edited by
SANDRO PARRINELLO
FRANCESCA PICCHIO

Fortresses and military architecture in the City of Gdańsk

FIRENZE
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ricerche | architettura, pianificazione, paesaggio, design

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Prison Tower. © Sandro Parrinello

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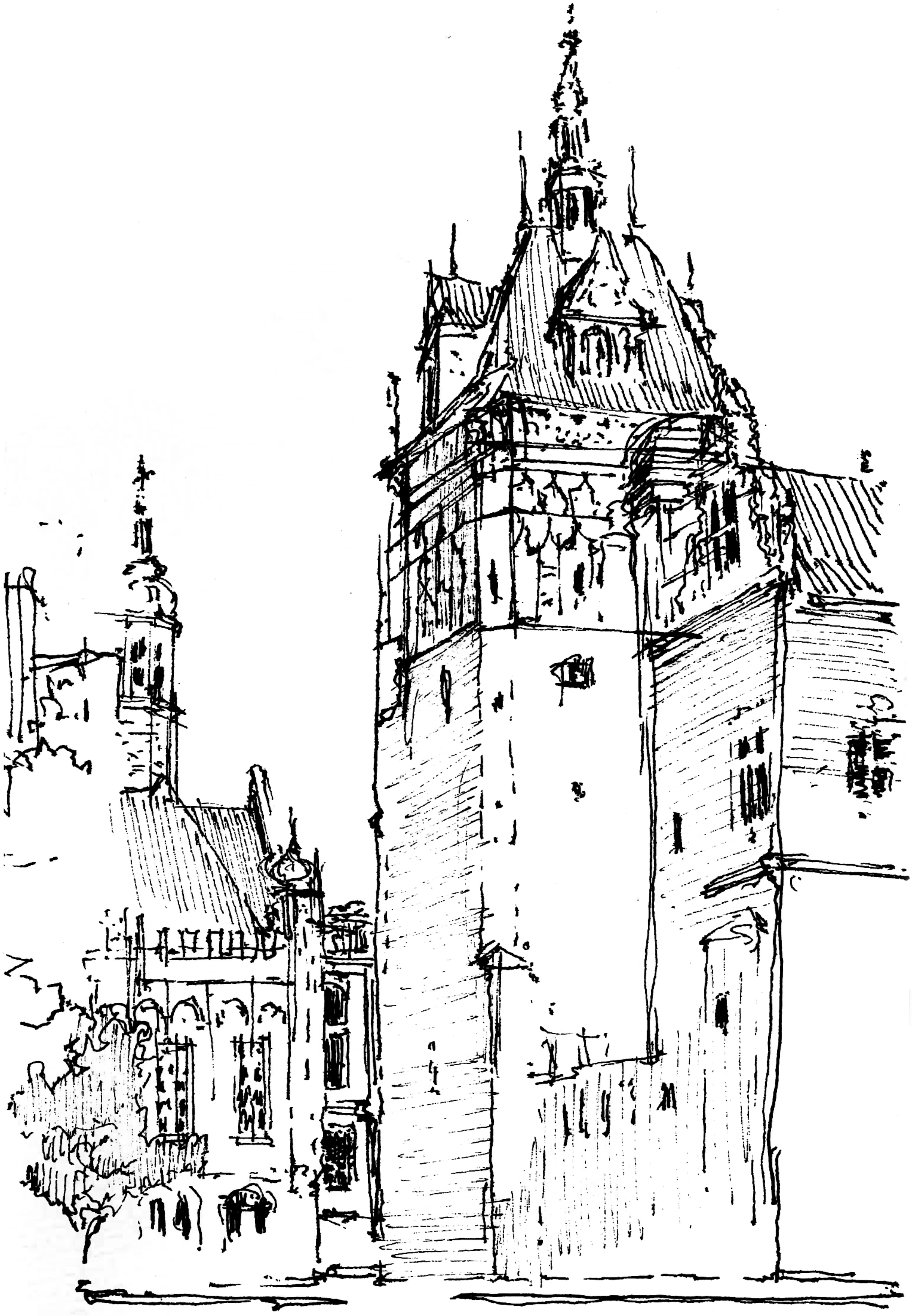
Introduction



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Side page, Fig. 01
Drawing of the Prison Tower in Danzica
The sketch evokes the sequence of monuments formed by the Golden Gate, the Prison Tower, and the High Gate, announcing the passage into the fortified body of the city. In these architectures, military and civic identities merge, giving shape to some of the most emblematic images of the historical landscape of Gdańsk. (Drawing credit: Sandro Parrinello)

Why an urban route? This was the question many people asked me when I proposed the case study of Gdańsk as part of the project. An urban cultural route can be imagined because cities are not only functional spaces, results of geopolitical or social processes, but also palimpsests of memory and stratifications of historical, architectural and social meanings. The spatial component, understood here not as relational space but as a dimension of route extension, plays a significant role in this. Imagine that ideally, any route, which by nature is defined by a departure and an arrival, is potentially infinite by the connections it activates along the way. It is natural to ask how influential the spatial component is. Space is a fundamental route attribute, but it is not the only element that defines it. A route is not simply a physical layout but can also exist as a conceptual and symbolic construction organised around cultural, narrative or experiential relationships.

While firmly rooted in a spatial context, an urban route has the capacity to transcend its geographical dimension and manifest itself through thematic, historical, or symbolic connections. It can take on an immaterial form, linked to narrative rather than physical continuity, as seen in literary itineraries that connect distant or imaginary places through storytelling and shared memory. In other instances, routes are developed in the digital realm, where the journey experience unfolds through virtual platforms that connect fragments of cultural heritage without necessitating physical movement. Even in the urban context, a route may not adhere to a fixed path but emerge from the relationships between elements that share a common value, as in the case of thematic routes that traverse the city without following a linear axis but interweaving spaces according to a conceptual logic.

Therefore, the existence of a route, ,does not depend exclusively on its materiality but on the ability to construct a path through connections of meaning, which may develop in physical space, in the virtual dimension, or in the narrative structure of a cultural experience.

This is necessary to ensure that certain places have a shared meaning, arising from a repetition of subjective and collective experiences since a route exists not only in its materiality but also in the experience and awareness of those who travel it. Therefore, the route must possess traceability, whether physical, digital, or symbolic. This means that there must be a way through which the route can be followed, documented, or retraced, ensuring that the route and its value over time can be recognised.

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Fig. 02
Neptune's Fountain
The drawing portrays Neptune's Fountain as the symbolic heart of Gdańsk, where the sea god rises at the centre of the square, anchoring the surrounding façades and evoking the city's deep connection with the sea, trade, and its layered history. (Drawing credit: Francesca Picchio)

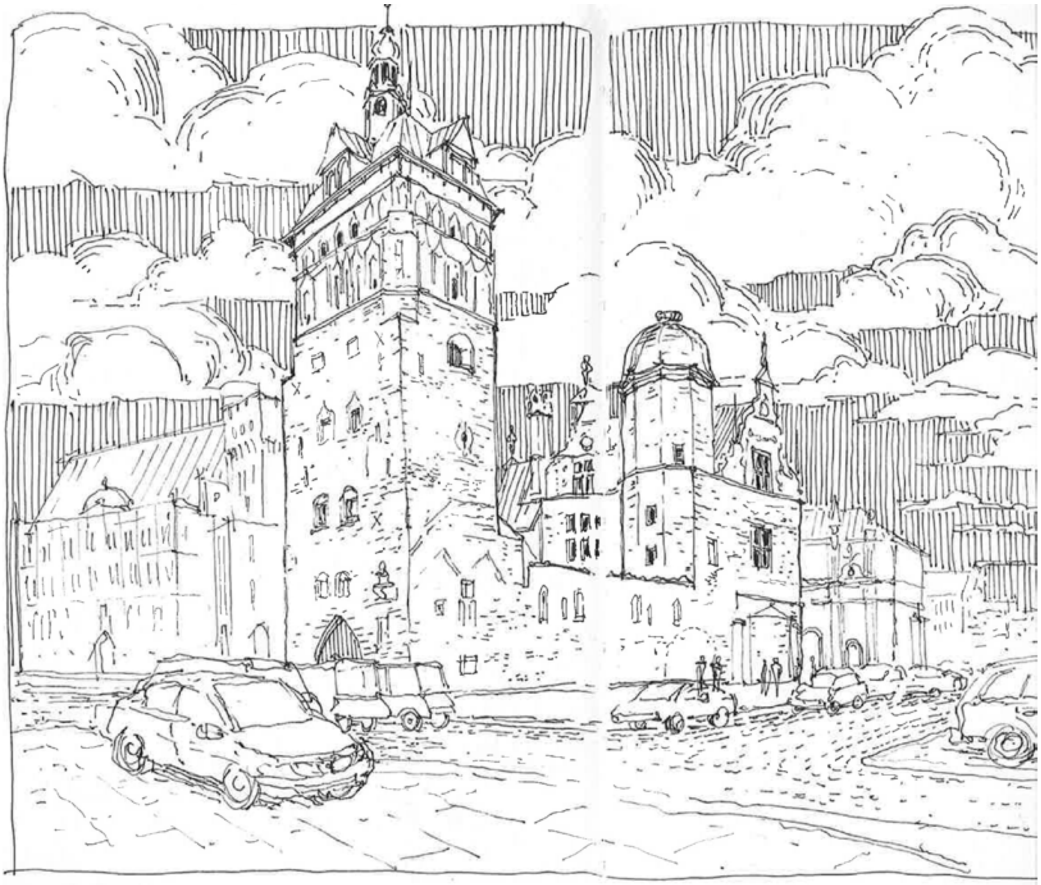
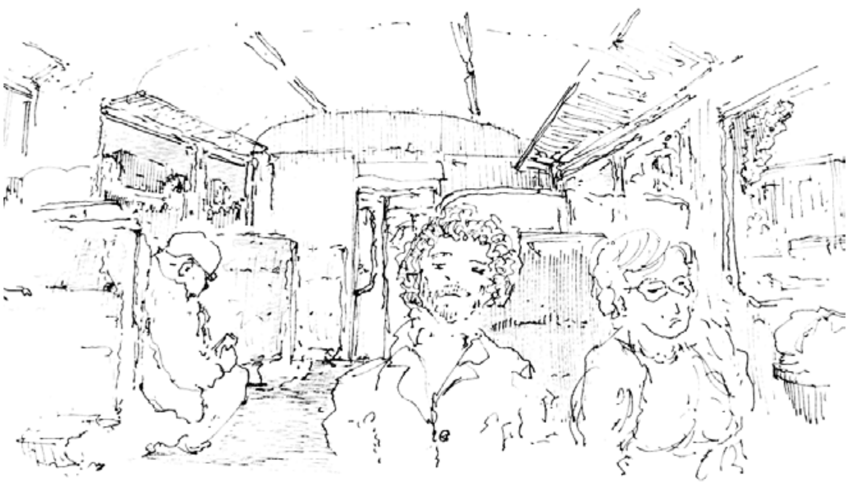


Fig. 03
Prison tower
The drawing highlights the Prison Tower as one of Gdańsk's most distinctive landmarks, positioned along the city's main axis together with the High Gate, the Golden Gate and the Green Gate, marking a sequence of thresholds that narrate the urban structure and the layered history of the city. (Drawing credit: Francesca Picchio)

The emergence of an urban cultural route is grounded in the historical stratification that characterises cities, resulting from centuries of transformations that have left visible traces in the urban fabric. This overlapping of epochs and architectural languages makes constructing narrative routes linking places and memories possible, providing an interpretative key to the city as an evolving palimpsest.

The possibility of identifying a cultural route is linked to urban identity and memory, as the city space is not a mere container of buildings but a repository of collective and individual histories. Through the construction of itineraries, the relationships between places and their evolution can be highlighted, giving the city a narrative dimension beyond structures' mere materiality.

A further element enabling the construction of a cultural route is the presence of thematic connections between the different points of interest. The selection and organisation of such points based on a specific theme, which may relate to art, architecture, historical memory or social and economic change, makes it possible to structure the route coherently and meaningfully. This thematic organisation highlights the interaction between space and meaning: the city is not a neutral set of streets and buildings, but a complex semiotic system in which each urban element takes on a symbolic and communicative value. The interpretation of these signs is made possible by constructing itineraries that facilitate reading the city as a text.



Figs. 04, 05
Sketches made with colleagues during an excursion to Sopot
The train journey, from the station platforms to the interiors of the carriages, gradually revealed the many layers of the Polish landscape, where movement, infrastructure, and atmosphere intertwined in a continuously shifting visual narrative. (Drawing credit: Sandro Parrinello)

Fig. 06
Malbork castel
The drawing reveals the interior of Malbork Castle, where vast brick halls, vaulted ceilings and austere geometries reflect the power and discipline of the Teutonic Order, creating a space that is both monumental and deeply atmospheric.(Drawing credit: Francesca Picchio)
Dluga street
In a sketch drawn from the roof of the Golden Gate, Dluga Street guides the viewer's gaze along its axis toward the cathedral's bell tower and clock tower, establishing a harmonious relationship between perspective and historical context. (Drawing credit: Francesca Picchio)

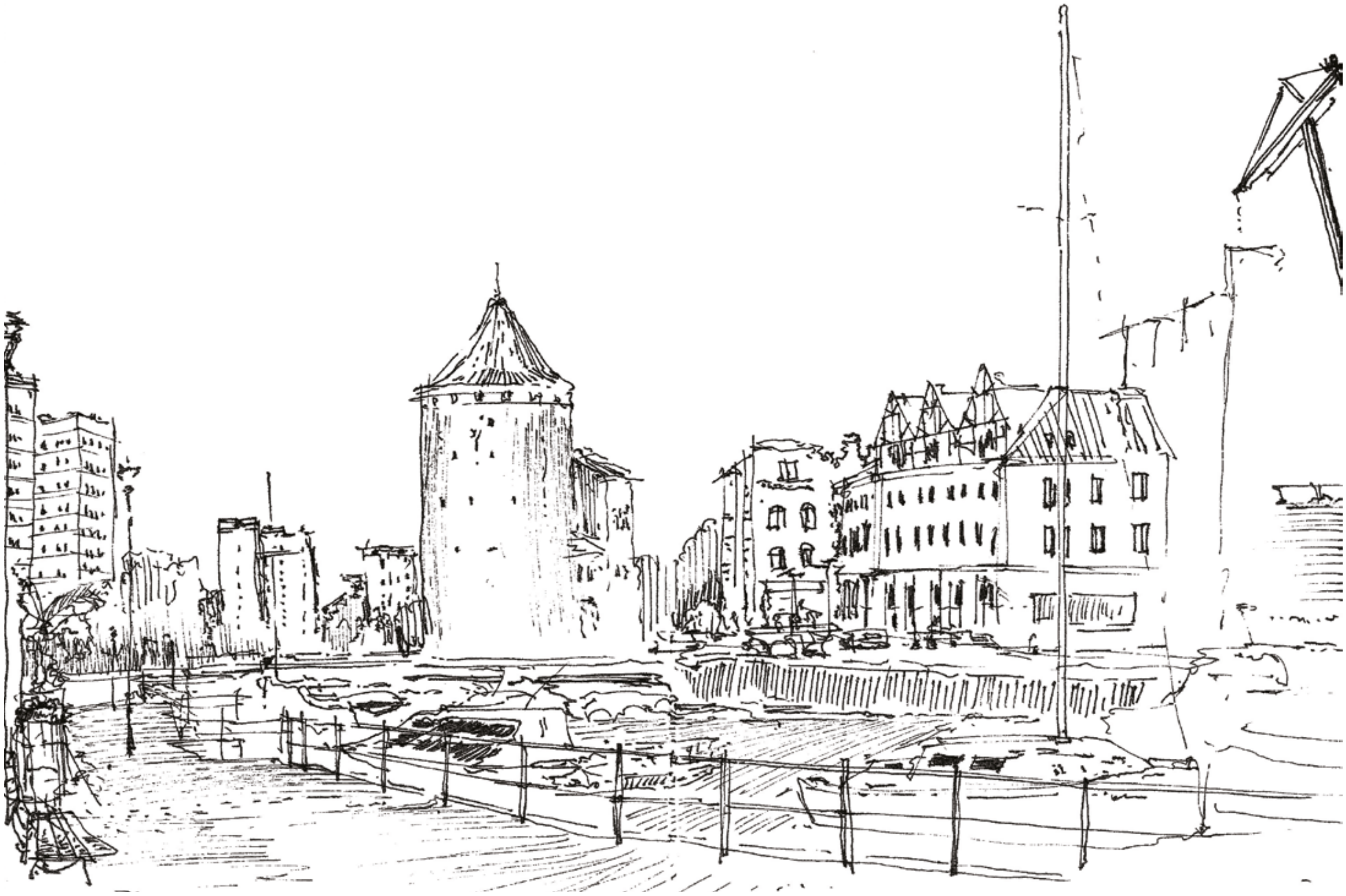
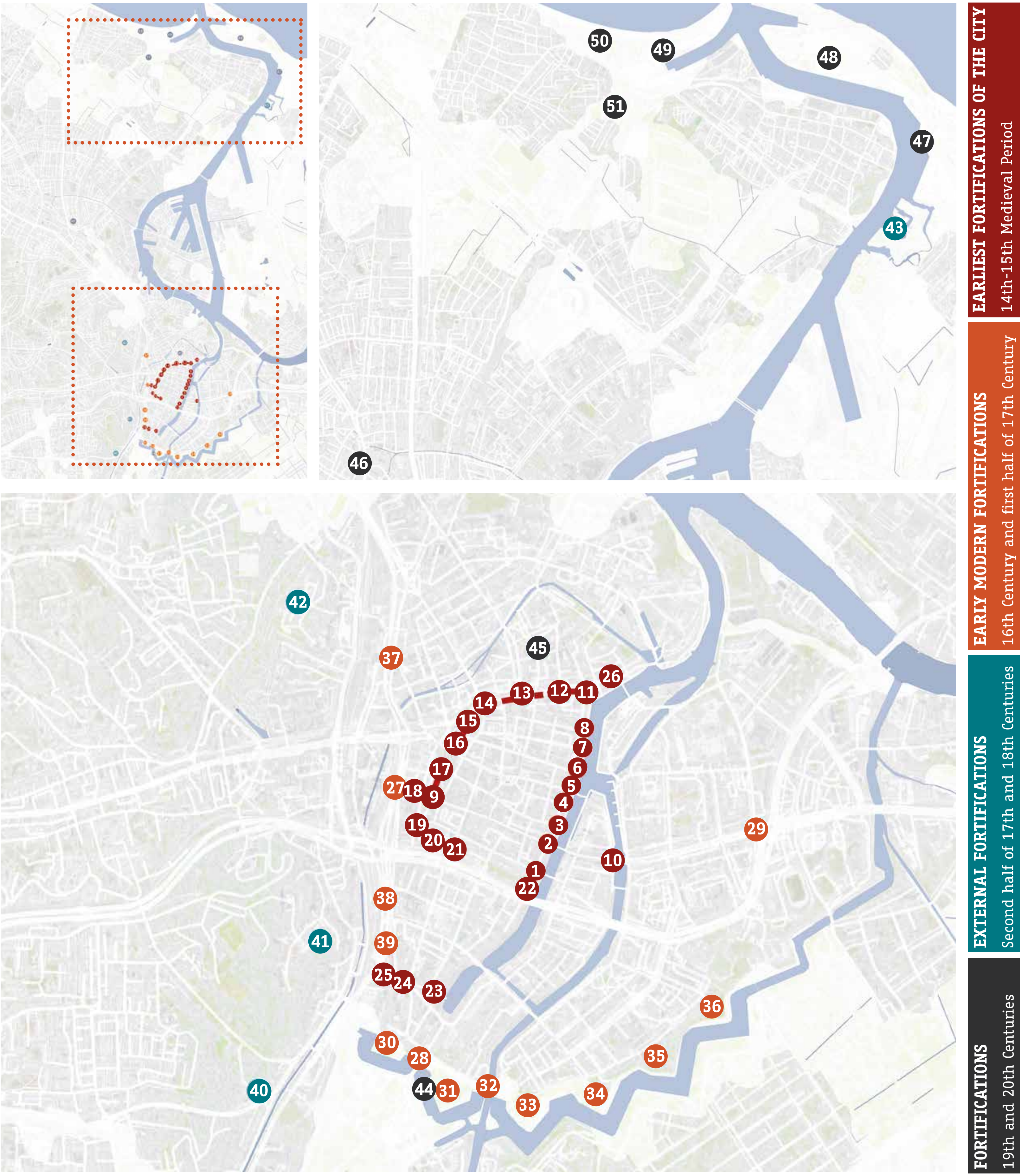


Fig. 07
Walking along the City's Edge
The drawing depicts the waterfront in central Gdańsk, illustrating a continuous promenade that extends between gates and towers along the river. This route defines the boundary of the historic core and provides access to the stratified harbour landscape. (Drawing credit: Sandro Parrinello)

Another fundamental aspect of urban cultural routes is their function in rediscovering and enhancing the urban heritage, particularly those places that have been forgotten or neglected over time despite their historical and cultural relevance. Including these spaces in a structured itinerary allows them to be re-read within a broader narrative, favouring their recovery and accessibility to citizens and visitors. In this sense, the cultural route takes on an interpretative and operational value, contributing to the protection and conscious enjoyment of heritage.

