rektorzy-poprzednich-kadencji/prof-adalbert-matthaei-historia-budownictwa-i
483. “Poland vs. History Museum, Gdańsk.” *The New York Review of Books,* May 3, 2016. Accessed December 23, 2024. https://www.nybooks.com/online/2016/05/03/poland-vs-history-museum-gdansk
484. “Pole bitwy na Westerplatte.” *Zabytek.pl.* Accessed December 24, 2024. https://zabytek.pl/pl/obiekty/gdansk-pole-bitwy-na-westerplatte-111
485. “Pochylone wieżyczki, sypiące cegły. Pogorszył się stan kościoła.” *Trojmiasto.wyborcza.pl.* Accessed January 12, 2024. https://trojmiasto.wyborcza.pl/trojmiasto/7,35612,24686287,pochylone-wiezyczki-sypiace-cegly-pogorszyl-sie-stan-kosciola.html
486. “Ponad 4700 niebezpiecznych przedmiotów i niemalże 3800 historycznych artefaktów znaleziono podczas prac saperskich na Westerplatte!” *Muzeum II Wojny Światowej w Gdańsku,* June 7, 2024. Accessed December 23, 2024. https://muzeum1939.pl/ponad-4700-niebezpiecznych-przedmiotow-i-niemalze-3800-historycznych-artefaktow-znaleziono-podczas/aktualnosci/7045.html
487. “Przesunięcie Wartowni nr 1.” Personal site of Tomasz Pluciński (University of Gdańsk). Accessed December 22, 2024. http://www.tomek.strony.ug.edu.pl/wartownia

488. Reeves, Amanda. “If Walls Could Talk: The Columns of Santa Maria in Trastevere.” *In Medias Res* (*Medium*), 2018. Accessed May 30, 2023. https://medium.com/in-medias-res/if-the-walls-could-talk-the-columns-of-santa-maria-in-trastevere-4c7e3bc0cbc2
489. RICOH360 Blog. “Looking Back over the Last 10 Years — Interviews Commemorating RICOH THETA’s 10th Anniversary.” *RICOH360 Blog,* March 14, 2024. Accessed September 13, 2024. https://blog.ricoh360.com/en/interviews-commemorating-the-10th-anniversary
490. “Rozstrzygnięto konkurs na koncepcję Muzeum Westerplatte. Jak wygląda zwycięski projekt.” *Gdańsk.pl,* October 31, 2023. Accessed December 23, 2024. https://www.gdansk.pl/wiadomosci/Rozstrzygnieto-konkurs-na-koncepcje-Muzeum-Westerplatte-Jak-wyglada-zwycieski-projekt-Muzeum-II-Wojny-Swiatowej-Sellin,a,252784
491. “Sesja Rady Miasta Gdańska: radni przyjęli apel w obronie terenów Westerplatte.” *Gdańsk.pl.* Accessed December 23, 2024. https://www.gdansk.pl/wiadomosci/Sesja-Rady-Miasta-Gdanska-Radni-przyjeli-apel-w-obronie-terenow-Westerplatte,a,146892
492. Socha, Ryszarda. “Wojna o Westerplatte wciąż trwa.” *Polityka,* July 10, 2018. Accessed December 23, 2024. https://www.polityka.pl/tygodnikpolityka/spoleczenstwo/1755390,1,wojna-o-westerplatte-wciaz-trwa.read
Słownik Języka Polskiego (PWN). “Symulacja.” Accessed May 20, 2025. https://sjp.pwn.pl/slowniki/symulacja.html
Stouhi, Dima. “The Story Behind Frankfurt’s New Old Town and How the Community Revived Its Medieval Identity.” *ArchDaily,* August 26, 2022. Accessed August 9, 2025. https://www.archdaily.com/987963/the-story-behind-frankfurts-new-old-town-and-how-the-community-revived-its-medieval-identity
493. Sutowski, Michał and Agnieszka Wiśniewska. “Muzeum refleksyjne, czyli sprzeczne z polską racją stanu.” *Krytyka Polityczna,* April 5, 2017 (updated February 5, 2020). Accessed December 23, 2024. https://krytykapolityczna.pl/kraj/muzeum-ii-wojny
494. “Teren Westerplatte wraca do miasta Gdańska. Jest ostateczny wyrok.” *Trojmiasto.wyborcza.pl.* Accessed December 23, 2024. https://trojmiasto.wyborcza.pl/trojmiasto/7,35612,27582288,teren-westerplatte-wraca-do-miasta-gdanska-jest-ostateczny.html
495. “The Royal Society. Stereoscopy: the Birth of 3D Technology.” *Google Arts & Culture.* Accessed September 11, 2024. https://artsandculture.google.com/story/stereoscopy-the-birth-of-3d-technology-the-royal-society/pwWRTNS-hqDN5g?hl=en
496. “Trzy recenzje są podstawą krytyki PiS wobec Muzeum II Wojny Światowej: jako pierwsi ujawniamy, co w nich jest.” *Gdańsk.pl,* July 9, 2016. Accessed December 23, 2024. https://www.gdansk.pl/wiadomosci/Trzy-recenzje-sa-podstawa-krytyki-PiS-wobec-Muzeum-II-Wojny-Swiatowej-Jako-pierwsi-ujawniamy-co-w-nich-jest,a,57214
UNESCO. “Review of the Convention for the Protection of Cultural Property in the Event of Armed Conflict.” 1993. Accessed June 28, 2025. https://unesdoc.unesco.org/ark:/48223/pf0000100159.locale=en
497. UNESCO World Heritage Centre. “Archaeological Site of Olympia.” *UNESCO World Heritage List,* no. 517. Accessed July 1, 2025. https://whc.unesco.org/en/list/517
498. UNESCO World Heritage Centre. “Belfries of Belgium and France.” *UNESCO World Heritage List,* no. 943. Inscribed 1999; extended 2005. Accessed June 29, 2025. https://whc.unesco.org/en/list/943
499. UNESCO World Heritage Centre. “Castle of the Teutonic Order in Malbork.” *UNESCO World Heritage List,* no. 847. Inscribed 1997. Accessed June 21, 2025. https://whc.unesco.org/en/list/847
500. UNESCO World Heritage Centre. “City of Vicenza and the Palladian Villas of the Veneto.” *UNESCO World Heritage List.* Inscribed 1994 (extended 1996). Accessed [n.d.]. https://whc.unesco.org/en/list/712
501. UNESCO World Heritage Centre. “Hiroshima Peace Memorial (Genbaku Dome).” *UNESCO World Heritage List,* no. 775. Inscribed 1996. Accessed October 19, 2024. https://whc.unesco.org/en/list/775
502. UNESCO World Heritage Centre. “Historic Centre of Riga.” *UNESCO World Heritage List,* no. 852. Inscribed 1997. Accessed August 6, 2025. https://whc.unesco.org/en/list/852
503. UNESCO World Heritage Centre. “Historic Centre of Warsaw.” *UNESCO World Heritage List,* site no. 30. Inscribed 1980; minor boundary modification 2014. Accessed June 29, 2025. https://whc.unesco.org/en/list/30
504. UNESCO World Heritage Centre. “Historic Fortified City of Carcassonne.” *UNESCO World Heritage List,* no. 345. Accessed June 21, 2025. https://whc.unesco.org/en/list/345
505. UNESCO World Heritage Centre. “Padua’s Fourteenth-Century Fresco Cycles.” *UNESCO World Heritage List,* no. 1623. Inscribed 2021. Accessed August 24, 2023. https://whc.unesco.org/en/list/1623
506. UNESCO World Heritage Centre. *Le Havre, the City Rebuilt by Auguste Perret. UNESCO World Heritage List,* no. 1181. Inscribed 2005. Accessed December 10, 2024. https://whc.unesco.org/en/list/1181

507. Vatican Museums. *Cylinder of Nebuchadnezzar II.* Vatican Museums online collections. Accessed July 12, 2022. https://www.museivaticani.va/content/museivaticani/en/collezioni/musei/museo-gregoriano-egizio/sala-viii--antichita-del-vicino-oriente-antico/cilindro-di-nabucodonosor-ii.html
508. Venice International University. "Visualizing Venice: Projects." Accessed July 1, 2025. https://www.univiu.org/vecchio-sito/103-summer-schools/1265-visualizing-venice-projects
509. "Virtual." *Etymology Online.* Accessed May 20, 2025. https://www.etymonline.com/search?q=virtual
510. Warhorse Studios. *Kingdom Come: Deliverance* (official website). Accessed July 1, 2025. https://kcd1.kingdomcomerpg.com
511. "Warszawa 1945." *Google Arts & Culture.* Accessed July 11, 2025. https://artsandculture.google.com/story/yQWhS5Gh6u2hLw?hl=pl
512. Walsh, Niall Patrick. "Edoardo Tresoldi's Basilica di Siponto Awarded the Gold Medal for Italian Architecture." *ArchDaily,* October 16, 2018. Accessed July 3, 2025. https://www.archdaily.com/903999/edoardo-tresoldis-basilica-di-siponto-awarded-the-gold-medal-for-italian-architecture
513. "Westerplatte w księdze wieczystej nadal własnością Gdańska." *Trojmiasto.wyborcza.pl.* Accessed December 23, 2024. https://trojmiasto.wyborcza.pl/trojmiasto/7,35612,27625242,westerplatte-w-ksiedze-wieczystej-nadal-wlasnoscia-gdanska.html
514. "Wojna o Westerplatte wciąż trwa." Ryszarda Socha. *Polityka,* July 10, 2018. Accessed December 23, 2024. https://www.polityka.pl/tygodnikpolityka/spoleczenstwo/1755390,1,wojna-o-westerplatte-wciaz-trwa.read
515. "Wyniki konkursu na koncepcję projektową MWiW 1939." *Muzeum II Wojny Światowej w Gdańsku.* Accessed December 23, 2024. https://muzeum1939.pl/node/5832
516. "Zabytek: Pole bitwy na Westerplatte." *Zabytek.pl.* Accessed December 24, 2024. https://zabytek.pl/pl/obiekty/gdansk-pole-bitwy-na-westerplatte-111
517. Zięba, Szymon. "Rusztowania wsparły sklepienie kościoła św. Mikołaja." *Trojmiasto.pl,* December 10, 2019. Accessed January 12, 2024. https://www.trojmiasto.pl/wiadomosci/rusztowania-w-kosciele-sw-Mikolaja-n140347.html

Online Models (developed by author)

518. DALAB_PG, *Medieval city of Gniew, Poland*, 3D model, by Szymon Kowalski and Paulina Bone, Sketchfab, published March 9, 2024; accessed June 12 2024, https://sketchfab.com/3d-models/medieval-city-of-gniew-poland-4051ac2b603144009091db18d66a41fe
519. DALAB_PG, Politechnika Gdańska, 3D model, by Szymon Kowalski and Paulina Bone, Sketchfab, published June 3, 2024. https://sketchfab.com/3d-models/politechnika-gdanska-342d4fe2b4da44418091223c7f94a003
520. DALAB_PG *Ruiny kościoła w Steblewie (Church ruins)*. 3D model, by Szymon Kowalski; Barbara Niedziela; Dominika Ochoćińska and Katarzyna Kiersztejna. Sketchfab. Accessed June 12 2024, https://sketchfab.com/3d-models/ruiny-koscioa-w-steblewie-church-ruins-7c141e3e8faa46509ec4767a1550aaa6
521. Dominikanie Gdańsk, *Zakrystia Św. Mikołaja w Gdańsku. Skan laserowy*, 3D model, model by Szymon Kowalski and Piotr Samól, Sketchfab, February 28, 2024; accessed 3 March 2024, https://sketchfab.com/3d-models/zakrystia-sw-mikoaja-w-gdansku-skan-laserowy-30c3bf9b57df475cb6489cc6a76949fc.
522. Dominikanie Gdańsk, *Zakrystia Św. Mikołaja w Gdańsku Etap 1*, 3D model, model by Szymon Kowalski and Piotr Samól, Sketchfab, published September 27, 2021; accessed March 3, 2024, https://sketchfab.com/3d-models/zakrystia-sw-mikoaja-w-gdansku-etap-1-8f1eb18757144a92b93a15de593895ff.
523. Dominikanie Gdańsk. *Zakrystia Św. Mikołaja w Gdańsku Etap 2*. 3D model. Model by Szymon Kowalski and Piotr Samól. Sketchfab. Accessed March 3, 2024. https://sketchfab.com/3d-models/zakrystia-sw-mikoaja-w-gdansku-etap-2-411ebf277f2f49deac6faeae277a8de3.
524. Dominikanie Gdańsk, *Zakrystia Św. Mikołaja w Gdańsku Etap 3*, 3D model, model by Szymon Kowalski and Piotr Samól, Sketchfab, accessed March 3, 2024, https://sketchfab.com/3d-models/zakrystia-sw-mikoaja-w-gdansku-etap-3-32a039af27db45bfa5f9872609ac2cad.
525. Dominikanie Gdańsk, *Zakrystia Św. Mikołaja w Gdańsku Etap 4*, 3D model, model by Szymon Kowalski and Piotr Samól, Sketchfab, accessed March 3, 2024, https://sketchfab.com/3d-models/zakrystia-sw-mikoaja-w-gdansku-etap-4-265b56f421434509b5bca3024a990a95.
526. Dominikanie Gdańsk, *Zakrystia Św. Mikołaja w Gdańsku Etap 5*, 3D model, model by Szymon Kowalski and Piotr Samól, Sketchfab, published October 6, 2021; accessed March 3, 2024, https://sketchfab.com/3d-models/zakrystia-sw-mikoaja-w-gdansku-etap-5-6392d74b7667471caaf1b520a5eacb5c.