Simultaneously, the experiential and participative dimension of an urban cultural route represents a crucial element. The route is not a mere path between points of interest but an immersive experience that engages the visitor in an active learning process. The walk becomes part of the discovery, encouraging direct interaction with the urban context and stimulating a deeper perception of the crossed spaces. Constructing an urban cultural route allows the city to be read and interpreted through a cultural and narrative key, creating connections between space, time, and memory. Historical stratification, urban identity, thematic coherence, symbolic interpretation of space, heritage valorization, and experientiality are all elements that contribute to defining the identifiability and function in the context of the use and understanding of the urban landscape.


EARLIEST FORTIFICATIONS OF THE CITY
14th-15th Medieval Period
EARLY MODERN FORTIFICATIONS
16th Century and first half of 17th Century
EXTERNAL FORTIFICATIONS
Second half of 17th and 18th Centuries
FORTIFICATIONS
19th and 20th Centuries

EARLIEST FORTIFICATIONS OF THE CITY 14th-15th Medieval Period

1_Cow's Gate, *Brama Krowia* (PL), *Kuhtor Gate* (DE), 54.346978, 18.654943

2_Cog Gate (now Green Gate), *Brama Kogi (teraz Brama Zielona)* (PL), *Koggentor (jetzt Grünes Tor) Gate* (DE), 54.347887, 18.656278

3_Chlebnicka Gate, *Brama Chlebnicka* (PL) *Brotbänkentor Gate* (DE), 54.348849, 18.656211

4_St. Mary's Gate, *Brama Mariacka* (PL), *Frauentor Gate* (DE), 54.349445, 18.656758

5_Holy Spirit Gate, *Brama Świętego Ducha* (PL), *Heilige Geist Tor Gate* (DE), 54.349929, 18.657081

6_Crane Gate, *Brama Żuraw / Żuraw* (PL), *Krantor Gate* (DE), 54.350517, 18.657427

7_St. John's Gate, *Brama Świętojańska* (PL), *Johannistor Gate* (DE), 54.351536, 18.657838

8_Straganiarska Gate, *Brama Straganiarska* (PL), *Häkertor Gate* (DE), 54.347363, 18.659858

9_Golden Gate, *Złota Brama* (PL), *Goldenes Tor (Langgasser Tor) Gate* (DE), 54.353146, 18.653596

10_Stągiewna Gate / Tower, *Brama, Stągiewna (Stągwie Mleczne)* (PL), *Milchkannentor Tower* (DE), 54.347363, 18.659858

11_Swan Tower, *Baszta Łabędź* (PL), *Schwanturm Tower* (DE), 54.353426, 18.658007

12_Eastern part of northern Walls, *Wschodnia część północnego muru obronnego* (PL), *Östliche Teil der nördlichen Verteidigungsmauer Walls* (DE), 54.353422, 18.656781

13_Western part of northern Walls, *Zachodnia część północnego muru obronnego* (PL), *Westlicher Teil der nördlichen Verteidigungs*mauer Walls (DE), 54.353146, 18.653596

14_ Jacek Tower, *Baszta Jacek* (PL), *Kiek in de Kök Turm Tower* (DE), 54.352894, 18.651248

15_Tower on the Behind/underWalls *Baszta na Podmurzu* (PL), *Turm an den Hintermauern* (DE).

16_Latarniana Tower, *Baszta Latarniana* (PL), *Wehrturm in der Laternengasse Tower* (DE), 54.351637, 18.649661

17_Straw Tower, *Baszta Słomiana* (PL), *Strohturm Tower* (DE), 54.352460, 18.650819

18_Torture House and Prison Tower, *Zespół przedbramia Ulicy Długiej (Katownia i Wieża Więzienna)* (PL), *Langerstraßentorkomplex (Peinkammer und Stockturm) Tower* (DE), 54.349926, 18.647039

19_Corner Tower, *Baszta Narożna* (PL), *Eckturm am Stadthof Tower* (DE), 54.348715, 18.647332

20_Western part of the southern Wall, *Zachodnia część południowego muru obronnego* (PL), *Westlicher Teil der südlichen Verteidigungsmauer Walls* (DE), 54.348281, 18.648391

21_Schultz Tower, *Baszta Schultza* (PL), *Schultz Turm Tower* (DE), 54.352465, 18.650829

22_Tower of Anchors, *Baszta Kotwiczników* (PL), *Ankerschmiedeturm Tower* (DE), 54.346446, 18.654427

23_ Pod Zręb Tower, *Baszta pod Zrębem / Baszta* (PL), *Atutowa Trumpfturm Tower* (DE), 54.342475, 18.648276

24_ White Tower, *Baszta Biała* (PL), *Weißer Turm Tower* (DE), 54.342933, 18.646512

25_New Tower, *Baszta Nowa* (PL), *Neuer Turm Tower* (DE), 54.342996, 18.645449

26_Remains of the walls of the Teutonic castle, *Relikty murów zamku krzyżackiego* (PL), *Relikte der Mauern der Deutschordensburg Walls* (DE), 54.353809, 18.659735

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27_High Gate, *Brama Wyżynna* (PL), *Hohes Tor Gate* (DE), 54.339827, 18.663039

28_Lowland Gate *Brama Nizinna* (PL), *Leeges Tor Gate* (DE), 54.340373, 18.647538

29_Żuławy Gate (Long Gardens Gate), *Brama Żuławska (Brama Długich Ogrodów) Langgarter Tor Gate* (DE), 54.348627, 18.668999

30_St Gertrude Bastion, *Bastion św. Gertrudy* (PL), *Gertrude Bastion* (DE), 54.340770, 18.645558

31_Aurochs Bastion B*astion Żubr* (PL), *Aurochs Bastion Maidloch Bastion* (DE), 54.339172, 18.649459

32_Stone Sluice (Main Sluice), *Śluza Kamienna (Główna Śluza)* (PL), *Steinschleuze (Hauptschleuse)* (DE), 54.339172, 18.649459

33_Wolf Bastion, *Bastion Wilk* (PL), *Wolf Bastion* (DE), 54.338256, 18.654124

34_Wyskok Bastion, *Bastion Wyskok* (PL), *Aussprung Bastion Bastion* (DE), 54.338821, 18.658688

35_Bear Bastion, *Bastion Miś* (PL), *Bëren Bastion* (DE), 54.339827, 18.663039

36_Królik Bastion, *Bastion Królik* (PL), *Kaninchen Bastion* (DE), 54.342195, 18.666019

37_St. Elizabeth's Bastion, *Bastion Św. Elżbiety* (PL), *Elisabeth Bastion* (DE), 54.356815, 18.646750

38_Cat Bastion, *Bastion Kot* (PL), *Katze Bastion* (DE), 54.345927, 18.645517

39_Wiebe Bastion, *Bastion Wibego* (PL), *Wieben Bastion* (DE), 54.342961, 18.645466

EXTERNAL FORTIFICATIONS Second half of 17th and 18th Centuries

40_ Jesuit Rampart, *Szaniec Jezuicki* (PL), *Jesuiten Schanze* (DE), 54.343821, 18.645620

41_Fortification of Bishops Hill *Fortyfikacje Biskupiej Górki* (PL), *Bishofs Berg* (DE), 54.341721, 18.638885

42_Fortifications of Gradowa Hill (Grodzisko) *Zespół fortyfikacji Grodziska* (PL), *Hagels Berg Fortification* (DE), 54.355306, 18.637739

43_Wisłoujście Fortress Complex, *Zespół fortyfikacji Wisłoujścia* (PL), *Weichselmünde Fortification* (DE), *54.395896, 18.679863*

FORTIFICATIONS 19th and 20th Centuries

44_Fortifications of Railway Gate, *Brama Kolejowa* (PL), *Bahntor* (DE), 54.339667, 18.648472

45_Osiek Shelter, *Schron na Osieku* (PL), *Luftschutzbunker in Osiek Shelter* (DE), 54.354574, 18.654656

46_Hospital Shelter, *Schron szpitala na ulicy Klinicznej* (PL), *Luftschutzbunker des Krankenhauses in der Kliniczna Strasse* (DE), 54.376488, 18.625982

47_Seagulls Rampart, *Mewi Szaniec* (PL), *Möwen Schanze* (DE), 54.400802, 18.682687

48_Westerplatte Peninsula Fortification *Zespół fortyfikacji Westerplatte* (PL), *Befestigung der Westerplatte* (DE), 54.406758, 18.666949

49_Port Battery *Bateria Portowa* (PL), *Port Baterie* (DE), 54.407527, 18.651132

50_Beach Battery *Bateria Plażowa* (PL), *Strand Baterie* (DE), 54.407653, 18.644741

51_Village Battery *Bateria Wiejska* (PL), *Dorfbatterie* (DE), 54.402538, 18.645103

Analysis and systematization of the fortified heritage

A BORDER LANDSCAPE BETWEEN WATER AND SILENCE

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Side page, Fig. 01
The Winter Waterscape of Gdańsk
A quiet winter view of Gdańsk, where canals and bastions emerge through the stillness of the season, shaping a layered urban landscape in which water, fortifications and the historic fabric are intimately intertwined.

The fortresses of Gdańsk constitute an essential element of its urban landscape and military history, outlining the city's evolution as a strategic center in the Baltic region. The defensive system developed progressively from the Middle Ages, adapting to military innovations and commercial expansion. As early as the 13th Century, under the rule of the Teutonic Order, the first fortified structures were built, including the Teutonic Castle, which was later destroyed in the 15th Century following the citizens' uprising against the knights. Subsequently, with Gdańsk's entry into the Hanseatic League and the consolidation of its commercial role, the defensive system was expanded with bastions and walls, which became more complex in the 16th and 17th centuries following the principles of bastion fortifications from the Flemish and Italian schools. The fortifications included monumental gates, such as *Brama Wyżynna* and *Brama Zielona*, as well as the formidable *Wisłoujście Fortress*, a circular tower at the harbor entrance for controlling maritime traffic. The *Bastion Góra Gradowa* complex, on the other hand, represented a crucial point for the city's land defense. These structures not only shaped the city's defensive identity but also influenced its urban development and its perception over time.

During World War II, the city suffered severe destruction, with the loss of over 80% of the historic center. The post-war reconstruction process was complex, oscillating between political needs and a philological recovery of urban identity. Unlike other Polish cities such as Warsaw, where reconstruction was almost entirely based on paintings and historical documents, Gdańsk opted for selective reconstruction, restoring major historic buildings and favoring the Hanseatic architectural language. The interventions primarily focused on *Długi Targ*, St. Mary's Basilica, and the ancient city gates, while some fortified areas were partially abandoned or modified. Today, the partially restored fortifications represent an important testimony to the city's military and urban evolution and are also the subject of studies on the restoration of war-related architectural heritage.

This historical stratification is still visible today in the urban fabric and in how the city presents itself to a contemporary observer. Gdańsk emerges as a complex urban organism, a synthesis of architectural geometries and hydrographic networks that interact with the surrounding landscape. At first glance, the compact structure of the historic center stands out, punctuated by slender buildings with strict metrics and facades adorned with gables and late Gothic and Mannerist decorations. The city stretches along the *Vistula* and the *Motława*, whose network of canals and port basins creates

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Fig. 02
The Medieval Waterfront of Gdańsk, repr.: Otto Kloeppel
The Motława riverfront in its medieval state, where the Crane Gate stands as a powerful landmark along the water's edge, flanked by moored ships and a continuous line of fortified buildings leading towards the Teutonic castle.

Fig. 03
Timber Market and the Foregate Complex of the Broad Gate
The Targ Drzewny (Timber Market) together with the foregate complex of the Broad Gate, including the Jacek Tower, forming a significant urban ensemble that marks one of the historic access points to the city and reflects its defensive and commercial character. (Polska Akademia Nauk Biblioteka Gdańska)

a complex spatial articulation, characterized by bridges and quays that connect the architecture to the fluvial dimension. The urban perspective is dominated by St. Mary's Basilica, an imposing brick structure that towers over the built fabric, marking with its volume the morphological identity of the center. The organization of urban spaces reveals a strict hierarchy of streets: the main axes are flanked by buildings aligned according to repeated modules, with narrow and vertically developed facades, a typical solution of Hanseatic cities. The perspective dimension is emphasized by the succession of building facades framing the view of *Długa* and *Długi Targ*, the focal point of urban representation. Observing the material textures, one can see the use of red brick, limestone in decorations, and wood in port structures, materials that testify to adaptation to the Baltic climatic and construction contexts. The defensive system, with bastions and walls following the course of the waters, is readable in its historical stratifications, from medieval fortifications to modern structures. Despite the wartime destruction, the city has preserved its original layout, reconstructed with philological attention to maintaining its local identity. Water, a central element in the perception of the urban landscape, manifests itself in the reflection of architecture on the river surfaces, a phenomenon that enhances spatial depth and makes the city a continuously changing visual entity. The morphological and iconographic analysis of Gdańsk highlights a city configured as a palimpsest of forms and styles, where every architectural detail tells the story of the relationship between the urban structure and its historical evolution.


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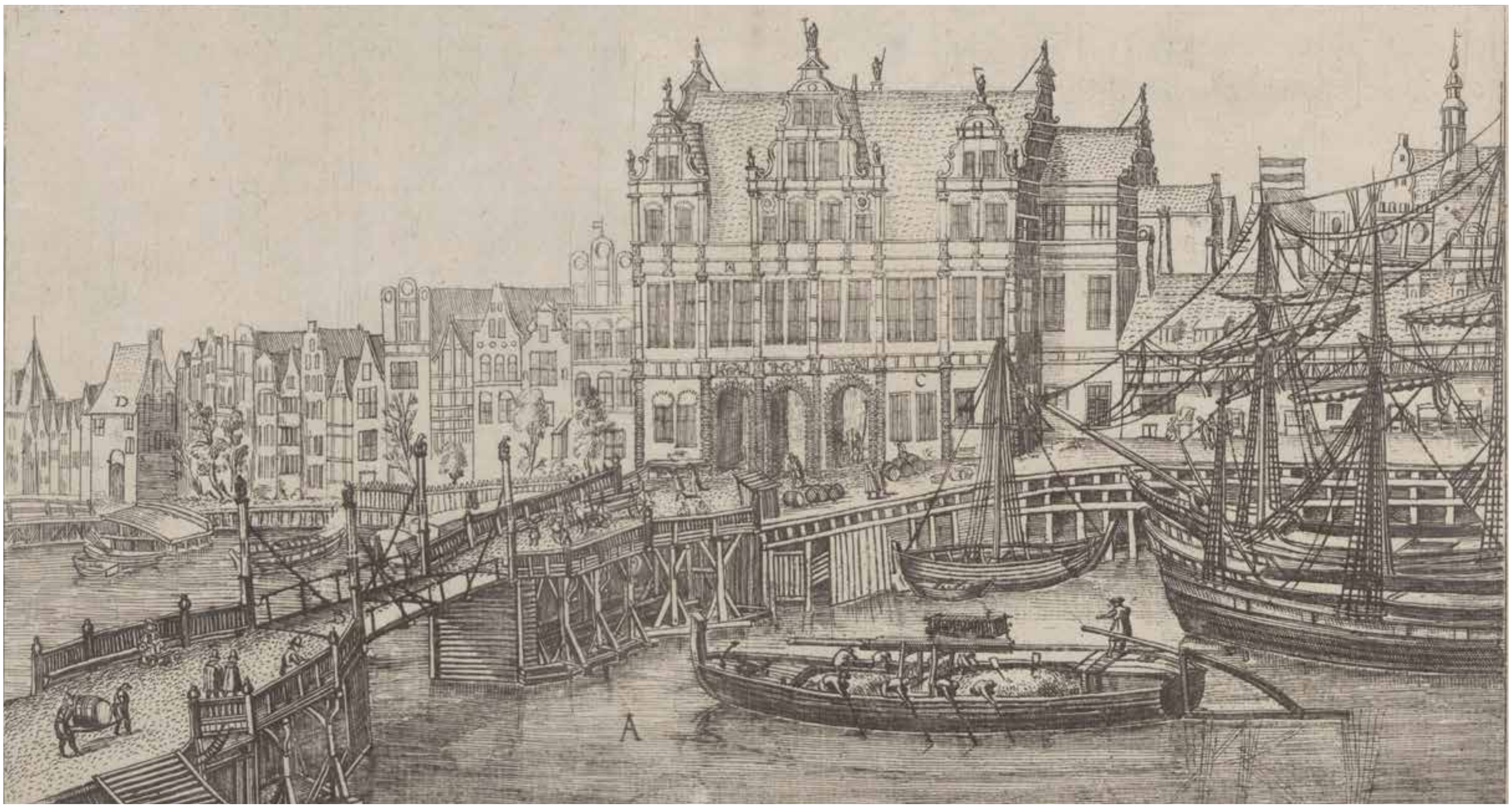
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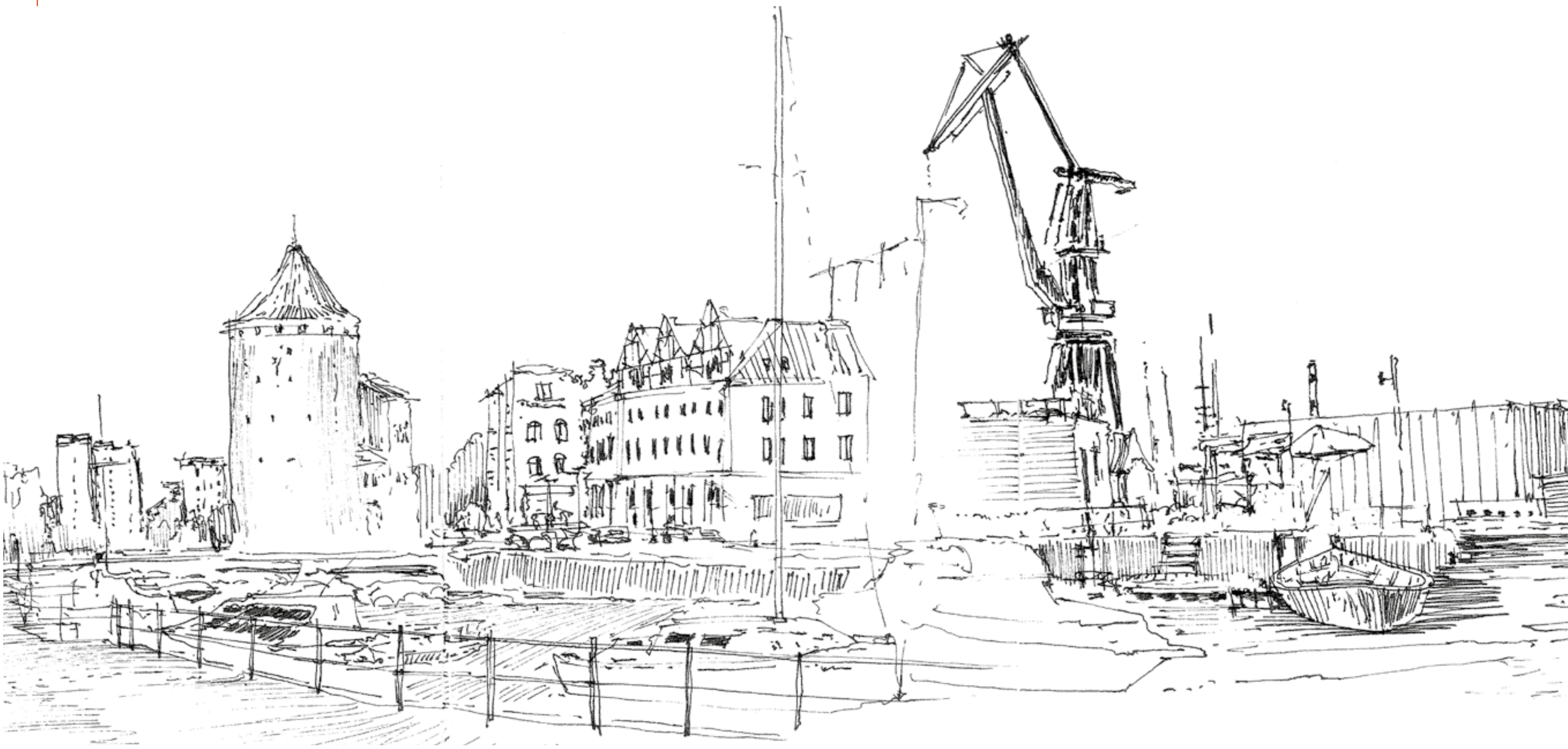