527. Museum of the Second World War, *Pomnik Obrońców Wybrzeża – Westerplatte*, 3D model by Szymon Kowalski and Wojciech Samól, Sketchfab, accessed April 9, 2024, https://sketchfab.com/3d-models/pomnik-obroncow-wybrzeza-westerplatte-8d8df2c4c84c4625b8ff59e97baf09eb.
528. Museum of the Second World War, *Wartownia nr 1 (Izba bojowa) – Westerplatte*, 3D model, model by Szymon Kowalski and Wojciech Samól, Sketchfab, May 20, 2024, https://sketchfab.com/3d-models/wartownia-nr-1-izba-bojowa-westerplatte-c2cab609af9f435ab3bc3de620dc30a5. Sketchfab
529. Museum of the Second World War, *Wartownia nr1 – Westerplatte*, 3D model, model by Szymon Kowalski and Wojciech Samól, Sketchfab, accessed December 28, 2024, https://sketchfab.com/3d-models/wartownia-nr1-westerplatte-9da2d59a77f848738ada2d8eca6e78df.
530. Museum of the Second World War, *Placówka "Fort" – Westerplatte*, 3D model, model by Szymon Kowalski and Wojciech Samól, Sketchfab, published August 21, 2024; accessed December 28, 2024, https://sketchfab.com/3d-models/placowka-fort-westerplatte-fb47ac1307ee44c7bf1b499b5c6cd023.
531. Museum of the Second World War, *Willa Oficerska – Westerplatte*, 3D model, model by Szymon Kowalski and Wojciech Samól, Sketchfab, published April 24, 2024; accessed December 28, 2024, https://sketchfab.com/3d-models/willa-oficerska-westerplatte-afb7a6a40f6e4e78805b4d69f0f971ac.
532. Museum of the Second World War, *Wartownia nr 5 – Westerplatte*, 3D model, model by Szymon Kowalski and Wojciech Samól, Sketchfab, published March 29, 2024; accessed December 28, 2024, https://sketchfab.com/3d-models/wartownia-nr-5-westerplatte-586e4f5c93f14bfbbb89c34ed9384b81.
533. Museum of the Second World War, *Nowy Cmentarz – Westerplatte*, 3D model, model by Szymon Kowalski and Wojciech Samól, Sketchfab, published April 24, 2024; accessed December 28, 2024, https://sketchfab.com/3d-models/nowy-cmentarz-westerplatte-430ad76b72f0436fbddb4784bf08efb3.
534. Museum of the Second World War, *Krzyż Virtuti Militari, cmentarz – Westerplatte*, 3D model, model by Szymon Kowalski and Wojciech Samól, Sketchfab, April 24, 2024; accessed December 28, 2024, https://sketchfab.com/3d-models/krzyz-virtuti-militari-cmentarz-westerplatte-0f9fd7897e844e429aa3c431880fdccd.
535. Museum of the Second World War, *Nowe Koszary – Westerplatte*, 3D model, model by Szymon Kowalski and Wojciech Samól, Sketchfab, published March 29, 2024; accessed September 20, 2024, https://sketchfab.com/3d-models/nowe-koszary-westerplatte-de756a7e1ff54d5593fd314230da8efb.

Online Models

536. egiptologo91. *Allegory of Divine Providence and Barberini Power*. 3D model. Sketchfab. Published March 31, 2017. Accessed August 20, 2025. https://sketchfab.com/3d-models/allegory-of-divine-providence-and-barberini-55404887774c45d8be3068ffeab39f21.
537. Matthew Brennan, *Church of the Gesù / Chiesa del Gesù*, 3D model, Sketchfab, published September 18, 2015; accessed December 28, 2024, https://sketchfab.com/3d-models/church-of-the-gesu-chiesa-del-gesu-fdd3f0aa834e45068b1f7a5e2a2644db.
538. ZeuxisVR, *Mantegna, Camera degli Sposi (Camera picta)*, 3D model, Sketchfab, published October 17, 2022; accessed December 28, 2024, https://sketchfab.com/3d-models/mantegna-camera-degli-sposi-camera-picta-3481c0e518a44e839e6774118c0fe68f.
539. ZeuxisVR. *Michelangelo, Vestibule of Laurentian Library*. 3D model. Sketchfab. Published January 9, 2022. Accessed December 28, 2024. https://sketchfab.com/3d-models/michelangelo-vestibule-of-laurentian-library-6175567cd0f54ede90c16e560cbf7194.

List of Illustrations

Fig. 1. General Timeline of architectural objects. Source: author. 8
Fig. 2. Dilatant Reconstruction. Left: Bobolice Castle (source: Zamek Bobolice website). Right: Poznań Castle (source: Muzeum Narodowe w Poznaniu). 9
Fig. 3. General methodological scheme. Source: author. 12
Fig. 4. Structure of the work scheme. Source: author. 13
Fig. 5. Structure of the work table in relation to research questions. Source: author. 13
Fig. 6. Reality–Virtuality Continuum, adapted from Paul Milgram and Fumio Kishino, 1994. 15
Fig. 7. Types of Extended Reality (XR), differentiating VR, AR, and MR (source: Vation Ventures website) 16
Fig. 8. Synthetic comparison between different technologies, with a narrowing of the topic to just Virtual Reality. Source: author. 16
Fig. 9. Virtual reality emulated via VR HMD and CAVE VR. Source: photos by the author. 17
Fig. 10. Example of use of AR directly in situ and remotely. Source: photos by the author. 18
Fig. 11. Example of use of MR in the architectural design process (source: Adobe webpage) 18
Fig. 12. Inscribed clay cylinder Inv. D723. of Nabuchadnezar II, Maradda, southern Iraq, Neo-Babylonian Period, Vatican Museum. Source: author, 2022. 31
Fig. 13. Arc of Constantine in Rome, Italy. Source: author, 2022. 32
Fig. 14. Interior of Basilica di Santa Maria in Trastevere, Rome, Italy. Source: author, 2022. 32
Fig. 15. The Church of Santa Maria degli Angeli e dei Martiri: exterior and interior. Source: author, 2024. 34
Fig. 16. Laocoon Group. Source: author, 2022. 36
Fig. 17. Remains of Ancient Pompeii. Source: author, 2020. 38
Fig. 18. Piranesi's engravings Antichita Romane 1756, left – Veduta di Campo Vaccino (source: Wikimedia Commons), right – Colloseo (source: Wikimedia Commons). 39
Fig. 19. Remains of Chorin Abbey. Source: author, 2022. 43
Fig. 20. The unfinished cathedral in 1855. The medieval crane was still in place, while constructions for the nave had been resumed earlier in 1814 (source: Wikimedia commons). 46
Fig. 21. Architectural copies. Left - Galeria Dei Lanzi, Florence, Italy. Right - Feldherrenhalle, Munich, Germany. Source: author, 2024. 48
Fig. 22. Analysis of Carcassonne by Villet-le-Duc in Dictionnaire raisonné de l'architecture française du XIe au XVIe siècle. . 51
Fig. 23. Carcassonne. Source: author, 20217. 52
Fig. 24. Malbork castle. Source: author, 2024. 53
Fig. 25. Architectural reconstructions. Left: San Paolo outside the walls. Right: The Campanile of San Marco in Venice. Source: author, 2023. 56
Fig. 26. Ypres Cloth Hall. Left- today's view after reconstruction (source: Wikimedia Commons), right- aerial view after the Great War (source: Wikimedia Commons). 64
Fig. 27. Monte Cassino. Left: Monastery after destruction (source: National Geographic). Right: Reconstructed monastery (source: Cassino Appartamenti website) 67
Fig. 28. Destroyed historic city centre of Warsaw (source: Wikimedia Commons). 68
Fig. 29. Left: Inventory of damage to Warsaw of the Bureau of Capital Reconstruction 1945-1946 (source: state archive in Warsaw). Right: Elevation of Piwna Street in Warsaw based on surveys, and reconstruction realisation in 1956 (source: Szanajca-Kossakowska 1956). 70
Fig. 30. Reconstructed historical city centre and Barbican, Warsaw. Source: author, 2025. 71
Fig. 31. Royal Castle in Warsaw. Source: author, 2025. 72
Fig. 32. Photographs of destroyed city of Gdańsk by Kazimierz Lelewicz (source: Google Arts & Culture). 75
Fig. 33. Change in building density. Left: prewar Gdańsk. Right: Gdańsk after reconstruction (source: Stankiewicz and Szermer 1959). 76
Fig. 34. Project of reconstruction of Ogarna street (source: Stankiewicz and Szermer 1959). 77
Fig. 35. Inventory of The Holy Spirit street in Gdańsk, post reconstruction state. Source: author in cooperation with students, 2022. 78
Fig. 36. Reconstructed Main Town of Gdańsk. Source: author, 2023. 79
Fig. 37. Kaiser Wilhelm Memorial Church in Berlin. Source: author, 2023. 80
Fig. 38. Rotterdam, White house with redeveloped city centre. Source: Anna Kolasa, 2024. 81
Fig. 39. Oradur-sur-Glane. Left: Aerial view of (source: Warfare History Network webpage. Right: Destroyed street (source: Wikimedia commons). 84
Fig. 40. Pointe Du Hoc. Left: Aerial view June 1944 (source: Normandie Tourisme webpage). Right: present day (source: D-Day-Overlord Media Library webpage). 86

Fig. 41. Hiroshima Memorial (source: Wikimedia commons). 87
Fig. 42. Auschwitz-Birkenau. Left: Reconstruction of the barracks. Right: remains of original barracks. Source: author. 88
Fig. 43. House of the Blackheads in Riga. Source: author, 2019. 90
Fig. 44. House of the Blackheads in Riga, detail with reconstruction date. Back façade of House of the Blackheads in Riga with visible fake transformations of the brick structure, resembling the state of pre destruction in 1940's. Source: author, 2019. 90
Fig. 45. Palace of the Grand Dukes of Lithuania in Vilnius. Source: author, 2015. 92
Fig. 46. Drezden reconstruction of urban "Quarter I" with reconstruction of Frauenkirche. Source: author, 2023. 94
Fig. 47. Frankfurt am Main, Römerberg square with the Ostzeile and reconstructed half-timber houses. Source: author, 2017. 95
Fig. 48. Summary table of examples presented in the chapter. Source: author. 99
Fig. 49. Entasis effect. Parthenon, Athens, Greece. Source: author, 2023. 103
Fig. 50. Cubiculum (bedroom) with colourful decoration featuring architectural motifs and an example of linear perspective, from the *Villa of Fannius Synistor* at Boscoreale, c. 50–40 BCE, today in Metropolitan Museum of Art, New York, USA (source: Metropolitan Museum of Art). 105
Fig. 51. Scheme of perspective analysis of *Villa of Fannius Synistor* frescoes with multiple vanishing points and converging lines that do not lead to a single point. Source: author. 105
Fig. 52. Interior of the Dome of Rotunda in Thessaloniki. Source: author, 2023. 106
Fig. 53. Popular depictions of architecture in medieval art. Right: polyperspective technique in *Effects of Good Government in the City* by Ambrogio Lorenzetti, fresco cycle, Palazzo Pubblico, Siena, 1339 (source: Google Arts & Culture). Left: Symbolic depiction of The Siege of the Castle of Mortagne, near Bordeaux, 1377, from *Recueil des croniques d'Engleterre* (source: British Library). 107
Fig. 54. Scenes from *Scrovegni Chapel* with linear perspective by Giotto. Source: author, 2023. 109
Fig. 55. Perspective analysis of Giotto's scenes, with multiple vanishing points and converging lines. Source: author. 109
Fig. 56. *Scrovegni Chapel* by Giotto di Bondone. Source: author. 109
Fig. 57. Padua Baptistery frescos surrounding the entrance to the baptistery. Source: author, 2023. 111
Fig. 58. Interior of *Oratory of San Giorgio,* Padova. Source: author, 2023. 112
Fig. 59. Detailed scenes of the *Oratory of San Giorgio* in Padova, showing the use of linear perspective and the depth effect. Source: author, 2023. 112
Fig. 60. Perspective analysis of scenes in of *Oratory of San Giorgio*. Source: author. 112
Fig. 61. Brunelleschi's perspective analysis. Left: Diagram reconstructed by Edgerton illustrating Filippo Brunelleschi's mirror perspective technique from a lost painting of the Battistero di San Giovanni (source: Edgerton 1975). Right: Todays view. Source: author, 2022. 114
Fig. 62. *The Tribute money* by Masaccio in Santa Maria del Carmine in Florence, Florence, Italy (source: Wikimedia commons). 115
Fig. 63. Perspective analysis of *The Tribute money* by Masaccio. Source: author. 115
Fig. 64. *The Holy Trinity, with the Virgin and Saint John and donors* by Masaccio in *Santa Maria Novella*, Florence, Italy. Left: Pre-restoration view (source: Britannica). Middle: Perspective analysis, source: author. Right: Holy trinity with a viewer (source: Flickr). 117
Fig. 65. Illusory *condottieri* epitaphs in Santa Maria del Fiore in Florence. Left: *Funerary Monument to Sir John Hawkwood* by Paolo Uccello. Right: *Epitaph of Niccola da Tolentino* by Andrea del Castagno. Source: author, 2022. 118
Fig. 66. Linear divisions in one-point perspective by Leon Battista Alberti, from *De Pictura*, reissued in 1804 by Società Tipografica de' Classici Italiani, Milan (source: Internet Archive). 120
Fig. 67. Ovetari Chapel by Andrea Mategna. Source: author, 2023. 121
Fig. 68. Scene From Ovetari Chapel by Andrea Mantegna. Left: Martyrdom of St. James, (source: Wikimedia commons). Right: Transportation of St. Christopher Beheaded Body, (source: Wikimedia commons). 122
Fig. 69. Perspective analysis, on Mantegna's works in Ovetari Chapel. Source: author. 122
Fig. 70. *San Zeno Altarpiece* by Andrea Mategna, with perspective analysis. Source: author, 2023. 123
Fig. 71. *Camera Degli Sposi* in Mantua Castle incorporated in Palazzo Ducale by Andrea Mantegna, Source: ZeuxisVR). Orthophotos based on 3D model created by *ZeuxisVR,* postproduction Szymon Kowalski. 124
Fig. 72. Fresco on the vault of *Camera Degli Sposi* in Mantua Castle incorporated in Palazzo Ducale by Andrea Mantegna. Source: author, 2023. 124
Fig. 73. *The Last Supper* by Leonardo da Vinci, seen from standing perspective. Source: author, 2023. 126
Fig. 74. *The School of Athens* by Raphael Santi. Source: author, 2022. 127
Fig. 75. Illusory presbytery of *Church of Santa Maria presso San Satiro* (1476-1482), Milano, Italy. Source: author, 2023. 128
Fig. 76. *Vestibule of the Laurentian Library*, source: author, 2025. Plan based on 3D model, (Source: ZeuxisVR, postprocessed by author). 129
Fig. 77. Interior of *Teatro Olimpico*, (source: Wikimedia commons). 130
Fig. 78. Parma Illusory Dome by Antonio da Correggio's *Assumption of the Virgin*. Source: author, 2023. 131