Privious page, Figs. 04, 05
The Waterfront of Gdańsk Today
The image shows the present-day Motława riverfront, where the Crane remains a clearly legible landmark along the water's edge, still marking the historic gateway to the city.

The Green Gate and the Motława Crossing
The drawing depicts the Green Gate with the city weigh house located at ground level, connected by a bridge over the Motława River, illustrating its dual role as both an point to the city and a key node in Gdańsk's commercial life. (Polska Akademia Nauk Biblioteka Gdańska)

Fig. 04
The key symbols of Gdańsk's aquatic landscape today
where the Motława River, historic gates, cranes and waterfront facades are reimagined as a cohesive system, expressing the enduring relationship between water, urban form and maritime identity. (Drawing credit: Sandro Parrinello)

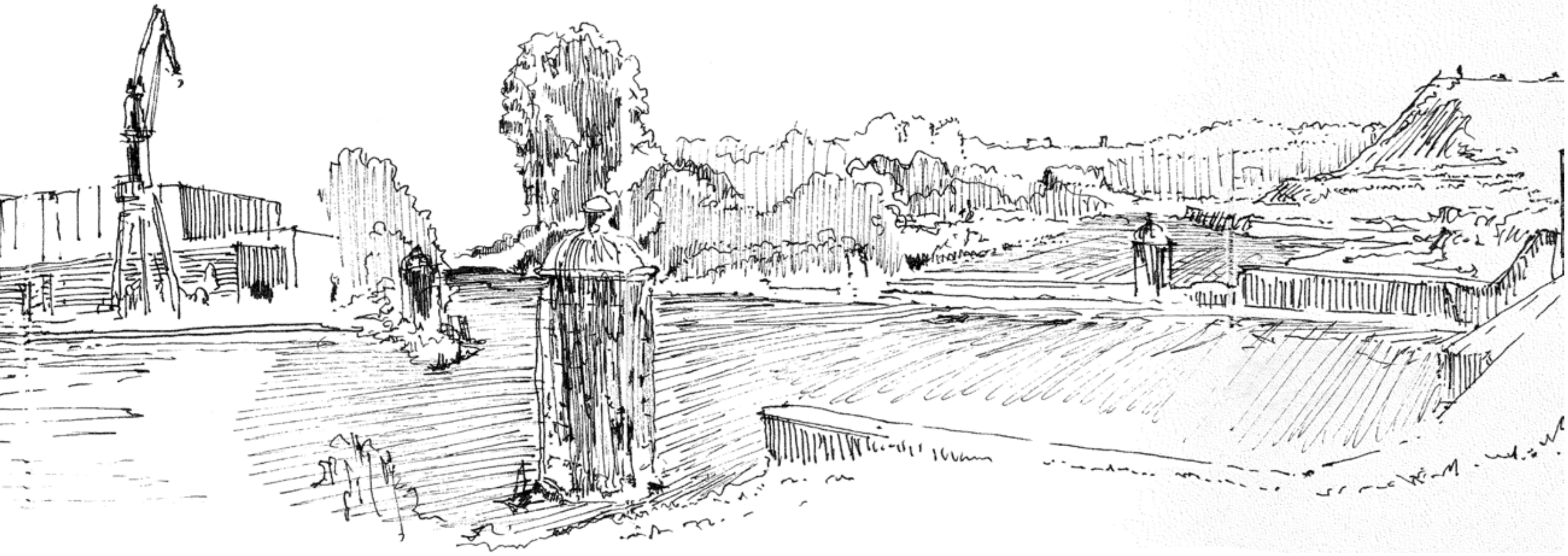
The skyline is punctuated by the towers of the ancient city gates and the spires of Gothic churches, while the facade of Artus Court and the monumental medieval-era port crane bear witness to the city's intense relationship with maritime trade. This relationship between the built environment and the hydrographic context is particularly significant in understanding the role of water canals in defining the urban landscape.

Urban hydrographic systems play a crucial role in shaping the landscape, contributing to territorial organization, historical memory, and place identity. In particular, the water canals in urban peripheries delineate complex landscape patterns, serving as connecting elements between past and present. The case of Gdańsk, a port city characterized by a dense system of waterways, offers a paradigmatic example of the interaction between hydraulic infrastructure and urban fabric, raising questions about the conservation and enhancement of fluvial heritage.

Gdańsk developed along the mouth of the *Vistula*, a river that has shaped the city's morphology since the Middle Ages. Its canal system, derived from the regulation of the river flow and port expansion, has helped define the relationship between the historic center, fortifications, and outskirts.

The image of Gdańsk's landscape is characterized by a balance between natural and anthropic elements: on one hand, water represents a structuring element that organizes urban space; on the other, hydraulic constructions and fortified architectures testify to the city's functional transformations.

Observing the urban landscape as a whole, it becomes clear how the water system has determined the city's growth and the distribution of its urban spaces. The canals not only facilitated maritime trade and economic expansion but also served as defensive lines and axes of urban development, as demonstrated by the *Wisłoujście* fortifications and port structures along the *Motława*.



Selected views of the city
The Golden Gate and the Prison Tower on the left, balanced by a view of the railway station, creating a layered composition that highlights Gdańsk's architectural landmarks and its urban continuity. (Drawing credit: Sandro Parrinello)

Fig. 06
Bird's-Eye View of Gdańsk's Historic Centre
The image presents an aerial view of Gdańsk's historic core, revealing the dense urban fabric, the linear sequence of streets and gates, and the close relationship between the city and the Motława River that defines its distinctive spatial structure. Photo by Dominik Werner

The role of water in constructing urban memory is particularly evident in Gdańsk, where the canal system reflects the city's historical phases, from medieval origins to post-war reconstruction. The river and its tributaries have marked the boundaries of urban expansion and, over the centuries, have undergone adaptations reflecting the political, economic, and military needs of the territory.
The study of the identity characteristics of these landscapes requires an interdisciplinary analysis integrating geographical, historical, and architectural aspects. Interpreting canals as elements of continuity allows for understanding the relationship between urban transformations and environmental dynamics, fortified structures, and place identity, highlighting how the presence of water has helped maintain a connection between historical memory and contemporary spatial perception.
An investigation into Gdańsk's fortresses, within a network somehow connected to the canals regulating this space, must consider their material and immaterial dimensions. The reading of the urban landscape in relation to memory is thus reflected in the water and can benefit from spatial analysis tools, historical documentation, and survey methodologies capable of providing an integrated vision of the context. Approaching the study of this landscape cannot ignore an assessment of its transformations over time: comparing historical maps with digital models enables the identification of the permanence and alterations of hydraulic structures, contributing to reflections on

sustainability and future heritage management. In this sense, the river—a dynamic element par excellence—becomes a metaphor for continuity and urban transformation, bearing witness to the flow of history through the landscape. The water canals of urban peripheries are a crucial element for understanding the evolution of the city's landscape. In the case of Gdańsk, the water system constitutes not only a testimony to the city's historical memory but also a fundamental point for discussions on the future conservation of architectural and environmental heritage. Studying landscape structures integrated into the urban fabric allows for appreciating the complexity of the relationship between architecture and territorial identity, promoting a sustainable vision of resource management in the contemporary urban context.

References

Bres J., Krosnicka K. A. 2021, *Evolution of Edges and Porosity of Urban Blue Spaces: A Case Study of Gdansk* in *Urban Planning*, 6(3), pp. 90-105.
Graham B., Ashworth G. J. (eds.) 2005, *Senses of Place: Senses of Time*, Routledge, London.

Marshall R. 2004, *Waterfronts in Post-Industrial Cities*, Taylor & Francis,

Nowak M. J. (Ed.) (2025). *The Protection of Green Spaces for Climate Change Adaptation: Planning Systems*, Policies and Instruments. Taylor & Francis.

Parrinello S., La Placa S. 2021, *Documentation of the waterways in the Pavia flat land. Experience in detection with SLAM technology for the development of information models*, in *DN*, 9, pp. 34-46.

Parrinello S., Borucka J. 2023, *VREA Project - a digital curator for architecture and digital perspectives for heritage management and enhancement*, in *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 48, pp. 289-296.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The perceptual analysis of a place, and its subsequent codification into a common language, are inevitably tied to a temporal dimension: sequences, interruptions, and pauses govern the rhythms through which the complexity of an urban environment is understood. In such contexts, time becomes a component both of the observer's experience and of the intrinsic complexity of the observed object.

When the object in question is an urban setting, the temporal component is also interwoven with the stratification of traces that have shaped it over centuries. This is why the perception of urban space often becomes fragmented and partial. The human mind filters certain elements over others, influenced not only by external stimuli but also by internal ones—cultural and personal structures that affect the overall understanding of a context.

When these stimuli gain significance, they become signs: recognizable elements considered universal and shareable within a specific cultural community.

The transposition of a perceived urban landscape into a recognizable and univocally transferable representation occurs, therefore, through the sign and, consequently, through drawing.

The sign/drawing acts as the minimal unit for representing spatial relationships: it defines an inside/outside boundary, encloses the volumes of a physical place or a landscape, and anchors them to a specific context. Each sign establishes a "model" in which meaning is attributed to an urban void, a distinctive object, or an element with specific qualities; as a signifier, it resonates through the built structure that contains it.

The identity-bearing signs of an urban space become iconemes, the minimal perceptual units of a place's identity. However, their interpretation is never purely visual—it also engages our logical and functional ability to read the landscape. This depends on our cultural level—our encyclopedic knowledge base—but also on our capacity to causally connect signs, to read the current functioning of the territory through its perceptual projection.

The architecture of the city of Gdańsk transforms its physicality into tangible signs that are legible within the urban landscape. Natural iconemes—such as waterways and riverside embankments—originally guided settlements, becoming true iconemes also in a symbolic sense.

There are also forms beyond the visible realm that, while not falling within the category of iconemes, deserve to be considered as equals.

Side Page, Fig. 01
Framed Perspective along Gdańsk's historic centre
The image captures a carefully composed view along Gdańsk's street, where the richly ornamented façade of the The Great Armoury (Wielka Zbrojownia) emerges at the end of the urban corridor, framed by the vertical rhythm, revealing the strong axiality and scenographic character of Gdańsk's historic centre.

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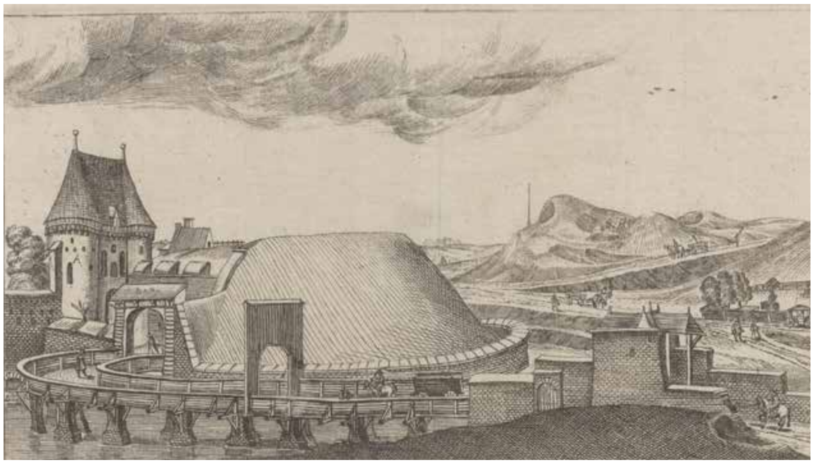

Figs. 02, 03, 04, 05
Views between Representation and Reconstruction
The composition juxtaposes a painted view of Gdańsk's urban street with historical engravings of its fortifications and landscape, including the Brama Bożego Ciała with its rondel (top right) and the Brama Wyżynna set within the line of the defensive ramparts (bottom right), revealing the contrast between lived city spaces and their defensive structures, and illustrating the layered relationship between everyday urban life and the broader territorial system. Research conducted at the Polska Akademia Nauk Biblioteka Gdańska.

These cannot be explained, only described, as carriers of potential symbols. That is why the symbol represents a dimension of meaning that transcends the iconeme: it surpasses visibility and enters the field of the invisible, probing deep cognitive processes rooted in experience, time, and culture. In the analysis of the fortified landscape that defines the cultural route through the city of Gdańsk, the symbol plays an essential role: it points to the "thing itself" in its full expressive force. Fortifications, in this sense, are cultural palimpsests—layers of signs sedimented over time—offering interpretive trajectories through the city. Walking through the city's streets is like entering a living timeline. Every alley evokes an era; every corner holds a memory. The tension between the twilight of narrow lanes and the visual openness of the canals creates a complex spatial experience.The vertical façades, with large aligned windows, end in sculpted and decorated gables, drawing a visual grid across the sky. This urban grammar—made of rules and proportions visible both in the urban fabric and along building facades—combines tradition with the architectural experimentation of post-war reconstruction. It forms an open-air architectural archive that preserves readable traces of its past. Through materials, construction techniques, color schemes, and mural decorations, the city presents itself as an experiential anthology. Every visitor feels compelled to document every detail, as each iconeme contributes to the city's collective mythology—from the Amber Road to the Prussian domain, up to post-war reconstruction. Fortifications offer a privileged interpretive path. Cataloging towers, bastions, walls, and fortresses allows us to reconstruct the city's boundaries—many of which have vanished, transformed, or been integrated into new structures.

These defenses are not merely physical artifacts, but a temporal network of signs extending from medieval ramparts to Prussian military architecture and twentieth-century urban interventions.
This layered design reflects the evolution of military strategies and technology, etching the landscape at the city's edges, along rivers, and to the sea.
Multiple eras remain visible today: from Gothic remnants to Prussian relics of the Schinkel era, to 20th-century urban rationalizations, and the post-war interventions that progressively reduced urban density while thoughtfully integrating new buildings.
After 1989, new architectural icons such as the Shakespeare Theatre, the Museum of the Second World War, and the European Solidarity Centre have completed the skyline, enriching it with new identity symbols.
In the Old Town, modern planning has introduced hotels, office towers, and residential buildings into areas that were once marshlands. Yet the original fortified structure remains clearly legible.
This centuries-old narrative configures a landscape of signs: an urban space where architecture, memory, and meaning intertwine. Fortified iconemes are updated with each era, adapting to new contexts while maintaining a continuous symbolic dialogue.
Analyzing such signs and traces is not merely a matter of academic inquiry or historical documentation. It becomes a foundational act in preparing for the digitalization of urban heritage.
In a world where digital twins, 3D models, and immersive heritage platforms are becoming the new language of preservation and transmission, understanding what constitutes a "meaningful sign" within the urban fabric is essential. The digital rendering of a cityscape is not simply a matter of geometry and texture; it requires interpretative depth.
Traces—whether physical, symbolic, or mnemonic—must be decoded and encoded with cultural richness if the digital copy is to convey more than just spatial fidelity.
In this sense, the sign is not just the smallest unit of spatial representation, but the key to semantic encoding in the digital realm.
Creating a digital archive of a place like Gdańsk, with its layered historical trajectories, involves more than scanning surfaces. It requires an epistemological approach: discerning which signs matter, which voids are meaningful, and which historical juxtapositions hold symbolic relevance.
A digital heritage project that ignores the semiotic richness of urban signs risks flattening complexity into superficial simulacra.
Moreover, digital tools open new possibilities for reactivating urban memory. Through interactive maps, augmented reality, and spatial narratives, signs that once belonged only to specialists can be made legible to the wider public.
This democratization of heritage interpretation relies on careful preparatory work: identifying and mapping the iconemes that form the symbolic skeleton of the city.