Fig. 79. *The fall of the Giants*, frescos in *Sala dei Giganti*, Palazzo del Te, Mantua. Source: author, 2023. 133
Fig. 80. Orthographic elevations with cross section and view from the bottom to the dome, with plan cross section of frescos in *Sala dei Giganti*, Palazzo del Te, Mantua, (source: VR, postproduction by Szymon Kowalski). 133
Fig. 81. Painted loggia architecture with landscape views 1619-21 by Agostino Tassi in Palazzo Lancellotti, (source: Web gallery of Art). 134
Fig. 82. *The Allegory of Divine Providence and Barberini Power* by Pietro da Cortona, (source: egiptologo91, post production by author). 135
Fig. 83. Perspective of vault and dome decoration of Il Gesu church in Rome, (source: Matthew Brennan, post production by author). 136
Fig. 84. Decorative interior of Il Gesu church in Rome, Italy. Left: "The Triumph of the Name of Jesus," Right interior of painted cupola and pendentives. Source: author, 2022. 137
Fig. 85. Andrea Pozzo, *Apotheosis of Saint Ignatius*, illusionistic barrel vault with quadratura and painted dome, *Church of Sant'Ignazio di Loyola*, Rome. Source: author, 2022. 139
Fig. 86. Scheme of tracing the illusory dome by Andrea Pozzo, from his book *Perspectiva Pictorum et Architectorum*, (source: Pozzo 1693). 140
Fig. 87. Painted architectural decorations. Left: the gatehouse of the *Certosa di Pavia*. Right: interior of the *Palazzo Spada* with painted windows creating a symmetrical composition. Source: author, 2025. 141
Fig. 88. Illusionistic Tyrolean façades. Left: Mannerist sgraffito decoration, late 16th century, courtyard of *Schloss Ambras*, Innsbruck, Austria. Right: late Baroque *Lüftlmalerei* decoration of the *Ansitz Liebenegg*, Innsbruck, Austria. Source: author, 2024. 142
Fig. 89. Rococo hall adjoining the Bamberg Town Hall with its illusionistic façade, including the detail of a sculpted putto's leg. Source: author, 2024. 142
Fig. 90. *Borromini Corridor* in the *Palazzo Spada*, Rome, Italy, source: author, 2025. Cross-section diagram, (source: adapted from the information panel in the Palazzo Spada, based on photo by author, 2025). 143
Fig. 91. Left: *Scala Regia* by Gian Lorenzo Bernini, source: author, 2023. Right: Plan and cross section of *Scala Regia* published in *Templum Vaticanum et ipsius origo* by Carlo Fontana in 1694, (source: Wikimedia Commons). 144
Fig. 92. Piazza San Pietro with its forced perspective, source: author, 2022. Right: Plan of Piazza San Pietro presented in Nolli's Plan of Rome (1748), (source: Interactive Nolli Map by Stanford University webpage) 145
Fig. 93. Vedute di Venezia. Left: *St. Mark's Basin from the Puntana della Dogana*. Right: *View of the Grand Canal toward the Punta della Dogana from Campo Sant'Ivo*. Both in collection of *Pinacoteca di Brera*, Milan, Italy. Source: author, 2023. 146
Fig. 94. Bernardo Belloto (Canaletto the Younger) View of Warsaw from the Royal Castle (1773). National Museum, Warsaw. Source: author, 2024. 147
Fig. 95. Method of projecting objects onto a cylinder's surface using descriptive geometry, (source: Sharma, Nett, and Ventura, "Unsupervised Learning of Depth and Ego-Motion,"). 148
Fig. 96. Edinburgh from Calton Hill by Robert Barker, (source: National Library of Scotland). 149
Fig. 97. Mesdag Panorama in Scheveningen, (source: Museum Panorama Mesdag). 150
Fig. 98. *Panorma Racławicka* central part with Kosciuszko Charge (source: National Museum in Wrocław). 152
Fig. 99. Interior of *Panorama Racławicka* Pavilion. Source: author. 152
Fig. 100. *Tirol Panorama*. Source: author. 153
Fig. 101. *View of the Boulevard du Temple*, Paris, by Louis-Jacques-Mandé Daguerre, 1838, (source: Wikimedia commons). 154
Fig. 102. Left: The first colour photograph, produced using the three-colour method in 1861, depicting a coloured ribbon, (source: Wikipedia commons). Right: Colour architectural landscape, *View of Agen, France*, showing St. Caprais Cathedral, 1877, created with the use of the *heliochrome* process, (source: Wikimedia commons). 155
Fig. 103. Stereoscopic photography (stereophotography) of the ruins of Valle Crucis Abbey in Llangollen by Francis Bedford, (source: Victoria and Albert Museum). 157
Fig. 104. *Zbiór zadań z geometrii wykreślnej* by Edward and Franciszek Otto. Use of anaglyphs to create a depth effect and enhance students' understanding of descriptive geometry. Source: author. 158
Fig. 105. Frames from *The Arrival of a Train at La Ciotat Station*, (source: Wikimedia commons). 159
Fig. 106. *Sensorama*, the first virtual immersion system, the technical table and the pictures shown at the presentation of the experimental product, (source: U.S. Patent 3,050,870). 160
Fig. 107. *The Sword of Damocles* by Ivan Sutherland, (source: Sutherland 1968). 161
Fig. 108. Left: *Videoplace* and Krueger showing his avatar interacting in virtual environment. Right: Two silhouettes projected via *Videoplace* installation with drawing possibilities, (source: Kreuger 1985). 163
Fig. 109. Left: Nasa's *VIEW* with Head Mounted Display and use of *wired glove* controller. Right: *VIEW* system graphic environment with virtual hand, based on wired glove controller, (source: Association for Computing Machinery). 164
Fig. 110. Virtual Reality Cave system. Faculty of Electronics Telecommunication and Informatics, Immersive 3D Visualization Laboratory, Gdansk University of Technology. Source: author, 2023. 165