Fig. 06
A Glimpse from Dluga Street
The detail captures a figure leaning out from one of the houses along Dluga Street, offering an intimate moment of everyday life that animates the facade and connects the domestic interior with the public space of the street. A.L. Randt. Painting, 1856. Polska Akademia Nauk Biblioteka Gdańska, Archive.

Fig. 07
Wisłoujście Fortress
The drawing depicts Twierdza Wisłoujście, a strategic maritime fortification at the mouth of the Vistula, where defensive architecture and navigational function converge, marking a key point of control and access to the port of Gdańsk. Polska Akademia Nauk Biblioteka Gdańska, Archive.

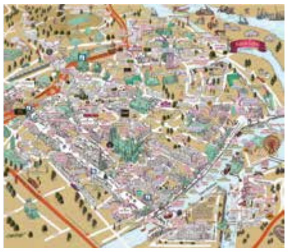

Fig. 08
Illustrating Gdańsk
The images present two illustrated maps of Gdańsk: the upper one offers a detailed and information-rich representation of the city, while the lower simplifies its form into a more symbolic and playful composition, highlighting key landmarks and the structure of the historic centre through a more abstract visual language. Source https://mapkazdaszkiem.com/GDANSK/map-of-Gdansk--hotel-restaurant-attractions; Illustrated map of the city of Gdańsk available online, designed by WorldAroundStore.

In this framework, fortified structures become more than historic remnants—they are anchors for digital storytelling, capable of bridging physical experience with virtual immersion.

The act of digitalization, therefore, is not neutral. It carries curatorial implications: what to include, how to represent it, and for whom.

A semiotically-informed analysis enables a more ethical and inclusive process. It helps avoid the risk of techno-aesthetic abstraction and instead promotes a meaningful reconstruction of urban narratives. Digital heritage initiatives can—and should—be informed by such methodologies, ensuring that each digitized element retains its expressive power, its narrative function, and its cultural weight.

Understanding the evolution of Gdańsk through its fortifications, then, means engaging in a holistic project that merges physical preservation, cultural interpretation, and digital projection. Each bastion, tower, or wall segment is a sign of an era, a function, a vision. Each digital replica becomes not just a model, but a medium for dialogue between past and future.

This fortified system is not merely composed of individual objects to be studied; rather, it represents a tool through which the city can be read, remembered, and reimagined.

It enables an iconemic mapping: revealing limits, thresholds, and transitions; giving rhythm to urban perception.

To understand Gdańsk through its fortified signs means achieving a scientific-humanistic synthesis, blending phenomenology, history, semiotics, and cultural memory—with digital technology as a new interpretive layer. The city thus emerges as a landscape of signs, continuously expressing and

narrating itself. Its fortifications encapsulate spatial, temporal, and symbolic dimensions in a single palimpsest. Through them, the city reveals itself not as a static artifact, but as a dynamic system of signs—a text to be read, interpreted, and rewritten, generation after generation—both on the ground and in the digital realm.

References

Assunto R. 1980, *Paesaggio, ambiente, territorio: un tentativo di precisazione concettuale*, in *Rassegna di Architettura e Urbanistica*, 47-48.

Bateson G. 1984, *Mente e natura*, Adelphi, Milano.

Cullen G. 1976, *Il paesaggio urbano*, Coldeni, Bologna.

Parrinello S., Borucka J., Szczepański J., Picchio F. 2023, *Persistences: analysis of the image of Gdańsk and its cultural identity through survey processes and digital architectural representation*, in Luigini A. (ed.), *IMG Journal. Imaging and Imagery in Architecture*, 8, Publica, Alghero, pp. 258-283.

Parrinello S., Dell'Amico A. 2019, *Experience of documentation for the accessibility of widespread cultural heritage*, in *Heritage*, 2(1), pp. 1032-1044.

Szczepański J., Dymnicka M. 2016, *Dilemmas of Identity in Contemporary Cities. The City of Gdańsk as an Example*, in *Procedia Engineering*, 161, pp. 1225-1229.

Fig. 09
Gdańsk reconstruction
The sequence juxtaposes archival images of wartime devastation with contemporary views of the same urban spaces, revealing the profound transformation of Gdańsk and the careful reconstruction of its historic fabric, where memory and renewal coexist in the present city.

Fig. 10
Gdańsk landascape, banner of the Prometheus project route
The composition assembles selected elements of Gdańsk's fortification system–bastions, gates and walls reinterpreted as a continuous landscape along the water, where defensive architecture and natural surroundings merge into a stratified and evolving territorial structure.

GDAŃSK THE CITY OF DIVERSITY,CONTRASTS AND A TURBULENT HISTORY

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Side Page, Fig. 01
Gdańsk territorial framework
Fragment of a map of Gdańsk showing the city centre and the area of the fortifications included in the project study.

Gdańsk is one of the most important and fascinating cities in Poland, featuring a diverse urban landscape rich in both tangible and intangible heritage. This heritage is present on multiple levels throughout the city. The strategic geographical location and dynamic development over the centuries have shaped Gdańsk into the city it is today, with a rich and unique history, spanning a thousand years. Since the Middle Ages, Gdańsk has been one of the largest trading ports on the Baltic coast, a unique Free City at various points in its history, the place where World War II began, and the birthplace of the Solidarity movement. The city seamlessly blends beautiful monuments and traces of diverse historical influences with contemporary culture and a vibrant atmosphere. Here one can encounter historic interiors, modern facilities, natural landscapes, and a thriving cultural scene. The cultural heritage of Gdańsk is reflected not only in its physical landscape but also in its spiritual legacy, which includes the tradition of Solidarity, the merchant ethos of the medieval Hanseatic League, and a number of outstanding personalities associated with the city, such as Johannes Hevelius, Daniel Fahrenheit, Arthur Schopenhauer, Daniel Chodowiecki, and Nobel Prize holders Günter Grass and Lech Wałęsa. The historic city, with its large port, thriving industry, and thousands of residents and tourists, was selected as one of the case studies for the Prometheus Project.

Gdańsk: between the hills and the sea

Gdańsk is located in the north of Poland at the Baltic Sea. It occupies an area of great natural diversity. To the west stretches the Gdańsk Upland, to the east the vast plain of the *Vistula* Delta. The city is placed on the edge of the Kashubian Lake District, which is part of the Pomeranian Lake District, where gentle moraine terrains with small hills, lakes and forests in the valleys dominate, and at the Radunia and Vistula rivers with their numerous tributaries create picturesque gorges and meanders. Situated at the mouth of the *Vistula* River, Gdańsk is closely connected to this crucial Polish river, which has played a significant role in its development. The river, which flows across Poland, has been integral to the city's growth, with Gdańsk's location at its mouth shaping much of what the city is today. The strategic location of Gdańsk at the river's mouth has historically linked the city to the mainland, facilitating trade. Goods transported via the *Vistula* River were processed in Gdańsk and sold there, contributing to the city's prosperity[1].

Fig. 02
Gdańsk's location in the north of Poland on the Baltic Sea at the mouth of the Vistula River
This location of Gdansk has shaped much of today's city.

[1] Szermer's work highlights the importance of this connection between Gdańsk and the Vistula River. Szermer B., Gdańsk past

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Fig. 03
View of Gdańsk Main Town with St Mary's Church, which is the landmark of the Main Town
Vistula lowlands landscape in the background photo by Szymon Kowalski

Beyond the river, Gdańsk's natural landscape is shaped by various elements, including moraine hills, the sea, picturesque beaches, dunes, and the *Vistula* lowlands, known as *Żuławy*. The most diverse natural scenery can be found in the moraine hills, formed by glaciers. These hills, covered with lush greenery, rise several meters above the surrounding landscape, extending to the high hills of nearby city of Gdynia. The area is further characterized by beautiful valleys and gorges. The steep slopes of the hills are mostly covered with trees and form a beautiful and very characteristic part of the natural landscape. The hills were also the natural borders of the city of Gdańsk and formed a boundary for the development of Gdańsk in the past. Two of these hills are Bishop Hill (*Biskupia Góra*) and Gradow Hill (*Grodzisko*). They form the western border of the city center and the natural fortifications of historical Gdańsk.

Another notable natural feature of Gdańsk is its coastline along the sea and the Gulf of Gdańsk, which is renowned for its attractive beaches developed over centuries. The coastline is primarily characterized by dunes and sandy beaches, including those extending beyond Nowy Port – Gdansk city district and *Westerplatte* penisula. Many of the dunes along the coastline are now protected as part of the region's natural heritage. These dunes are covered with greenery typical of dune eco-systems and play a crucial role in shielding the adjacent *Vistula* Delta lowlands. This area, situated approximately 1.2-1.8 meters below sea level, represents a distinct natural landscape influenced by

and present (in Polish: Gdańsk przeszłość i współczesność), Wydawnictwo Interpress, Warszawa 1971, pp. 7-8.

Fig. 04
Bird's-Eye View of Gdańsk's Historic Centre
The image presents an aerial view of Gdańsk's historic core, highlighting the compact urban fabric, the ordered sequence of streets and gates, and the strong relationship between the city and the Motława River, which shapes its distinctive spatial structure. Photo by Dominik Werner.

the surrounding environment. Much of this landscape is man-made. In the past it was settlers and the deliberate human activity that brought these areas into the city. There are still many *Grobla* channels in the meadows around Gdańsk. Interestingly, we can also find them in the names of Gdańsk streets. This diverse landscape places many development restrictions on the city, but also unique opportunities and potential.

Gdańsk is bordered by the waters of the Baltic Sea, the forested areas of the Kashubian Lake District, the moraine hills, and the *Vistula* Delta, including the *Żuławy* region, which lies below sea level. These diverse geographical features have historically played a crucial role in the city's defence and have significantly influenced its urban structure.

Today, Gdańsk stretches over an land area of 258 km^2 (Report…, 2023)[2]. Together with the nearby resort of Sopot and Gdynia - a city built from scratch in the early 20th Century, it forms an agglomeration called the Tricity. The natural landscape of the entire Tricity and its unique location facilitate the cultural and economic and historical development of the city. Known as "Poland's window to the world", Gdańsk had the opportunity to develop rapidly, contributing to its turbulent history and the dynamic nature of its inhabitants.

[2] Gdańsk, including the area under the internal sea waters of the Gulf of Gdańsk, covers an area of 683 km2, while the land area of the city of Gdańsk has an area of 258 km^2. (Report ..2023 p.4)

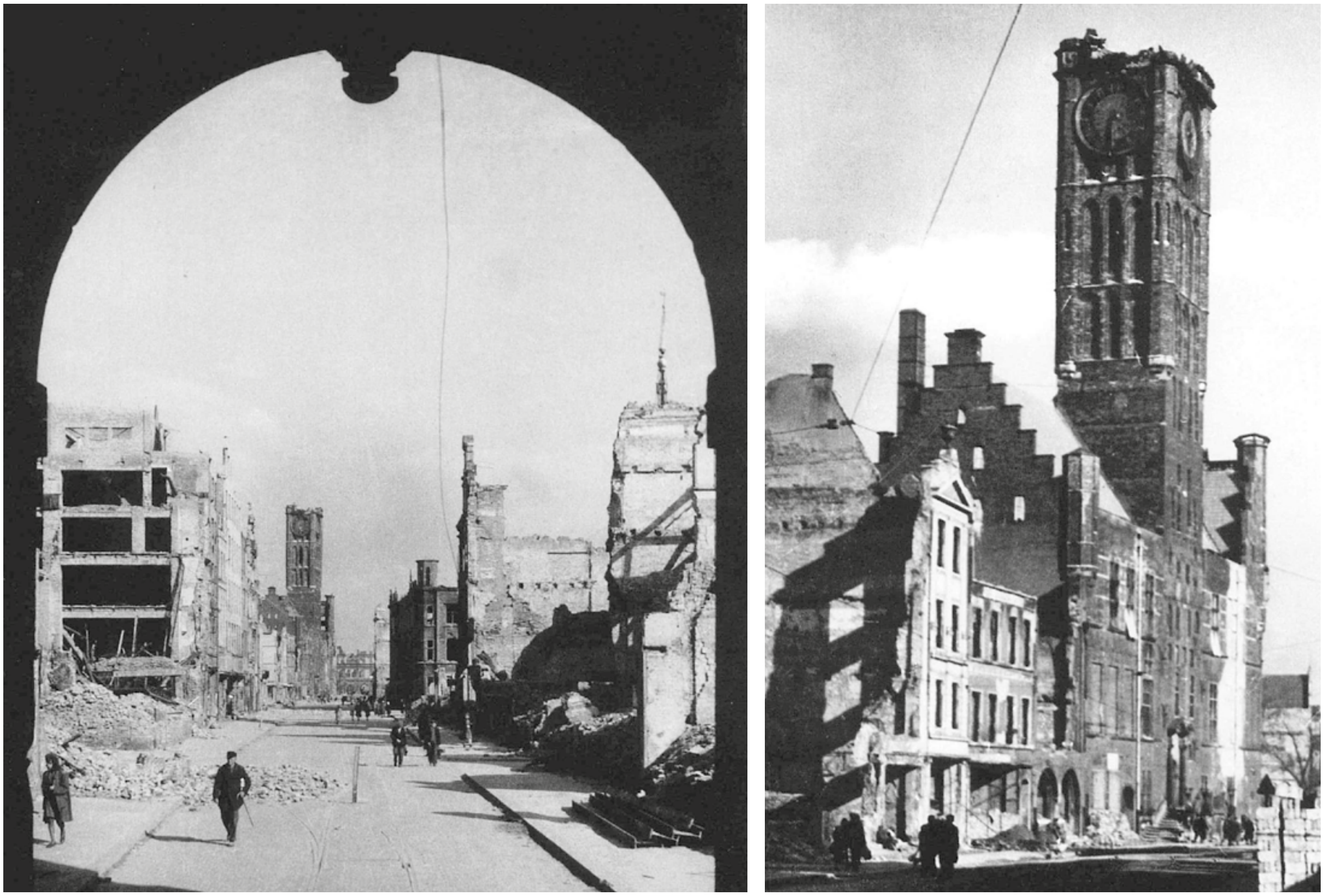
Fig. 05
View of Gdańsk
Top left
Bird's-eye view of Gdańsk with the heritage of the fortification system clearly visible in the landscape, photo by W. Stępień (source: https://www.gdanskstrefa.com/adam-koperkiewicz-gdanscy-tworcy-europejskiej-nauki/obraz1/)
Top right
View of the Gdańsk shipyard in the immediate vicinity of the city centre, Gdańsk port and Gdańsk bay in the background photo by Dominik Werner
Bottom left and right
Two contemporary architectural icons of Gdańsk: Museum of the Second World War (left) and Solidarity Centre (right) photos by Szymon Kowalski.

The history milestones of Gdańsk city

Gdańsk is one of the oldest cities in Poland. By exploring its history and key events that have shaped the city, we uncover a wealth of fascinating discoveries. While the past is rich and vibrant, it is also complex and challenging to fully grasp. Throughout Gdańsk's tumultuous history, we can identify several pivotal moments that transformed the city's character.

The beginnings of Gdańsk's history date back to the 10th Century[3]. The foundation of Gdańsk at a key crossroads—where land and water trade routes of medieval Europe intersected, including the Amber Road to the south and the Vistula Road running through Poland—was crucial to its early development. The city experienced rapid growth, but in 1308, it was seized by the Teutonic Order. Under Teutonic rule, medieval Gdańsk evolved into a group of cities. In 1454, the inhabitants of Gdańsk overthrew the Teutonic Knights and the city returned to Polish control. However, during the second partition of Poland in 1793, Gdańsk was annexed by Prussia. In 1807, during the Napoleonic Wars, French troops occupied the city, which briefly gained the status of a free city. This status

[3] Stankiewcz, Szermer (1971), *Gdańsk. Landscape and architecture of the urban complex (Gdańsk. Krajobraz i architektura zespołu miejskiego.*

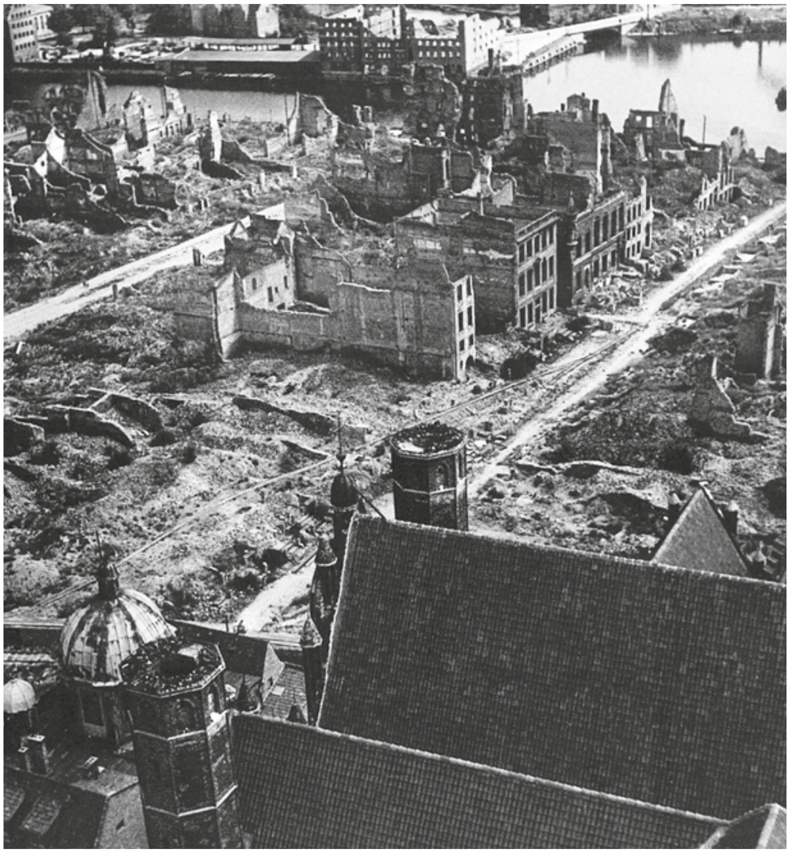


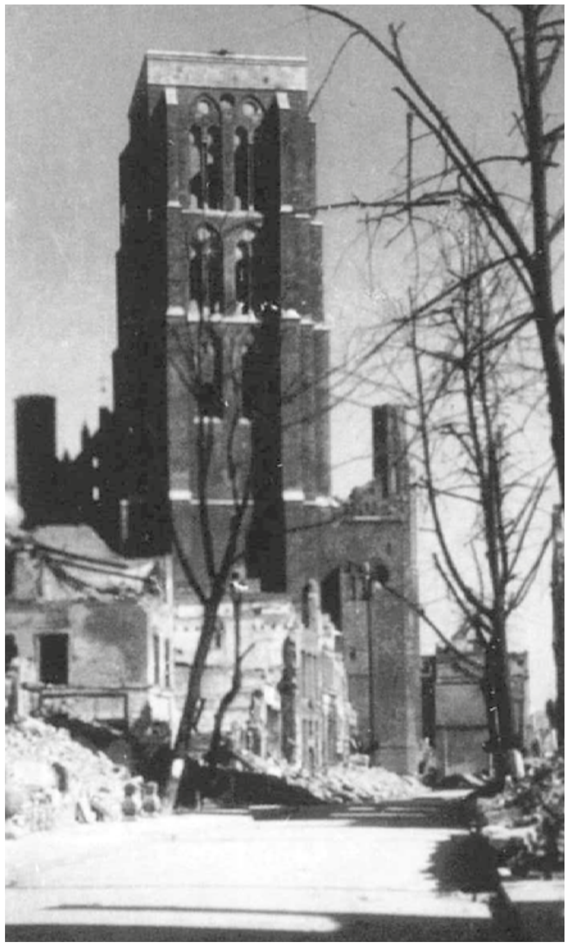
was revoked in 1815 when the Congress of Vienna confirmed Gdańsk as part of Prussian territory. The next significant change came in 1920 with the establishment of Gdańsk as a Free City. This status was altered with the outbreak of World War II. In 1939, Gdańsk was the site where the war began, and the city was incorporated into Nazi Germany. It was liberated in 1945, but not before suffering immense destruction, with 90% of the historic center being devastated. Since the end of World War II, Gdańsk has been a Polish city, but it is distinct from other Polish cities due to its wartime history. Despite the extensive damage and the challenges of post-war recovery, including efforts to erase traces of Prussian influence and plans to replace the historic city center with working-class residential areas, efforts were made to partially restore and revive the city's former splendor[4]. Thanks to this reconstruction, we can now see that modern Gdańsk is a continuation of its rich history. It is this history, spanning over a thousand years, that breathes life into the city, thanks to its society and residents.

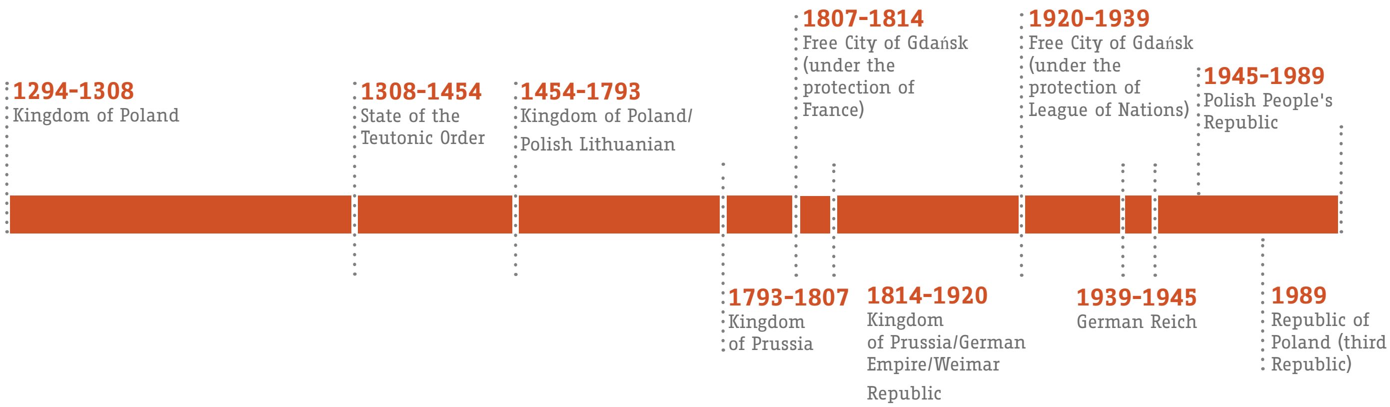
Fig. 06
The historic centre of Gdańsk was destroyed by 90% during World War II
The ruins on Dluga Street (left) and the destroyed tower of the Main Town's city hall (right), photo by Wieslaw Gruszkowski (from collection of Faculty of Architecture GdanskTech).

Next page, Fig. 07
The historic centre of Gdańsk was destroyed by 90% during World War II
The sequence contrasts scenes of destruction with moments of reconstruction, revealing how Gdańsk's historic centre was not only rebuilt but reinterpreted, where fragments of the past informed a deliberate process of architectural and urban redefinition. The ruins on Dluga Street (left) and the destroyed tower of the Main Town's city hall (right), photo by Wieslaw Gruszkowski (from collection of Faculty of Architecture GdanskTech).

[4] Cieślak, Biernat Cz. (1995), *History of Gdańsk*.







Previous page, Figs. 08, 09
The rich history of Gdańsk is inscribed in its architectural landscape
A characteristic element of Gdańsk's architecture are tenements with stoops (top view: post-war photograph of the remains of the original stoops elements, authentic in form and substance, bottom view: facades of the reconstructed buildings), photo by Wieslaw Gruszkowski (from collection of Faculty of Architecture GdanskTech).

Fig. 10
City development - Timeline
The change of Gdańsk's statehood over the centuries - timeline. Panoramic view of the centre of Gdansk - Długie Pobrzeże - waterfront promenade in Gdansk's Main Town, stretching along the west bank of the Motlawa River (photo abowe) photo by Harald Gatermann.

Next Page, *Fig. 11*
Dluga and Dlugi Targ street
Main axes of the Main Town, View form Golden Gate.

Gdańsk city today as a vibrant Europe hub for society

Today, Gdańsk has over 480,000 inhabitants and stands as a vibrant European cultural hub and dynamic social center. The city is a blend of many cultures and communities, a characteristic that has always defined it. As an important port city in the Baltic Sea region, Gdańsk has long welcomed newcomers. The city has been tolerant and open to new cultures and religions, making it a truly multinational place. Gdańsk has been home to Prussians, Poles, Germans, and immigrants from the Netherlands, Scotland, and other European countries fleeing religious persecution. This diversity has made the city a thriving center for the development of urban life, culture, and science, contributing significantly to its enrichment[5]. Gdańsk has given the world many notable figures, such as the renowned astronomer Johannes Hevelius, Daniel Fahrenheit, who introduced the temperature scale still in use today, and the accomplished draughtsman and painter Daniel Chodowiecki. The city is also the birthplace of the great philosopher Arthur Schopenhauer and Nobel Prize laureates like the writer Günter Grass and Lech Wałęsa, who is globally recognized and strongly associated with the Solidarity movement.

[5] Loew (2013), *Danzig: Biographie einer Stadt (Gdańsk: biografia miasta, transl. Górny J.)*; Loew (2012), *Danzig und seine Vergangenheit 1793-1997 Die Geschichtskultur einer Stadt zwischen Deutschland und Polen (Gdańsk i jego przeszłość: kultura historyczna miasta od końca XVIII wieku do dzisiaj, transl. Mosakowski J.)* .

Fig. 12
Elisabeth Hevelius
Observing the sky with a brass octant. Detail from an engraving from Johannes Hevelius's "Machinae Coelestis: Pars Prior", (1673), fig. 0, facing p. 254.

Fig. 13
Johanna Schopenhauer
Doris Maurer: Charlotte von Stein. Frankfurt am Main, insel 1997. S. 230.

During its golden age in the 17th and 18th centuries, Gdańsk was not only a center of cultural development but also a place where women enjoyed considerable emancipation. Among the prominent women of Gdańsk, we can mention Elżbieta Koopman, the first female astronomer and wife of Jan Hevelius, and Johanna Schopenhauer, the mother of the famous philosopher. The city was partially abandoned at the end of the World War II.

The new inhabitants of Gdańskcame from the former Polish lands as a result of migration. Thanks to the new economic situation and new perspectives, the newcomers, despite their different backgrounds and origins, successfully tried to restore the former glory of Gdańsk, to rebuild the city and restore its development. Today's generations do not remember Gdańsk in ruins, but are still very active in searching for the city's development and thinking about the legacy of Gdańsk's former inhabitants. Today, the city continues to honor the memory of its past and the significant contributions of its citizens[6]. Currently, the city is an important center of cultural life including events, such as festivals, concerts and exhibitions. There are many annual events and performances in the public space of the city, that effectively weave elements of the history and heritage of the city, such as the green areas of the fortifications. As previously mentioned, the city has experienced numerous migrations of people throughout its history. The influences of various cultures and nations are still evident in the city's layout, its divisions, and the names of its districts and streets.

Unique urban tissue

Gdańsk consists of many districts, which reflect the historical development of the city and the influence of its residents. The structure of the city is very diverse. Individual districts are clearly outlined in the context of the entire city. Each of them has its own character and creates a unique atmosphere. For example, the contemporary Gdańsk made out of large-prefab housing estates (among others *Przymorze*, *Zaspa*, *Piecki-Migowo*) or historical ones, such as Oliwa and *Śródmieście* districts- are all very different and unique. It was the Downtown (*Śródmieście*) that was rebuilt with great care after World War II. Here too, within the historic city center, we can distinguish individual elements of the urban structure, such as: Main Town (*Rechtstadt*) - the most important element of medieval and modern Gdańsk, with the main axis of *Długa* and *Długi Trag* streets (Fig. 10), the dominant feature of which is the Church of the Blessed Virgin Mary, magnificent Gothic and Renaissance buildings, built between the 14th

[6] The city hosts the Solidarity center - a museum of an important movement in Poland, which greatly influenced the current political state of Europe. There is also a new city art galleries dedicated to, among others, Günter Grass and Daniel Chdodwiecki, one of the branches of the Gdańsk Museum has been restored to its original state of Uphagen House, others are located in nobility buildings of Gdańsk architecture - the complex located at the foregate of the main city.

Fig. 14
The architectural image of the city is a unique spectrum of history of art of construction
The Neptune's Fountain and St Mary's Church are two of the city's most distinctive landmarks.

and 17th centuries, during the heyday of the Hanseatic League[7], destroyed during the Second World War, but rebuilt with great care and attention to detail on the basis of the historical urban fabric, Old Town (Altstadt) - the second most important part of the Gdańsk urban complex, with its own Town Hall, a dominant architectural complex along the Radunia Canal, such as the Great Mill, built in the second half of the 14th Century, St Catherine's Church, the Brigittine Monastery, Granary District with a series of granaries on the other side of the Motława River, the so-called Granary Island[8] (*Speicherinsel*) and Ołowianka Island (*Bleihof*), which is a separate island with some industry, Suburbs: the Old Suburb (*Vorstadt*) and the Lower Town (*Niederstad*), which border the Main Town district to the South, with preserved 17th-Century bastions and new residential buildings currently being built on the waterfront. All these main elements of Gdańsk's city centre are surrounded by man-made fortifications built in depressions or on natural hilltops, such as the Bishop's Hill and Gradowa Hill.

[7] Gdańsk exemplified a typical Hanseatic city. The shared economic activities of the Hanseatic League cities influenced various aspects of daily life, leading to similarities in their structure. The urban design of these cities followed a comparable pattern, featuring a characteristic street layout, distinctive buildings, town halls, churches, gates, and marketplaces, all primarily constructed from brick.
[8] Granary Island, in the heart of the city, is currently undergoing a rebirth with the construction of modern buildings.

Fig. 15
Panoramic view of Gdańsk city center
The image presents the waterborne entrance to Gdańsk, where the Motława River opens onto the historic skyline, revealing a continuous frontage of facades, the Swan tower on the right and landmarks that define the city's identity as a maritime gateway.

An important element of Gdańsk's current landscape are the shipyard areas to the north of the city centre- these areas arecurrently being developed into a new district, called the Young City. The architectural image of the city is a unique spectrum of history of art of construction. Starting in the Middle Ages, in the Gothic style, through new architectural forms brought by the period of the mid-16th and early 17th centuries, then the Renaissance, Prussian architectural remains and the transformation of the city into a modern commercial, industrial and administrative centre. This last transformation begun in the middle of the last century. The new order of the western part of the city centre was built in a metropolitan style around 1900. The structure of today's city is also influenced by the post-war period: a reduction in the density of development in the city centre, the intuitive introduction of new buildings in the 1950s, and the tidying up of newly built structures after political changes. The picture is completed by newly created architectural icons: the Shakespeare Theatre, the Museum of the Second World War and the European Solidarity Centre. In the Old Town, less attention was paid to the reconstruction of the city's former image, and a plan for a modern Gdańsk was implemented, but based on the old layout and street grid: with high-rise hotels and office buildings and free-standing residential buildings. Due to the marshy areas on the southern side (*Żuławy Gdańskie - Danziger Werde*r), the city's development was directed northwards. When analysing the very diverse structure of Gdańsk, two key features immediately stand out. First, the original layout of the city, protected by bastions, is still clearly visible. Second, we can distinguish three separate centres: the northern one, called the Old Town, the central Main Town and the southern one, called the Old Suburb. The historical city centre of Gdańsk thus includes: the Old Town, the Main Town and the Old Suburb, the Granary Island and the *Ołowianka* Island, as well as the areas to the east, within the boundaries of the former city fortifications, historically known as the Long Gardens and the Lower Town. In the context of the Prometheus project, it was important to define the territorial scope of the project, and this was mainly the area of the city center, as described above, and the areas in the immediate vicinity, where the important elements of fortifications. It is this diverse area of modern Gdańsk that became the subject of analysis of the military structure at the city level[9].

[9] Parrinello, et al (2023), *Persistences: analysis of the image of Gdańsk and its cultural identity through survey processes and digital architectural representation*,.pp. 258-283.

Fig. 16
City development - Between Historic Fabric and Contemporary Development
The image highlights the contrast between the historic cityscape and recent architectural interventions, with the cathedral rising in the background above the dense urban fabric, while the Shakespeare theatre built by architect Renato Rizzi (2014) occupies the foreground, expressing the ongoing dialogue between heritage and contemporary urban transformation.

Gdańsk is a city of many facets, characterized by its rich natural landscape, vibrant culture, and thriving economy. Another crucial aspect is its turbulent history, which spans over a thousand years. This history is embedded in the city's diverse landscape and urban structure, visible in its ornate tenement houses, monuments, and significant buildings such as town halls, grand churches, towers, and defense systems. Exploring these elements allows us to understand and preserve this unique heritage. Understanding the blend of tradition and modernity, along with the factors that unite them, reveals the contemporary image of Gdańsk. This was primary goal of the Prometheus project.

References

Cieślak E., Biernat Cz. 1995, *History of Gdańsk*, Fundacja Biblioteki Gdańskiej, Gdańsk.

Loew P. O. 2013, *Danzig: Biographie einer Stadt (Gdańsk: biografia miasta, transl. Górny J.)*, Instytut Kultury Miejskiej, Gdańsk.

Loew P. O. 2012, *Danzig und seine Vergangenheit 1793-1997 Die Geschichtskultur einer Stadt zwischen Deutschland und Polen(Gdańsk i jego przeszłość: kultura historyczna miasta od końca XVIII wieku do dzisiaj, transl. Mosakowski J.)*, Wydawnictwo Słowo/obraz Terytoria, Gdańsk.

Parrinello S., Borucka J., Szczepański J., Picchio F. 2023, *Persistences: analysis of the image of Gdańsk and its cultural identity through survey processes and digital architectural representation*, in *IMG Journal*, 8, pp. 258-283.

Stankiewcz J., Szermer B. 1971, *Gdańsk. Landscape and architecture of the urban complex (Gdańsk. Krajobraz i architektura zespołu miejskiego)*, Arkady, Warszawa.

Szermer B. 1971, *Gdańsk past and present (Gdańsk przeszłość i współczesność)*, Interpress, Warszawa.

Urząd Miasta Gdańska 2023, *Report on the State of the City of Gdańsk for 2023(Raport o stanie miasta Gdańska za 2023 rok)*, Gdańsk.

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Side Page, Fig. 01
The Maricka Street a view from the St. Mary's Gate in Gdańsk
A glimpse into the heart of a city shaped by time and tradition.

The urban landscape of Gdańsk has been shaped by its history and geographical location. The city is situated on the Central European Plain, formed during the Pleistocene glaciation by the Scandinavian glacier. Within the plain, there is a scarcity of suitable stone for construction, aside from boulders transported by the glacier. However, there is an abundance of clay suitable for brick production. Therefore, the primary building material used in Gdańsk buildings since the 14th Century has been red brick, typically measuring around 65-90 mm in height. The production of this type of brick began in the 12th Century in Lombardy. Through the intermediary of the Cistercian, Dominican, and Franciscan orders, via routes through Denmark, northern Germany, and southern Poland, brick became widespread in the Gdańsk Pomerania region[1]. The dominance of brick as a building material in the Gdańsk region was noted as early as the Middle Ages. The castle near Gdańsk in Malbork (Marienburg) was often referred to as being made of mud, in contrast to Milan with its marble and Buda in Hungary with its stone: "*Ex marmore Mediolanum, ex lapide Ofen (Buda), ex luto Marienburg*"[2].

Hard, difficult-to-work glacial stones, gathered from fields around Gdańsk, were used solely for constructing foundations and building plinths. Stones were also imported from Swedish islands, primarily limestone from Öland and sandstone from Gotland. Öland limestone, with its reddish, greenish, and gray hues, was used for flooring. Light-colored Gotland sandstone was used for architectural details, especially portals and sculptures. In the Middle Ages, most facades of Gdańsk buildings were covered with a thin red plaster in such a way that the texture of the brickwork was visible[3]. Geometric decorations in various combinations of white, red, and black complemented the structures.

Brick was a characteristic material for the central and middle areas of the Hanseatic League. This league, existing from the 13th to the 17th Century, comprised over 200 cities across present-day Netherlands, Germany, Denmark, Sweden, Poland, Latvia, Estonia, and Finland, with trading posts (kontors) in England, northern France, Norway, Lithuania, and Russia. The Hanseatic League was an organization protecting the economic interests of its members, but it was also a cultural and architectural community.

[1] Samól (2016), *The origins of the brick architecture in Pomerania*.
[2] de Anna (2019), *Il ruolo della Cavalleria nella cristianizzazione del Baltico nord-orientale*, pp. 263-309.
[3] Kriegseisen (2021),*Kolory Gdańska. Kompozycje barwne fasad od XVI do końca XVIII wieku*.

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Fig. 02
Gdańsk around 1600
After the construction of bastion fortifications on the western side. The individual districts are still separated by medieval walls and moats. In the center there is the Main Town, north of it (at the top) the Old Town, in the south Old Suburb and in the east the port and Granary Island surrounded by the branches of the Motława River. Swedish National Archives.

A distinctive variation of brick Gothic architecture developed here[4], with Gdańsk emerging as one of its major centers.In the 14th Century, the urban structure of the city was established, and it consisted of partially independent parts. The most important and wealthiest was the centrally located Main Town. To the north of it was the Old Town, and further north, along the *Vistula* River, was the Young Town. Each of these urban entities had its own fortifications and self-governing bodies. Along the *Motława* River, near the castle, was Osiek, which also had partial self-government but did not have its own defensive walls. To the south of the Main Town was the Old Suburb, and to the east there were several islands with warehouse buildings, including the largest, Granary Island. These islands and the Old Suburb were also surrounded by fortifications. This complex spatial layout was intersected by waterways. The Vistula and *Motława* rivers served as transportation routes, with port quays located along their banks. The waters of the *Motława* also fed the city's moats. The *Radunia* Canal provided power to numerous water mills located in the Old Town. The Siedlecki Stream supplied drinking water.