Fig. 111. Oculus Quest 2. Source: author, 2025.....167
Fig. 112. Microsoft HoloLens attached to the hardhat of construction worker, (source: Microsoft webpage). 168
Fig. 113. *Apple Vision Pro,* presented in 2024, as an example of a mixed-reality device positioned as a potential successor to traditional personal computers, (source: YouTube). 169
Fig. 114. Graphical synthesis of historical development of immersive virtual reality. Source: author.....173
Fig. 115. Left: Drawn Domus Romanus House of Vari, Panels in British Museum, source: author. Right: Drawn reconstruction of Dominican monastery in Gdańsk, by Piotr Samól, (source: Samól 2022).....176
Fig. 116. Survey and reconstruction of Lago Traiano, *Galleria delle Carte Geografiche* in the Vatican Museums, painted between 1580 and 1585 by Ignazio Danti. Source: author, 2022.....176
Fig. 117. Colour reconstruction of Gdańsk in late middle ages, 1937 by Otto Kloeppel, (source: Kloeppel 1937). 177
Fig. 118. Left: Plastico di Roma imperiale, (source: Plastico Roma Blog). Right: 3D printed Reconstruction of Chorin Kloster. Source: author, 2022. 178
Fig. 119. Bronze casted model of reconstruction of Malmo and its fortifications in 18th century. Source: author, 2022. 178
Fig. 120. Reconstruction models of castle-fortress Hohensalzburg. Left: Wooden model showing state around 17th century. Middle: Digital mapping on physical model. Right: Plaster Reconstruction of Colosseum. Source: author, 2023. 179
Fig. 121. See thru panels in Carnuntum, Austria of Heidenthor, (source: Wikimedia commons). 179
Fig. 122. Left: Complementing an antique mosaic using a video projector. Source: author. Right: Eduardo Tresoldi's mesh reconstruction of Basilica di Siponto, (source: Edoardo Tresoldi). 180
Fig. 123. Rome Reborn, (source: Yorescape). Left: Current state. Right: Reconstruction. 181
Fig. 124. Visualizing Venice, (source: Visualizing Venice). Left: Basilica dei Santi Giovanni e Paolo. Right: Mapping technique. 182
Fig. 125. Digital Karnak with current state photographs, (source: Digital Karnak). 183
Fig. 126. Pointe du Hoc. Right: Frame from the game Call of Duty 2, (source: Call of Duty 2). Right: Today's view, (source: Google Street View).....184
Fig. 127. Recreation of churches of Santa Maria del Fiori and Santa Maria Novella in Florence in the game Assassin's Creed II, (source: Assassins Creed fandom webpage). 185
Fig. 128. Sasau Monastery comparison. Left: photograph real state in 2018. Right: in-game footage depicting the medieval state during the construction of the monastery, (source: steam community). 185
Fig. 129. Reconstruction of medieval Kutna Hora, In-game footage, (source: Kingdome Come II webpage).....186
Fig. 130. Palmyra VR Reconstruction, (source: Staatliche Museen zu Berlin – Museums-Website).....187
Fig. 131. Rotatable Screen with digital reconstruction of the Cluny Abbey before its destruction, (source: Strabic. Cluny-III en 3D).....188
Fig. 132. Comparison of the existing state of Chorin Cloister and its digital reconstruction view via the dedicated smartphone application, with the correction. Source: author. 189
Fig. 133. Chorin Abbey by Georg Dehio and Gustav von Bezold 1901, (source: Dehio and von Bezold). 190
Fig. 134. Digital reconstruction of Nymphaion, (source: Olimia Back in Time webpage). 191
Fig. 135. Left: Remains of Doric Temple of Temple of Zeus at Olympia, source: author. Right : Concept of Virtual Reconstruction Zeus's Temple, (source: Olimia Back in Time webpage). 191
Fig. 136. Tourist sightseeing the Ancient Olympia with the Virtual Reality goggles. Source: author. 191
Fig. 137. General typology of architectural survey methods. Source: author.....192
Fig. 138. Practical methods and tools for surface documentation in architectural heritage. Source: author.....195
Fig. 139. Post-construction inventory drawing of Main Building of Gdańsk University of technology 1904 Author: Albert Carsten with the team, (source: Architekturmuseum der Technischen Universität Berlin). 197
Fig. 140. Digital Camera, Nikon Z6II + Nikon Nikkor Z 24-200 mm f/4-6.3, used in the photogrammetry process. Source: author. 198
Fig. 141. Drones (DJI Mavic 3, DJI Mavic Mini 3, DJI Phantom 4) in use for aerial photogrammetry. Source: author. 198
Fig. 142. Photogrammetry methodological workflow. Source: author. 199
Fig. 143. Architectural scale photogrammetry: combined ground and aerial photogrammetry of the church in Steblewo processed in Metashape software. Source: author. 200
Fig. 144. Architectural scale photogrammetry: textured 3D mesh model of the church ruins in Steblewo. Source: author...200
Fig. 145. Urban scale photogrammetry: processing of the historical city centre of Gniew using aerial imagery in Metashape software. Author: Source: author in cooperation with Paulina Bone.....201
Fig. 146. Urban scale photogrammetry: Comparison of untextured mesh with textured mesh of historical city centre of Gniew in Metashape software. Source: author in cooperation with Paulina Bone. 201
Fig. 147. Terrestrial laser scanners: Leica RTC 360 and Faro Focus 70. Source: author.....202
Fig. 148. Mobile laser scanners. Source: author. 202
Fig. 149. Terrestrial and mobile laser scanning methodological workflow. Source: author. 203
Fig. 150. Registration of clusters. Source: author. 203