Since the 14th Century, the fabric of the city has been composed of tall, multi-story tenement houses, approximately 7 meters wide, topped with high roofs. As in other Hanseatic cities, the most important room in these houses was the grand hall located on the ground floor, reaching a height of up to 6 meters. In front of the tenement houses, there were decorated terraces adorned with stone vertical slabs covered with reliefs. Above the tenement houses, the imposing masses of brick parish churches, convents, and hospitals dominated the skyline. Secular public utility buildings included town halls, separate ones for the Main Town, Old Town, Young Town, and Osiek. Additionally, impressive buildings for merchant guilds were constructed, such as the Artus Court and the Brotherhood of St. George Court.

The medieval fortifications of the Main Town consisted of a double ring of brick walls with moats between the outer walls. The walls were reinforced with rectangular, circular, or octagonal towers. There were six defensive gates on the landward side and eight gates facing the port on the Motława River.

It wasn't until the middle of the 16th Century that modern forms began to appear in Gdańsk's architecture. Facades of buildings began to be renovated, while still retaining their structure with impressive hallways. For decoration, white-and-blue ceramic tiles were used in the hallways, contrasting with dark ceilings, furniture, and floors made of Swedish limestone. In the second half of the 16th Century and in the 17th Century, Gdańsk architecture took on the forms of the so-called "Northern Renaissance", characteristic of areas around the North and Baltic Seas from Flanders through the Netherlands, northern Germany to Scandinavia and northern Poland. The Northern Renaissance retained many features of brick Gothic, such as slender proportions of buildings, the use of red walls with black and white decorations, high roofs, and corner turrets in an octagonal plan. The economic development of the city in the 16th and 17th centuries did not bring about changes in the urban structure of Gdańsk's city center.

[4] Schildhauer (1984), *Die Hanse*.

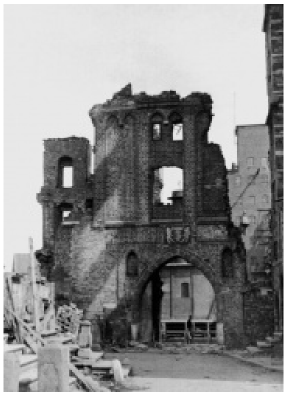

Fig. 03
Brick Gothic - St. Mary's Gate
After 1457 (in the middle) and brick northern Renaissance – House of the Natural History Society, 1597-1599 (on the right). Before 1945 (down) and after the war damage (up).

Conservative burghers were satisfied with renovations of existing buildings. Among the few new-style structures entirely built anew are the Great Armory and the Old Town Hall. The massive Gothic churches fulfilled the needs of the residents. In the 17th Century, only two new Baroque sacral buildings were erected, both intended for the Catholic minority in the Protestant city. These were the Royal Chapel in the historical center and the Jesuit church in the southern suburb of Stare Szkoty, beyond the line of defensive walls. The most significant changes that occurred in the 16th and 17th centuries concerned the system of fortifications. Advances in military technology, particularly the increased range of artillery, necessitated the replacement of medieval walls with more modern fortifications. The western front of the city, facing the hills, was the most vulnerable. After 1570, a series of brick Italian-style bastions were erected to defend the Old Town, Main Town, and Old Suburb[5]. The number of gates was reduced. The High Gate, the most important western entrance to the city, was redesigned to resemble a Roman triumphal arch.

At the beginning of the 17th Century, fortification efforts extended to the north, east, and south of the city. A line of mighty earthworks in the form of "old Dutch" bastions, protected by wide moats, was constructed. New gates were erected: *Low* Gate from the south, *Żuławy* Gate from the east, and St. Jacob Gate from the north. The area covered by the new fortifications provided opportunities for the development of Gdańsk's city center towards the east, in the area known as Lower Town. The encirclement of the entire city with a unified ring of fortifications and the gradual dismantling of parts of the medieval walls and moats caused the division into districts to become less distinct.

The next stage in the development of modern fortifications was the reinforcement of the hilltops adjacent to the city from the west in the second half of the 17th Century, as well as the valley between these hills. The fortifications on the hills, along with the road leading along the Vistula River to the Wisłoujście fortress, were strengthened and rebuilt throughout the 19th Century as a result of experiences during sieges in the Napoleonic Wars. In the second half of the 17th Century, Poland was engulfed in wars, leading to a prolonged economic and political crisis, which culminated in the partition of the country between neighbours - Russia, Austria, and Prussia - from 1772 to 1795. The weakening of the country resulted in an economic downturn for its most important trading center - Gdańsk. In the 18th and 19th centuries, the city's architecture became increasingly provincial. The potential for development in the city center, in the areas of Lower Town was not realized. The lack of economic opportunities led to Gothic and Renaissance buildings continuing to dominate the cityscape. One of the few exceptions during this period was the neoclassical theater building constructed between 1799 and 1801.

Almost until the end of the 19th Century, Gdańsk remained a fortress. A wide strip of land surrounding the city was designated, with strict building restrictions in this area. As a result of these limitations, areas

[5] Bukal (2006), *Fortyfikacje Gdańska 1454–1793*, pp. 20-47.

between the historic center and the newly developing suburbs of *Wrzeszcz* and Nowy Port remained undeveloped, which is still visible today in the form of discontinuity in the city's fabric.

At the turn of the 19th and 20th centuries, several new public buildings were constructed, echoing the architecture of the "Northern Renaissance" from the city's prosperous times. These included primarily the buildings of the Technical University, the main railway station, and the market hall[6].

As a result of the provisions of the Treaty of Versailles in 1920, Gdańsk became the Free City. The city's economic separation from Poland did not foster economic development, and as a result, significant architectural projects did not emerge. Ambitious plans for the expansion of the northern suburbs were not realized. By 1939, the historic centre of Gdańsk had survived with hundreds of preserved Gothic and Renaissance buildings from the city's "golden age." However, in the final weeks of World War II, in March 1945, the centre area was almost completely destroyed.

In 1948, a decision was made to rebuild the historic centre[7]. The architectural division into former districts of the city was restored. In the area of the Main Town, the historic urban layout and façade lines referring to the city's last years of glory in the 18th Century were reinstated. Behind the historicizing facades, modern residential buildings were concealed. The Old Suburb was rebuilt according to modernist urban planning concepts, erecting standalone residential blocks that contrasted with the preserved Gothic churches. In the Old Town area, various conceptual projects were started but not completed. The development of Granary Island began only in the 21st Century.

References

Bukal G. 2006, *Fortyfikacje Gdańska 1454–1793*, in G. Bukal (ed.) *Fortyfikacje Gdańska*, Gdańsk, pp. 20–47.

de Anna L.G. 2019, *Il ruolo della Cavalleria nella cristianizzazione del Baltico nord-orientale*, in *Chiesa e Storia*, IX, pp. 263-309.

Kriegseisen A. 2021, *Kolory Gdańska. Kompozycje barwne fasad od XVI do końca XVIII wieku*, Gdańsk.

Samól P. 2016, *The origins of the brick architecture in Pomerania*, in *3rd International Multidisciplinary Scientific Conference on Social Sciences and Arts SGEM2016 Book 4: Artis, Performing Arts, Architecture and Design*, vol. II, pp. 757-764.

Schildhauer J. 1984, *Die Hanse*. Geschichte und Kultur, Leipzig.

Szczepański J., Dymnicka M. 2016, *Dilemmas of Identity in Contemporary Cities. The City of Gdansk as an Example*, in *Procedia Engineering*, 161, pp. 1225-1229..

Szczepański J. 2019, *Architektura zespołu Politechniki Gdańskiej 1904-2018*, Gdańsk.

[6] Szczepański (2019), *Architektura zespołu Politechniki Gdańskiej 1904-2018.*

[7] Szczepański, Dymnicka (2016), *Dilemmas of Identity in Contemporary Cities. The City of Gdansk as an Example, pp. 1225-1229.*

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Side Page, Fig. 01
Targ Węglowy (Dominikański), od północy, Gr Al. 4099/21 (from the collection of the Polish Academy of Sciences Gdansk Library).

The historical knowledge gained by historical research in archives and all activities dealing with existing documentation of the heritage always constitute the strong base and foundation for the future investigation. Before working with the built heritage one must understand the object of the research, its history and development in order to define the current state and its future existence. It was extremely crucial for the definition of the current problems and needs of the urban fortification system in Gdańsk for dealing with this heritage, its protection, maintenance and future use. It has been studied by many researchers before being a good starting point for the project. Strong involvement of the researchers of history of architecture from the Gdańsk University of Technology project research group was also the advantage of the partnership and the project. The investigation of the Gdańsk urban fortified heritage for the Prometheus Project was initiated by activities on site combined also with activities in historical archives, historical maps and drawings analysis.

Archive sources for research and study

The subject of the project's research are the fortifications of Gdańsk. The Gdańsk fortress played an important role in the wars in Northern Europe, which led to the creation of a large, complex defence system that has been the subject of scientific research since the 19th Century[1]. After World War II, the main center for research on Gdańsk fortifications became the Department of the History of Architecture at the Faculty of Architecture of the Gdańsk University of Technology[2]. Due to the battles for Gdańsk fought by many nations, documents regarding the Gdańsk fortifications

[1] Hoburg (1852), *Geschichte der Festungswerke Danzigs (History of Danzig's fortifications)*; Koehler (1893),*Geschichte der Festungen Danzigs und Weichselmünde bis zum Jahre 1814 in Verbindung mit der Kriegsgeschichte der freien Stadt Danzig (History of the fortresses of Danzig and Weichselmünde up to 1814 in connection with the war history of the free city of Danzig)*, Kloeppel (1937), *Das Stadtbild von Danzig in den drei Jahrhunderten seiner großen Geschichte (The cityscape of Gdańsk in the three centuries of its great history)*.

[2] Stankiewicz, Szermer (1959), *Gdańsk, rozwój urbanistyczny i architektoniczny oraz powstanie zespołu Gdańsk-Sopot-Gdynia (Gdańsk, urban and architectural development and the creation of the Gdańsk-Sopot-Gdynia complex)*; 1960; 1976; Biskup, 1998; Bukal (2006), *Fortyfikacje Gdańska (Fortifications of Gdańsk*; Bukal (2012), *Fortyfikacje Gdańska i ujścia Wisły 1454-1793. Studium z dziejów nowożytnej architektury militarnej (Fortifications of Gdańsk and the mouth of the Vistula river 1454-1793: A study in the history of modern military architecture)*; Hirsch (2009), *Początki fortyfikacji nadbrzeżnych Gdańska (The beginnings of Gdańsk's coastal fortifications)*, pp. 35-46; Szczepański (2000), *Stone Sluice Mill, in International Conference Preservation of the Engineering Heritage Gdańsk*; Samól at al. (2021), *History of the Lighthouse of the Wisłoujście Fortress in Light of a 2018 Architectural Study*, Samól at al. (2022), *Wreath from the Wisłoujście Fortress, Dating from the 1560s, and Its Transformation and Damage in the War of 1577 in the Light of Architectural Research from 2020–2022* 2023, pp. 62-79; Samól at al. (2023), *Where the Second World War in Europe broke out. The landscape history of Westerplatte*, p. 596.

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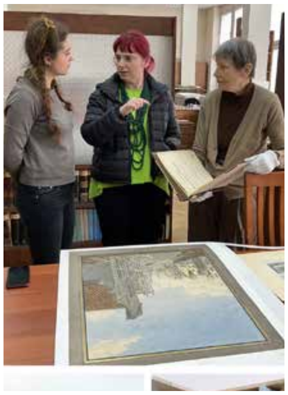






Fig. 02, 03
Activities in historical archives
Historical maps and drawings analysis in Polish Academy of Sciences Gdańsk Library (*Polska Akademia Nauk Biblioteka Gdańska*) and State Archives in Gdańsk (*Archiwum Państwowe W Gdańsku*)conducted by project research team. The investigation of the urban fortified heritage of Gdańsk for the Prometheus Project is based on historical sources from the State Archives in Gdańsk (*Archiwum Państwowe w Gdańsku*).

are in the archives of many countries. These are primarily: Poland, Germany, Sweden and France. A large collection of iconographic sources, including maps and plans of Gdańsk's fortifications, can be found in the State Archive in Gdańsk. Hundreds of drawings and descriptions depicting fortifications are contained in, among others, archival collections: 10/1121/0 Royal Prussian Fortification in Gdańsk (Koniglisch-Preussich Fortifikation der Stadt Danzig), in a collection of 263 plans of Gdańsk fortifications from 1649-1916; 300.18 - Military (1520-1821); 300.92 - Files of the Senate of the First Free City of Gdańsk (1774-1814); 300.20 - Wall Office (1547-1813); 300.90 - War Council (1658-1812), 300.MP - Collection of Plans and Maps (1520-1942). A large part of historical documents is digitized and available on the Internet at the following addresses: https://www.gdansk.ap.gov.pl/ and https://www. Szukawarchiwach.gov.pl/. The second Gdańsk institution that contains numerous historical iconographic documents regarding Gdańsk fortifications is the Gdańsk Library of the Polish Academy of Sciences, including the Graphic Arts Workroom, Cartography Workroom and Photography Workroom (https://bgpan.gda.pl/). Among the archives outside Gdańsk, the most important are: Secret State Archives of Prussian Cultural Heritage Berlin (https://gsta.preussischer-kulturbesitz.de), which contains numerous drawings of Gdańsk fortifications from the times when the city belonged to Prussia. Documents from the Napoleonic Wars are located in the Archives at *Chateau de Vincennes* in France (https://www.servicehistorique.sga.defense.gouv.fr/). A relic of the wars fought in the 17th and 18th centuries are the collections of plans for the fortifications of Gdańsk in the Royal War Archive, which is part of the Swedish National Archives (https://riksarkivet.se/stockholm). Collections of photographs of Gdańsk fortifications are located at the Herder Institute for Historical Research on East Central Europe (https://www.herder-institut.de/bildkatalog/). Design drawings of the military barracks can be found at the Technical University Berlin Architecture Museum (https://architekturmuseum.ub.tu-berlin.de/). During the exchange of partners/ conducting the project work many research profited from those surces of information and only some of them were visited: Gdansk National Archive, GdanskTech Architecture Library Archive, PAN Library Archive.

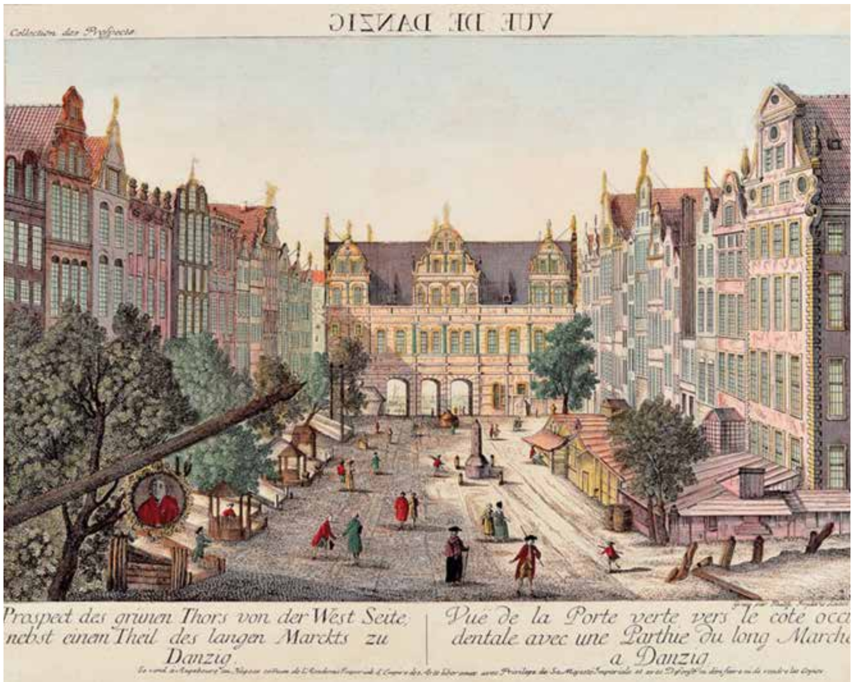
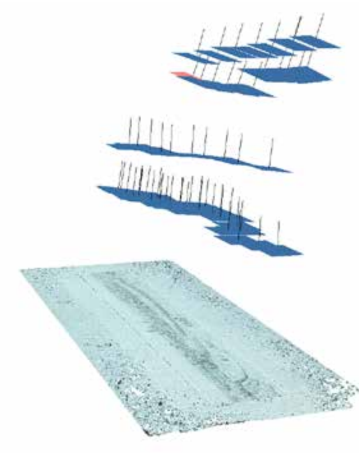


Fig. 04-07
View from the archives
Above Left – View of the Green Gate from the western side with a fragment of the Long Market, Gdańsk. Engraving by Balthasar Friedrich Leizel, publisher; Negoce Commun de l'Académie [...], Augsburg, second half of the 18th century. Source https://www.nasz.gdansk.pl/ Above Right – Gdańsk fortifications – bastioned plan Down Left: Gothic and modern fragment of the Main Town from: Aegidius Dickmann, Praecipuorum locorum et aedificiorum, quae in urbe Dantiscana visuntur, adumbracio, 1617, etching: The Dluga Street towards the west, Gr AL. 4091/11 (from the collection of the Polish Academy of Sciences Gdansk Library) Down Right: Gdansk, General view from the northwest, 1573. From: G. Braun, H. Hogenberg, Civitates orbis terrarum...Coloniae, vol. II, 1575, etching, inv. no. 4488 (from the collection of the Polish Academy of Sciences Gdansk Library).

Type of archive material studied

From the very beginning of the project specific research regarding the topic of the Gdansk fortification system the continued archive work and documentation has been undertaken / conducted. Preparatory research, preliminary based on online doucmntation and individual collaboration and przedglad documentatcji in the 3 most avaible places of source mentioned above: Gdańsk National Archive, GdańskTech Architecture Library Archive and Polish Academy of Science (PAN) Library Archive. Additional documentation activities at the historical archives were conducted, by the Italian and Polish research team (University of Pavia and Metaheritage enterprise), in January 2023 and April 2023. Coordinating the activities, before, during and following the visits, was a multidisciplinary team from Gdansk University of Technology. The collaboration between Polish and Italian researchers was particularly evident in this phase of the project, in which the historical expertise of the Gdansk Tech professors was complemented by that of digitization and analysis of urban maps and architectural representations, conducted by the Italian team.



The documentary material researched, images and texts useful for understanding the evolution of Gdańsk's fortifications, is catalogued and written in Polish or German. Similarly, simultaneous translation of the valuable explanations given on historical maps and photographs by the archivists, who led the team's visiting activities, was necessary for each visit to archives and libraries[3]. To ensure the continuity of the research work, even at the end of the mobility periods, the Italian researchers had the opportunity to view the documents, through the use of their digital copies, via access credentials to the online cataloging of the archives[4] and high-resolution scans provided by the archivists themselves. The analysis covered different types of documents: among the most recent (19th-20th Century) books, photographs and postcards describing the historic center of Gdansk, the main axis of *Dluga* Street, which runs between the fortified city gates of Golden Gate and Green Gate, but also the conformation of the ramparts and punctual fortifications of *Vistula* and *Portowa* Battery.

Fig. 08
Anton Möller's Gdańsk print
Perspective drawing
The indoor capture, without additional lighting, gave the photographs a blue hue. Below: the capture technique and exposures for digitizing the document.

[3] Special thanks to dr Anna Walczak - Director of the Polish Academy of Sciences Gdańsk Library (PAN Library Gdansk) and dr Zofia Tylewska-Ostrowska - Head of the Special Collections Department and archivists: Krystyna Jackowska and Marta Pawlik-Flisikowska from Special Collections Department (Graphic Collections) of Polish Academy of Sciences Gdańsk Library (PAN Library Gdańsk) , and assist prof. Justyna Borucka GdańskTech for the simultaneous translation provided to support the understanding and analysis of each document viewed.

[4] During the first in-archives documentation activity, assist prof. Piotr Samól GdanskTech explained to the UNIPV team how to access and move around the State Archive in Gdańsk site, both to request to view the documents in-person and to be able to browse the catalogue remotely (albeit with some limitations).

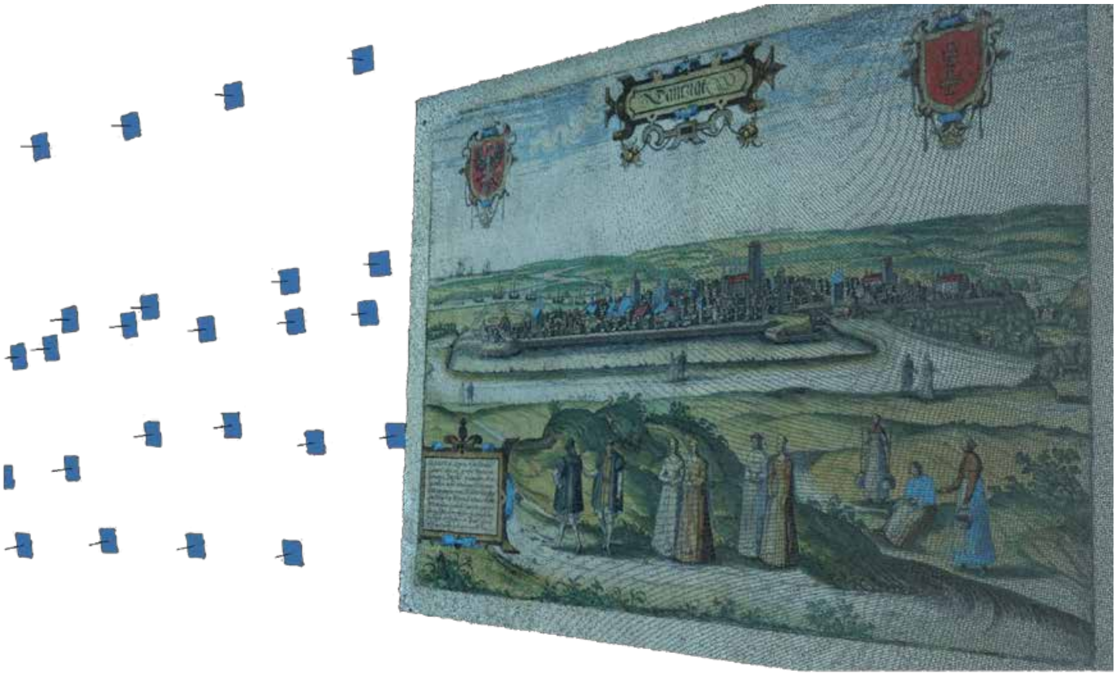
From the textual and graphic records, information was also found on the architectural typology (internal distribution and relationship to the surrounding buildings and public space) of the downtown dwellings; now modified according to the changing needs and choices of post-war reconstruction. Less recent documents (18th-19th centuries) include numerous paintings executed in pencil (and sometimes watercolor) on paper or cardboard, as well as engravings, almost always plans or bird's-eye views probably made for wartime purposes, whose legends provide valuable information on the layout and function of military structures. In analyzing such drawings, the biggest challenge, still open even to local researchers, concerns the reliability of the historical representation. Many of the cartographies and distorted perspectives, which frame the entire city from the ramparts, were produced centuries later than the Gdańsk they represent. For example, archives preserve maps dated to the 16th Century but produced by 18th-Century authors. The drawer may therefore have made the work by copying it from a now-lost original, or by figuring it based on a textual description. In either case, a possible significant component of the author's subjective interpretation must be taken into account when studying urban evolution and fortifications.

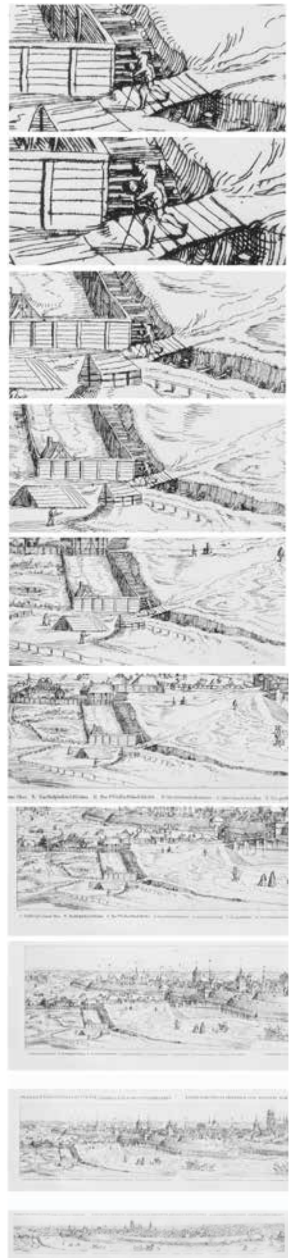
Fig. 07
Results of capture tecnique and image optimization.
The image shows the result of the color correction which brings the document back to its original color.

New methodology for archives studies

The archives have been digitized to allow for greater accessibility in the future, to enable the consultation of resources without necessarily handling them and thus increasing their preservation, and finally, to be able to view every tiny detail by surpassing usual magnification levels. We were able to digitize 11 historical maps provided by the archive, never before digitized. With this technique, it is indeed possible to achieve up to 100 levels of zoom on images over 16,000 x 12,000 pixels. The technique used is experimental but has shown excellent results from the start. It is based on the methodology of acquiring gigapans but then applied to photogrammetry. The shooting technique is essentially the same as that used for software like PTGUI[5] or similar. When shooting, you must imagine following an ideal checkerboard, so each shot must have at least 20% overlap with both the previous and subsequent photos, as well as those in the rows above and below. This shooting method must be repeated at different distances, increasing the number of shots as you get closer without changing the focal length. Taking as an example of Anton Möller's Gdańsk perspective drawing[6], an old print with a white cardboard frame, 60 images were taken using the methodology described above in both JPEG (6000x4000, 180 dpi, 24 bit) and RW2 (6024 x 4016 px) with a full-frame mirrorless Lumix S Full-Frame DC-S5 camera with a 35mm lens. These images were then developed with Camera Raw, balancing the white, removing lens distortion, and finally developing always at 6000x4000 but with 150 dpi. Developing the photos is essential to restoring the original color to the scan. Once this step was completed, the images were inserted into Agisoft Metashape[7], using the workflow suggested by the user manual for creating orthophotos: align photos, calculate point cloud, calculate DEM (*Digital Elevation Model*). Instead of calculating the mesh and texture, the orthophoto was generated directly on the DEM model.

[5] https://ptgui.com/
[6] Anton Möller, Gdańsk, Large-format general view from the perspective of Biskupia Górka, ca. 1592-93 (probably as a model for the competition for the concept of new, south-western fortifications, etching), courtesy of Polish Academy of Sciences Gdańsk Library (PAN Library Gdańsk).
[7] https://www.agisoft.com/





Once the orthophoto was obtained, it was decided to further increase the resolution to reach 2000 dpi through the image resampling algorithms of Topaz Gigapixel AI[8]. The final step was in Photoshop for color, contrast, and level retouching. As shown in the figures, it is possible to increase the zoom level up to 2000% of the original image size. The resulting scan is a valuable support for research as well as for document preservation, allowing the user to appreciate every tiny detail visible on the original only with the aid of analog magnification tools. Research on the fortifications of Gdańsk was carried out by the GdańskTech research group even before the start of the project. Archival work, as one of the first and key phases of the Prometheus project, was intensified and directed during its duration. This led to very fruitful and expected results in the form of detailed studies based on materials from archives used in a variety of ways. As mentioned above, the research on archival architecture has provided the basis for future work and the development of research and studies within the Prometheus project. The sources available are of course much wider and only selected aspects could be studied and experimented with. However, the material was sufficient to provide an insight into the history of the city's development and the spatial, political and social conditions that determined its fortification system. The researchers involved in the Prometheus project had a unique opportunity to cooperate with historians and specialists who conduct detailed research on the fortification system in Gdańsk. Of course, not all information was used for the needs of the project. All the results of the research and field work in the archives were extremely important for the understanding of the heritage, the development of the urban system, the comparison of different hypotheses of evolution of the urban space, the recognition of the key

Fig. 08
High-Resolution Imaging and Photogrammetric Precision: From Gigapan Capture to Ultra-Detailed Output.
Above, the shots used for the high-definition photographic acquisition (Gigapan) were also used for the photogrammetric calculation. Right, The resulting image retains no loss of resolution. Even at 2000% zoom, fine detail can be appreciated.

[8] https://www.topazlabs.com/gigapixel

Fig. 09
Gdańsk, sketched freehand: delicate lines and details capture (Drawing credit: Justyna Borucka)

elements of urban landscape and the fortification system immersed in it in the form of its individual elements and buildings. It was also an important and necessary starting point for further research and digitisation work in the field. The method of image digitisation allowed a deeper understanding of the development of individual elements of the fortifications and, in terms of visualisation, the presentation of the stages of creation and their use. The photogrammetry process was useful not only for historical research and understanding the subject of research, but also for: detailed examination and analysis of historical documents in great detail, even from a distance, thanks to which the availability and clarity of the images made it possible to share historical maps of Gdańsk in order to study the development of the city, In addition, it created the basis for enriching the project's information database. It was also an element of experimenting with new methodologies and enabling the progress of scientific research on detailed methods of photogrammetric acquisition (as described in the methodological part, which explains the advantages of using a lens and a camera for digital restoration), and ultimately to promote the heritage itself. The results of the digital documentation were also used as part of the final result of the project, which is important for the desamination and popularisation of the heritage values. The possibility of presenting virtual images of the past (drawings and hypotheses based on available archive material), the present and the future also made the results of the studies useful for future final output of the project. Conscious digitization of heritage enables the use of digital images for its dissemination and popularization. Showing the past, present and future in virtual reality gives the opportunity to get to know the valuable urban landscape of Gdańsk and promote it among cities and beyond.

References

Biskup K., Stankiewicz J. 1998, *Fortyfikacje miejskie Gdańska od XVI do końca XIX wieku (City fortifications of Gdańsk from the 16th Century to the end of the 19th Century)*, in Kostarczyk A. (eds.), *Gdańsk pomnik historii*, Gdańsk.

Bukal G. (eds.) 2006, *Fortyfikacje Gdańska (Fortifications of Gdańsk)*, Gdańsk.

Bukal G. 2012, *Fortyfikacje Gdańska i ujścia Wisły 1454-1793. Studium z dziejów nowożytnej architektury militarnej (Fortifications of Gdańsk and the mouth of the Vistula river 1454-1793: A study in the history of modern military architecture)*, Sopot.

Hirsch R. 2009, *Początki fortyfikacji nadbrzeżnych Gdańska (The beginnings of Gdańsk's coastal fortifications), in Fortyfikacje nadbrzeżne Zatoki Gdańskiej - XXIV Seminarium Krajoznawcze Wojska Polskiego*, Gdynia, pp. 35-46.

Hoburg K. 1852, *Geschichte der Festungswerke Danzigs (History of Danzig's fortifications)*, Wedelsche Hofbuchdruckerei, Danzig.

Koehler G. 1893, *Geschichte der Festungen Danzigs und Weichselmünde bis zum Jahre 1814 in Verbindung mit der Kriegsgeschichte der freien Stadt Danzig (History of the fortresses of Danzig and Weichselmünde up to 1814 in connection with the war history of the free city of Danzig)*, vol. 1: Bis zum Jahre 1734, Wilhelm Koebler, Breslau.

Kloeppel O. 1937, Das Stadtbild von Danzig in den drei Jahrhunderten seiner großen Geschichte (The cityscape of Gdańsk in the three centuries of its great history), Kafemann, Danzig.

Samól P., Hirsch R., Woźniakowski A. 2021, *History of the Lighthouse of the Wisłoujście Fortress in Light of a 2018 Architectural Study*, in *Journal of Heritage Conservation*, 66, pp. 21-36.

Samól P., Hirsch R., Woźniakowski A. 2022, *Wreath from the Wisłoujście Fortress, Dating from the 1560s, and Its Transformation and Damage in the War of 1577 in the Light of Architectural Research from 2020–2022*, in *Journal of Heritage Conservation*, 72, pp. 62-79.

Samól W., Kowalski S., Woźniakowski A., Samól P, 2023, *Where the Second World War in Europe broke out. The landscape history of Westerplatte*, Gdansk/Danzig, in *Land*, 12, p. 596.

Stankiewicz, J., Szermer B. 1959, *Gdańsk, rozwój urbanistyczny i architektoniczny oraz powstanie zespołu Gdańsk-Sopot-Gdynia (Gdańsk, urban and architectural development and the creation of the Gdańsk-Sopot-Gdynia complex)*, Arkady, Warszawa.

Szczepański, J. 2000, *Stone Sluice Mill, in International Conference Preservation of the Engineering Heritage Gdańsk*, Outlook 2000 Proceedings: September 7-10, Gdańsk - Tczew.

ANALYSIS, SYSTEMATIZATION AND CLASSIFICATION OF THE GDAŃSK CULTURAL HERITAGE ROUTE

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Side Page, *Fig. 01*
Historical development schemes of Gdańsk's urban and fortification systems at the present-day layout

The fortification systems of Gdańsk are deeply interwoven with the city's identity and continue to shape its contemporary urban landscape. Gdańsk, located on the Baltic Sea at the mouth of the Vistula River, has long held a position of geopolitical and economic importance. Over the centuries, the city developed a complex and layered system of fortifications designed to protect it from both land and sea invasions. These structures—walls, bastions, towers, moats, and military zones—not only defined the city's physical growth but also reflected the political tensions, shifting technologies, and evolving urban priorities of each era.

The fortified perimeter of Gdańsk evolved in distinct historical phases, each shaped by the city's strategic needs and the military technologies of its time. The medieval fortifications established the first line of defense and defined the spatial logic of urban development. With the rise of gunpowder warfare, the early modern period introduced bastioned walls and earthworks, reshaping the city's interface with its surroundings. In the late 17th and 18th centuries, a broader ring of external fortifications emerged, expanding control over the high ground and approaches to the city. The 19th and 20th centuries brought dispersed systems of artillery batteries and bunkers, more technological, less monumental, marking the final phase of Gdańsk's defensive architecture.

However, the continuity of this defensive structure has been profoundly disrupted. The devastation of World War II left vast areas of Gdańsk in ruins, and the fortified elements were not spared. Many gates, towers, and bastions were lost to bombing, fire, or post-war clearance. What remains today is a fractured legacy fragments of walls, isolated strongholds, partial earthworks, each one a trace of a once-cohesive system. In some cases, the only indication of their former presence is the curvature of a street, the alignment of a canal, or the name of a hill.

This material loss is not only architectural; it is ontological. The destruction of fortifications erases not just stone and brick, but also the memory, identity, and spatial logic embedded in those structures. The historical image of the city, its silhouette, its thresholds, its protective margins becomes unstable, and with it, the narrative of its resilience and autonomy.

In this context, preserving what remains is not merely an act of conservation; it is a cultural imperative. To reconstruct, document, and interpret these elements is to engage in a form of urban storytelling, one that resists amnesia and acknowledges both presence and absence. Even in their damaged or partial state, the remnants of Gdańsk's fortifications carry symbolic weight.

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Fig. 02
Gdańsk in the 17th Century: A View from Biskupia Góra Gdańsk
Large-format general view taken from the perspective of Biskupia Gora, 1620. C.J. Vischer according to the matrix of A. Dickmann from 1617, etching inv. no. 44899.

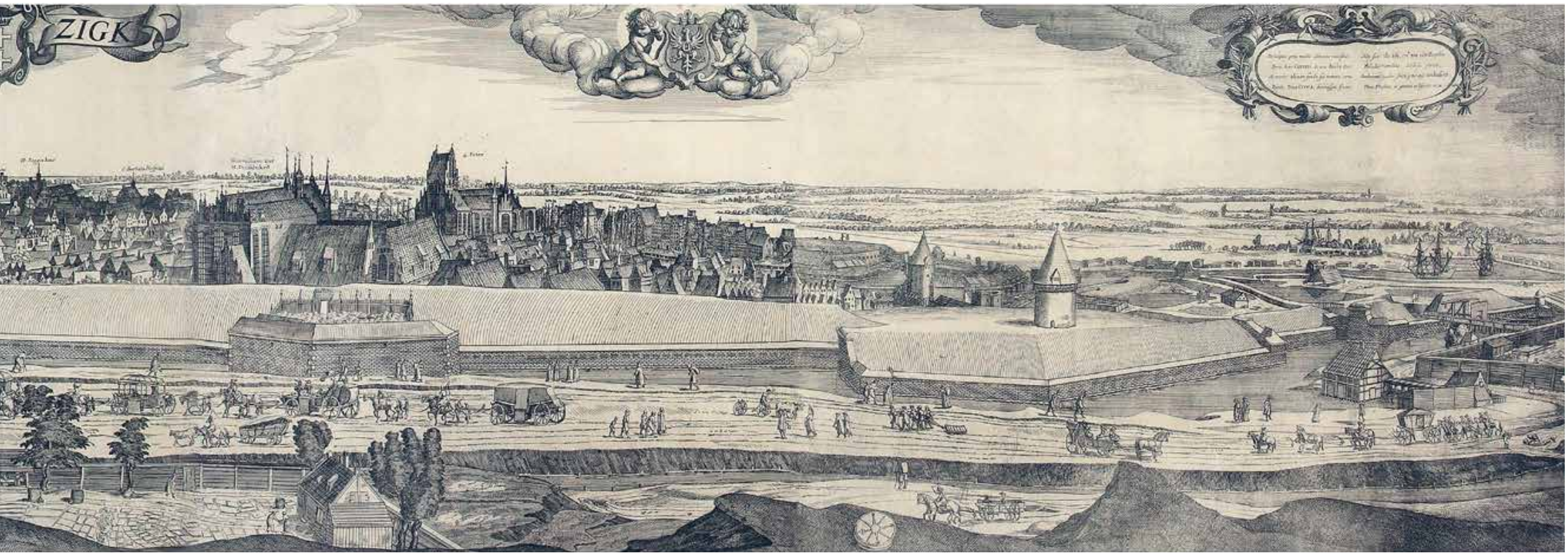
They are monuments to continuity, to the idea that cities are not static entities but palimpsests inscribed with layers of meaning, conflict, and renewal.