Fig. 151. *The Golden Gate* in Gdańsk. Left: laser scan orthophoto; centre: laser scan orthophoto with adjusted opacity; right: synthesised inventory drawing derived from the digital survey. Source: author, drawing by Zofia Piwońska. 204
Fig. 152. Urban-scale laser scan of the Dominican Quarter in Tallinn. Source: author. 205
Fig. 153. VR phone holder with spherical lenses, made of plywood and based on the original Google Cardboard design. Designed by Szymon Kowalski and cut on a CNC machine. Source: author. 206
Fig. 154. Virtual Reality Goggles (Head Mounted Display) model Oculus Quest 2 by Meta. Source: author. 207
Fig. 155. Big cave. Source: author. 208
Fig. 156. Left: Mini CAVE. Right: Midi CAVE. Source: author. 208
Fig. 157. Visualization Workflow: Transforming 3D Models into Immersive Environments. Source: author. 209
Fig. 158. Overview of Case Studies. Source: author. 211
Fig. 159. General methodological scheme. Source: author. 212
Fig. 160. Summary table on publications related to the research. Source: author. 214
Fig. 161. Virtual reconstruction in immersive environment. Source: author. 214
Fig. 162. Adaptive reuse concept design. Visualisations of exterior and interior of adapted watermill showing the potential conceptual design using BIM software with TLS laser scan integration. Source: Silvia La Placa, Andrea Bongini and author. 215
Fig. 163. Methodological scheme of the case study. Source: author. 217
Fig. 164. Northern elevation of the church and monastery plan, after Bartel Ranisch, (source: Ranish 1695). 218
Fig. 165. Left: Reconstruction of the first Romanesque church of St. Nicholas and its relation to the Gothic presbytery and sacristy, (source: Nawrowski 1917). Right: Elevation of the southern wall of the presbytery seen from the interior of the sacristy, (source: Nawrowski 1917). 219
Fig. 166. Support structure in the southern nave with vertical shoring and visible crack in the arcade. Source: author. 221
Fig. 167. Invasive research conducted in the sacristy of St. Nicholas Church, 2019, showing plaster removal. Source: author. 222
Fig. 168. Statistical analysis of brick proportions used to identify production batches and corresponding construction phases. Source: author. 223
Fig. 169. Outline of 3 different vault forms superimposed on 2019 inventory. Source: Drawing by author based on Piotr Samól's research. 223
Fig. 170. Sacristy during conservation works, with blue markers introduced for photogrammetry scanning. Source: author. 225
Fig. 171. Digitized elevation of the northern wall of the sacristy, with blue markers introduced to correct distortion during photogrammetry scanning. Source: author. 225
Fig. 172. Brick measurement for photogrammetry scaling and digitized Gothic rib profile bricks. Source: author. 225
Fig. 173. Cross-section of the sacristy represented as a laser point cloud after conservation works, showing the northern wall with visible masonry anomalies that confirm the existence of earlier vaulting systems. Registered in February 2023. Source: author 226
Fig. 174. The laser point cloud of the interior of Saint Nicolaus Church. Registered in July 2024. Source: author. 226
Fig. 175. Development of 3d models of the interior based on the digital representation in Rhinoceros software. Source: author. 227
Fig. 176. Early stage of the development of 3D models based on the photogrammetry scan. Source: author. 228
Fig. 177. Original design of a simple five-span cross-ribbed vault sacristy, ca. 1348. The southern wall is shown in transparent form to indicate the hypothetical layout. Source: author and Piotr Samól. 228
Fig. 178. Interior of completed one-storey sacristy from around 1360-1370, covered with the vaults based on triangles. Source: author and Piotr Samól. 229
Fig. 179. Interior of the sacristy dated ca.1650. Source: author and Piotr Samól. 230
Fig. 180. Interior of the Prussian stylistic restoration. Source: author and Piotr Samól. 230
Fig. 181. The information plate with QR codes to access the model. Source: author and Piotr Samól. 232
Fig. 182. Virtual remote sightseeing using the Oculus Link Cable connection with PC. Source: author. 233
Fig. 183. The interior of the sacristy of St. Nicholas Church in Gdańsk, after restoration, experienced by the Dominican Prior through the *synchronised worlds* effect. Using a VR HMD, the Prior walks through the virtual sacristy, navigating earlier architectural stages while immersively exploring its evolution in real time. Source: author. 233
Fig. 184.Simulation of the sacristy interior projected in the CAVE system at the Immersive 3D Visualisation Laboratory, Gdańsk University of Technology. Source: author. 234
Fig. 185. Interior view of different phases of the sacristy during a group immersive tour in the CAVE system. The blurred appearance results from stereoscopic imaging, which enhances depth perception when viewed with specialised glasses. Source: author. 234
Fig. 186. 360° scene from the author's master's thesis illustrating the blending of reality and digital reconstruction: on board the "Schleswig-Holstein" during the first day of the siege of Westerplatte. Source: author. 236

Fig. 187. 360° scene from the author's master's thesis illustrating the blending of reality and digital reconstruction. Left: digital reconstruction of the "Old Barracks." Right: German assault. Source: author. 236
Fig. 188. Project "Digital Westerplatte." Left: 3D models of scanned and digitally reconstructed objects around Westerplatte, made available online via the Sketchfab platform. Right: 3D-printed model of a scanned monument. Source: author. 238
Fig. 189. Comparison between Westerplatte layout. Left map dated 1936, Right map dated 2021, (Source: Samól et al., "Where the Second World War in Europe Broke Out," *Land*, 2023). 241
Fig. 190. Conceptual visualisations of reconstructed objects: the railway gate and station building, the non-commissioned officers' villa, the officers' villa, and the munitions warehouse, (source: Gazeta Wyborcza Trójmiasto). 246
Fig. 191. Conceptual Visualisations by Proconcept, Restudio and Fort Targowski, (source: Museum of Gdańsk). 247
Fig. 192. New Cemetery at Westerplatte Peninsula during night time. Source: author. 247
Fig. 193. Winning design, (source: Architektura i Biznes). 248
Fig. 194. Methodological scheme of the case study. Source: author. 250
Fig. 195. Virtual tours of inaccessible spaces: the bunker beneath Guardhouse No. 1 and the fort. Source: author. 251
Fig. 196. Digital Inventory of the remains of Officers' Villa and Guardhouse no. 5. Source: author. 252
Fig. 197. Methodological scheme of the case study. Source: author. 253
Fig. 198. Archival photographs of the Officer's Villa. Top row: the villa during the resort period; bottom row: the villa after the battle in September 1939. Source: Materials obtained through the archival research of Wojciech Samól, Museum of the Second World War. 254
Fig. 199. Colourisation of digitally restored black-and-white archival photographs of the Officer's Villa using AI tools. Source: author. 254
Fig. 200. Elevations of digitally reconstructed model of officers' villa, synthesis of knowledge. Source: author. 255
Fig. 201. Elevations of digitally reconstructed model of officers' villa, synthesis of knowledge. Source: author. 255
Fig. 202. Elevation of digitally reconstructed model of Warehouse no. 10. Source: author. 256
Fig. 203. Digital Reconstructions of Ammunition Warehouse and Officers' Villa at Westerplatte, based on meshified laser scans. Source: author. 257
Fig. 204. Augmented Reality Application in situ. Frames of Digital reconstructions superimposed on the ruins at Westerplatte Peninsula, Sketchfab AR visualizer with use of smartphone. Source: author. 258
Fig. 205. Methodological scheme of the case study. Source: author. 260
Fig. 206. Laser scan of New Barracks. Left – full raw scan, visualized in Faro Scene Software. Right – axonometric view after the cleaning and optimalization process. Source: author. 261
Fig. 207. Laser scan of New Barracks, adapted to the form of digital remote sightseeing tour on the Sketchfab platform. Source: author. 262
Fig. 208. Laser scan of New Barracks, adapted to the form of digital remote sightseeing tour on the Sketchfab platform. Immersive view screenshot. Source: author. 262
Fig. 209. New Barracks. Left: around 7–8 September 1939; right: second half of September 1939. Source: Archival photographs courtesy of Wojciech Samól. 263
Fig. 210. New Barracks after the fighting. Around September 1939. Source: Archival photographs courtesy of Wojciech Samól. 263
Fig. 211. 3D models of digital reconstruction, including: a) the construction, b) brick infill, coloristic c) reconstruction and d) integration with existing part of New Barracks. Source: author in collaboration with Wojciech Samól. 264
Fig. 212. Elevation of New Barracks. Source: author in collaboration with Wojciech Samól. 264
Fig. 213. 3D model of full digital reconstruction with colours of New Barracks. Source: author in collaboration with Wojciech Samól. 265
Fig. 214. Partial Digital Reconstruction of the missing wing of New Barracks, using the point cloud solution adjoined to the original scan, based on the architectural investigations. Source: author in collaboration with Wojciech Samól. 266
Fig. 215. 3D printed model of New Barracks. Source: author. 267
Fig. 216. 3D immersive visualization. Left Big Cave, Right Midi Cave. Source: author. 268
Fig. 217. Immersive visualisation of the New Barracks, using Enscape plugin. Source: author. 268
Fig. 218. Methodological scheme of the case study. Source: author. 270
Fig. 219. Historical Etchings. Left: View on Heiligenbrunn Manor. 50 Views of Gdańsk, plate 37, (source: Deisch 1765). Right: *Royal Valley* and *Heiligenbrunn* Manors on Helmsaurer's etching, (source: 271
Fig. 220. Kings Valley (*Königstal*) Manor gardens, reconstructed by Hans Rechow, (source: Reichow, 1927). 271
Fig. 221. Historical sources. Left: Map of the terrain between Wrzeszcz and Gdańsk by Peter Willer, 1691, (Source: BG PAN, C I 54). Right: Friedrich Bernhard Engelhardt, *Map of the Danzig Surroundings,* 1813 (detail of Heiligenbrunn), (Source: Collection of the Royal Castle in Warsaw). 276
Fig. 222. Map of 1885 underlay under the today buildings outline, in ArcGIS, visualizing the differences. Source: author. 277
Fig. 223. Urban stratification plan. Source: author. 278

Fig. 224. Heiligenbrunn area in 2025. Source: author. 279
Fig. 225. Heiligenbrunn area in 1930. Source: author. 279
Fig. 226. Heiligenbrunn area in 1895. Source: author. 280
Fig. 227. Heiligenbrunn area in 1814. Source: author. 280
Fig. 228. Digital survey methodological workflow. Source: author. 281
Fig. 229. Heiligenbrunn Mannor digital inventory. Source: author. 282
Fig. 230. *Heiligenbrunn* Manor inventory. Source: author with students from documentation practice. 282
Fig. 231. Royal Valley *(Königstal)* Manor inventory. Source: author with students from documentation practice. 283
Fig. 232. Aerial Lidar point cloud of Gdańsk University of Technology and area of Heiligenbrunn in ArcGIS software. Source: author. 284
Fig. 233. Filtered aerial lidar point cloud of Gdańsk University of Technology, projected to the map of 1930 in ArcGIS. Source: author. 285
Fig. 234. Aerial point cloud transferred to mesh model using method Point cloud to TIN, with raster to TIN as ground model. Source: author. 286
Fig. 235. Left: filtered aerial lidar point cloud of the Wrzeszcz district acquired via Geoportal and processed in ArcGIS. Right: the same point cloud transferred into the mesh model. Source: author. 287
Fig. 236. One of the 3d models showing historical campus of Gdańsk University of Technology, published at the Sketchfab platform. Source: author and Paulina Bone. 288
Fig. 237. The six individual aerial photogrammetry scans of the entire area were joined and unified into a single master scan. Source: author. 288
Fig. 238. Simplified model showing 2025 using segmented building from a scanned photogrammetry model with integration of TIN buildings and a mesh terrain model. Source: author. 290
Fig. 239. Reconstruction of the 1930 state, with missing buildings in red, based on the previous model. Source: author. 290
Fig. 240. Surroundings of Royal Valley and *Heiligenbrunn,* original lithograph by Carl August Helmsauer around 1825. 291
Fig. 241. Virtual model based on Helmsauer's lithograph. Source: author. 291
Fig. 242. Immersive simulation of Royal Valley in 1825, using HMD. Source: author. 292
Fig. 243. Comparison of the "complete" reconstruction and the more restrained approach. Left Visualisation: (source: 'Mezzano' company 3D renders based on models by Andrzej Ditrich.) Right: Created by the author. 296

Acknowledgements

As no work is ever the result of a single effort, this doctoral thesis was made possible through the invaluable help of many wonderful people. Without them, I would not have succeeded in completing both this research and the life adventure it represents, and I will remain forever grateful.

I would like to express my sincere gratitude to my supervisors, Prof. Jakub Szczepański and Prof. Piotr Samól, for their invaluable support, guidance, and patience throughout the process of writing this dissertation. Their insightful comments, constructive feedback, and inspiring discussions not only shaped the direction of my research but also contributed significantly to the development of my academic and professional skills. I am especially grateful to Piotr Samól for numerous walks, coffees, and his direct involvement in architectural, conservation and archaeological field investigations.

I would also like to thank my colleagues Wojciech Samól and Arkadiusz Woźniakowski, without whom this work could not have been completed, for their collaboration on the topic of Westerplatte, which resulted in many scientific outcomes. My warmest thanks go as well to Silvia La Placa and Elisabetta Doria for their support in introducing me to new technologies and for their direct assistance in the study of the sacristy of St. Nicholas. I am likewise grateful to Joanna Badach for her involvement in the topics of urban digitalisation and the use of GIS, without whose expertise I would not have been able to achieve the highest possible standard. I also wish to thank Paulina Bone for her invaluable help and our shared passion for drones.

For technological support and the opportunity to carry out visualisations in the CAVE system, I would like to thank Prof. Jacek Lebiedź and his team: Robert Trzosowski, Ivan Vakulko, Michał Barański, and Błażej Kowalski, from the Immersive 3D Visualization Lab at Gdańsk University of Technology.

I also wish to express my appreciation for the collaboration on numerous scientific projects in which I had the privilege to participate, as well as for the many opportunities to take part in research internships that allowed me to visit inspiring places in Italy, greatly enriching this work. In this context, I am particularly grateful to Justyna Borucka, Prof. Sandro Parrinello, and Prof. Francesca Picchio.

I would like to address special thanks to Prof. Małgorzata Dymnicka for her support in the early stage of my scientific career, it is to her that I owe the very beginnings of my academic path. I am also deeply grateful to Prof. Robert Jankowski for his support, first as Discipline Coordinator and later as Director of the Doctoral School at Gdańsk University of Technology, for his assistance in resolving numerous complicated administrative matters and for his constant willingness to help.

Special thanks are due to Aneta Kawala for her direct involvement in the acquisition of essential equipment, without which this research could not have been carried out; to Magdalena Byzdra and Aneta Studzińska for their invaluable help in securing and realising scientific grants; and to Kamila Zygnerska for her involvement in the administrative aspects of the doctoral thesis submission.

Finally, I would like to express my deepest gratitude to my parents and close family for their unwavering help and support throughout the completion of this PhD thesis. I am especially grateful to my beloved brother, who has been my inspiration since childhood and who introduced me to the world of architecture and heritage, ultimately leading me to this PhD. Above all, I wish to thank Kamila Kondraciuk for her invaluable emotional support during many moments of crisis throughout this work.

Their guidance, inspiration, and love have shaped this journey, and it is to them that I owe both its completion and its meaning.