Ultimately, the preservation of the city's fortified heritage is not only about protecting monuments from further decay. It is about restoring the city's capacity to remember itself, to offer future generations an intelligible image of its past. In a world where cities are increasingly defined by speed, erasure, and reinvention, the choice to preserve is an act of resistance—and an affirmation of meaning.

As part of this research project, a comprehensive field survey and documentation campaign of fortified sites in Gdańsk and its surrounding areas was carried out. The objective was twofold: on the one hand, to reconnect the city's physical landscape with its layered military history; on the other, to establish a coherent and comparative analytical framework that could inform future conservation strategies, educational tools, and planning policies.

The survey methodology combined direct site visits, visual documentation, archival research, and the construction of a structured monitoring database. A dedicated Excel file was developed to systematize the findings, ensuring that each fortification element was recorded according to a consistent set of criteria. Each entry in the database contains:

- The name of the site in Polish, English, and German, acknowledging the multilingual and multicultural legacy of Gdańsk;
- Precise geographic coordinates, enabling geospatial mapping and potential integration into GIS platforms;
- The historical period of construction, grouped into four main chronological categories;
- The current state of conservation, assessed in terms of visibility, material integrity, and degree of physical preservation;
- The level of accessibility, classified as open, restricted, or inaccessible to the public.
- This structured classification allowed for a clear grouping of the fortified elements into four principal historical categories:



- Medieval fortifications (10th–15th centuries), including city walls, moats, gates, and watchtowers;
- Early modern fortifications (16th–mid-17th century), characterized by bastioned systems and the implementation of artillery-based defense principles;
- External fortifications (late 17th–18th century), built on elevated terrain and forming a larger ring of defense beyond the medieval perimeter;
- 19th and 20th-century fortifications, including coastal artillery batteries, shelters, bunkers, and modern fortified structures from the Prussian, interwar, and postwar periods.

Fig. 03
Plan of the Western Wall, 1768
J.E. Schmidt drew, watercolour, inv. no. 2718.

This same logical and temporal structure informed the development of the Prometheus digital map and route, a key deliverable of the project. The digital route was designed not only as a tool for spatial orientation and interpretation, but also as a way to visually reconstruct the historical defense network of the city. The mapping followed the typological and chronological schema developed in the database, and enabled the clear identification and localization of all relevant fortified elements—including walls, gates, ramparts, battery shelters, and bastions.
Through this integrated digital approach, the Prometheus route offers both specialists and the wider public an intelligible, layered reading of Gdańsk's fortification system—linking past structures to their present state and restoring coherence to a landscape that is today often fragmented or obscured.This four-fold division was not only temporal but spatial and functional, allowing for comparative assessment across periods. A key methodological approach in parallel was the comparative analysis of Gdańsk's urban and fortification schemes from three significant time frames—1600, 1710, and the present—which were used to trace the morphological transformation of the city and the role of military structures in shaping that evolution.

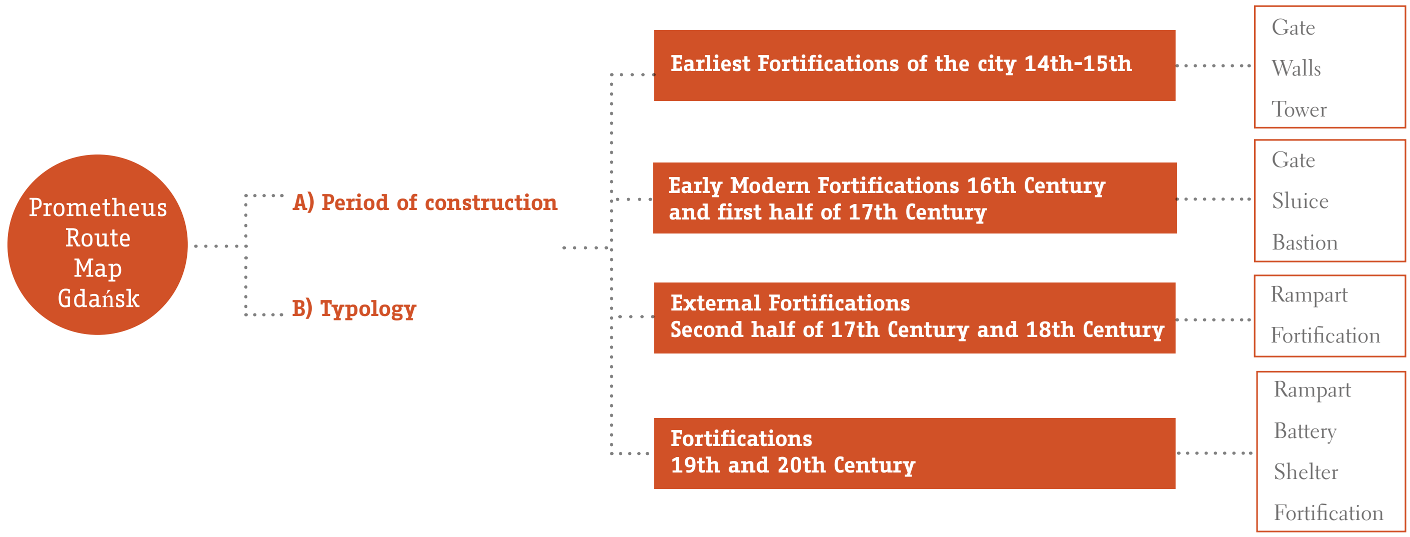


Fig. 04
An overview of the criteria used to select and define case studies along the Gdańsk Route
The framework highlights the typology and the period of construction.

Special attention was given to post-war reconstruction, during which many fortifications were either demolished, integrated into modern infrastructure, or reinterpreted within the new socialist urban agenda. The database allowed researchers to track which elements survived, how they were transformed, and their current role in the urban landscape—whether as heritage objects, public spaces, or neglected ruins. Despite decades of urban change, the spatial footprint of Gdańsk's defensive systems remains legible. The historic line of fortifications continues to influence urban zoning, topography, and even everyday movement patterns in the city. The coexistence of medieval cores and later military structures offers a unique opportunity to understand both continuity and rupture in urban development. As Dąbrowska-Budzillo (1990)[1] eloquently put it, Gdańsk presents "a magnificent, lively, and colourful image of the city, which speaks of its past, and at the same time, shows its present beauty." Ultimately, this research highlights that the study of Gdańsk's fortified heritage is not merely historical documentation—it is an analytical tool through which to understand the city's spatial history, cultural identity, and long-standing relationship with defense, autonomy, and reconstruction. The database developed through this project stands as a platform for continued study, conservation planning, and public engagement. In this context, the monitoring database becomes more than a research tool—it is a platform for advocacy and informed decision-making. It enables heritage professionals, local authorities, and civic actors to prioritize interventions, justify funding, and guide sustainable urban transformations. Furthermore, it creates a baseline for potential UNESCO World Heritage nomination, particularly in the case of the Wisłoujście Fortress, whose exceptional maritime defensive character and historical continuity from the 10th to 17th century align with criteria of outstanding universal value.

Beyond the institutional sphere, the preservation of Gdańsk's fortifications calls for public engagement and education. Many of these sites, once built to defend the city, can now serve as open-air

[1] Dąbrowska-Budziło K. (1990), *Wśród panoram Krakowa*.

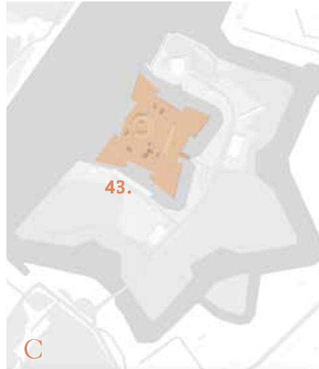


Fig. 05
A) Earliest Fortifications of the city 14th-15th. 1. Cow's Gate, 2. Cog Gate 3. Chlebnicka Gate, 4. St. Mary's Gate, 5. Holy Spirit Gate 6. Crane Gate, 7. St. John's Gate, 8.Straganiarska Gate, 9. Golden Gate, 10. Stągiewna Gate / Tower, 11. Swan Tower, 12. Eastern part of northern Walls, 13. Western part of northern Walls, 14. Jacek Tower, 15. Tower on the Behind/under Walls, 16. Latarniana Tower, 17. Straw Tower, 18. Torture House and Prison Tower, 19. Corner Tower, 20. Western part of the southern Wall, 21. Schultz Tower, 22. Tower of Anchors, **B) Early Modern Fortifications 16th Century and first half of 17th Century** 23. Pod Zręb Tower, 24. White Tower, 25. New Tower, 26. Remains of the walls of the Teutonic castle, 27. High Gate, 28. Lowland Gate, 29. Żuławy Gate, **C) External Fortifications Second half of 17th Century and 18th Century** 30. St Gertrude Bastion, 31. Aurochs Bastion, 32. Stone Sluice, 33. Wolf Bastion, 34. Wyskok Bastion, 35. Bear Bastion, 36. Królik Bastion, 37. St. Elizabeth's Bastion, 38. Cat Bastion, 39. Wiebe Bastion, 43. Wisłoujście Fortress Complex, 44. Fortifications of Railway Gate,

classrooms, cultural venues, and community landmarkslinking past functions to future possibilities. Safeguarding the fortified heritage of Gdańsk means safeguarding the memory of how the city negotiated its place between land and sea, between war and commerce, between destruction and resilience. These defenses, though often silent, speak clearly of identity, adaptation, and continuity. Recognizing their value, recording their presence, and integrating them into contemporary urban life is not only an act of conservation; it is a commitment to understanding the city in its full historical depth and projecting that legacy into a shared future.






Figs. 06,07
Earliest Fortifications of the city 14th-15th
The historic fortifications of Gdańsk form a layered defensive system developed between the Middle Ages and the early modern period, where gates, towers and walls define the boundary of the old city. The Prison Tower, connected to the Golden Gate, combines defensive and symbolic functions. Its facades feature stone bas-reliefs with heraldic motifs, allegorical figures and ornamental details in late Gothic and Renaissance style.

In a broader sense, safeguarding Gdańsk's fortifications is about more than preserving stones and soil. It is about preserving memory, identity, and the traces of decisions—political, architectural, and human—that shaped the city's unique place in European history. These fortifications, though often silent and overlooked, are vital elements of the cultural landscape. They must be protected not only as monuments of the past but as resources for the future.

Fortifications from the Medieval Period

The earliest fortifications of Gdańsk date back to the 10th–13th centuries and are primarily known from archaeological findings and sparse references in historical chronicles. Starting in 1343, a systematic construction of city defenses began. These fortifications enclosed the autonomous districts of the growing city, including the Main Town, Old Town, Old Suburb, and Granary Island. A substantial portion of this medieval fortification system has survived. It was composed of brick defensive walls, moats, watchtowers, and fortified gates. In certain areas, wooden and earthen ramparts were added to reinforce the system. One significant development occurred in 1482 with the construction of a cylindrical defensive tower near the mouth of the Vistula River, about 5 km from the city. This structure also served as a lighthouse, highlighting Gdańsk's dual military and maritime character. By the 16th century, however, the medieval fortifications began to lose their strategic relevance due to advancements in military technology. Parts of the system were dismantled, while others were adapted for new purposes. Despite this transformation, the remnants of Gdańsk's medieval defenses remain visible today and continue to define the spatial logic of the historic urban fabric.

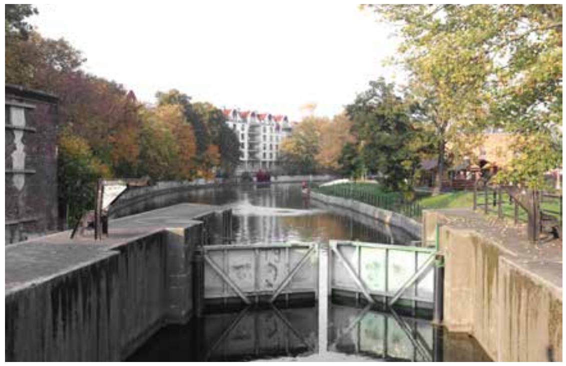
Early Modern Fortifications (16th – Early 17th Century)

In response to new military threats and technological advances, Gdańsk undertook a major upgrade of its defensive systems in the late 16th century. A new bastion-style fortification line was constructed on the city's western side, using brick and incorporating modern principles of military engineering. This marked a significant evolution from the vertical medieval walls to horizontal, angular earthworks better suited to resist artillery. During this period, the Wisłoujście Fortress also underwent significant expansion, becoming a key element in the city's maritime defense network. One of the most ambitious defensive projects in Gdańsk's history took place between 1622 and 1625, when the city was encircled with an extensive system of earth ramparts and bastions, complete with broad moats. These fortifications, built in the Old Dutch style, enclosed the northern, eastern, and southern perimeters of the city and represented a high point in Gdańsk's early modern military architecture The shift in design and scale reflected Gdańsk's growing strategic importance and its desire to maintain autonomy amid regional conflicts and shifting powers.

Figs. 08, 09, 10, 11
Along the perimeter of the city, several towers that once formed part of the defensive system are still visible, in particular in the photos from left to right: Jacek Tower, Żuławy Gate, White tower, Straw towe.r

External Fortifications (Late 17th – 18th Century)

In the second half of the 17th century, the city of Gdańsk further strengthened its defensive system by expanding beyond the immediate urban perimeter. Beginning in 1655, fortifications were established on the hills west of the city—*Biskupia Górka* (Bishop's Hill) and *Grodzisko*.



Figs. 12, 13, 14
The external fortifications
Along the Vistula River
It is possible to see the external fortifications along the Vistula River, with surviving brick remains, gates, and the river lock system.

These elevated positions provided strategic advantage for surveillance and artillery placement, and the valley between them was also fortified to ensure territorial continuity. During the 18th century, these outer defenses were extended and modernized to address emerging military threats. Meanwhile, the *Wisłoujście* Fortress continued to be upgraded as the cornerstone of Gdańsk's maritime defense, reflecting its ongoing strategic role at the mouth of the *Vistula* River. These external fortifications marked a shift toward a more comprehensive defense-in-depth strategy, integrating topography and distance to protect the urban core while allowing space for urban expansion and reorganization.

Fortifications of the 19th and 20th Centuries

By the 19th century, evolving warfare technologies and changing political landscapes prompted further modernization of Gdańsk's defensive infrastructure. Between 1868 and 1900, thirteen coastal artillery batteries were constructed along the seashore to protect the city and its port from naval threats. After 1910, these were supplemented by four more modern seaside batteries[2].

[2] Hirsch R. (2009), *Początki fortyfikacji nadbrzeżnych Gdańska (The beginnings of the coastal fortifications of Gdańsk)*, pp. 35-46.Woźniakowski (2009), *Zarys historii rozwoju fortyfikacji nadbrzeżnych Gdańska w latach 1887-1919 (Brief history of the development of Gdańsk's coastal fortifications between 1887 and 1919)*, pp. 47-61.

Fig. 15
Bastions along the Vistula river
Today, the bastions and the Vistula River running alongside them have been redeveloped, with several pedestrian and cycle paths introduced.

At the start of the 20th century, fortifications near the mouth of the *Vistula* River were expanded to defend the New Port and the *Westerplatte* Peninsula—a strategic area that would later become symbolic in the outbreak of World War II. The road connecting Gdańsk to the *Wisłoujście* Fortress was also fortified, while the high-ground defenses at *Biskupia Górka* and *Grodzisko* were reinforced. Between 1921 and 1939, the Polish Military Transit Depot operated on the Westerplatte Peninsula. Its defensive system consisted of fortified barracks and several combat bunkers. During World War II, the city was further militarized with the construction of numerous air-raid shelters. In the postwar period, the last generation of Gdańsk's military architecture emerged with the installation of fixed artillery battery systems, constructed between 1952 and 1955 and operational until 1977. These installations marked the end of a millennium-long tradition of military fortification in the city owards recognition and preservation of Gdańsk's fortified heritage. The layered fortification systems of Gdańsk represent more than defensive structures—they are physical testimonies of a city at the crossroads of maritime trade, military strategy, and cultural exchange. Each wall, bastion, and fortified outpost tells a story not only of threats and responses, but also of innovation, resilience, and adaptation. These elements are key to understanding the city's historical continuity and spatial evolution. The layered fortification systems of Gdańsk represent more than relics of past military might—they are enduring spatial markers of the city's role as a maritime gateway, a contested borderland, and a resilient urban organism.

Fig. 16, 17, 18, 19
External Fortifications Second half of 17th Century and 18th Century
The fortress of Wisłoujście Fortress and its bunkers are still present along the coast near the mouth of the Vistula River, once serving as defence against attacks from the sea.

Across nearly a millennium, Gdańsk has developed, transformed, and adapted its defensive architecture in response to shifting geopolitical contexts, advances in military technology, and changing visions of urban identity. Today, these structures—some prominent, others almost forgotten—form a fragmented but powerful narrative inscribed in the urban fabric. This study not only traced the historical evolution of Gdańsk's fortifications, but also undertook a systematic survey and categorization of existing sites through the creation of a detailed monitoring database. This Excel-based tool serves as a foundation for future heritage and planning efforts. Each entry in the database captures critical metadata: multilingual toponyms (Polish, English, German), precise coordinates, historical period of construction, current conservation state, and degree of public accessibility. This structure allows for cross-comparison, integration with cartographic and GIS tools, and scalable analysis. The fourfold periodization—medieval fortifications, early modern bastions, external 17th–18th-century defenses, and 19th–20th-century military structures—provides a flexible yet historically grounded framework. This typological model supports both targeted conservation strategies and broader cultural heritage policies, and could inform municipal planning, tourism development, and educational outreach. Importantly, the research reveals not only the richness of Gdańsk's fortified heritage, but also the precariousness of its preservation. While many structures are officially recognized—such as the *Wisłoujście* Fortress or the fortification belt included in the 1994 national monument designation—others remain underprotected or at risk due to urban development, erosion, or neglect. The disparities between symbolic recognition and legal safeguarding are a critical challenge. Not all culturally valuable elements are listed in the heritage register, and some fall outside the jurisdiction of current preservation policy.

References

Borucka J., Gatermann H. 2016, *Architekturführer Danzig: Gdańsk Sopot Gdynia (Gdańsk Architectural Guide)*, *Connerton P. 1989*, *How Societies Remember*, Cambridge University Press, Cambridge.

Dąbrowska-Budziło K. 1990, *Wśród panoram Krakowa*, Wydawnictwo Literackie, Kraków.

Hirsch R. 2009, *Początki fortyfikacji nadbrzeżnych Gdańska (The beginnings of the coastal fortifications of Gdańsk)*, in Aksamitowski A., et al. (eds.), *Fortyfikacje nadbrzeżne Zatoki Gdańskiej*, PPHU Drukpol, Tarnowskie Góry, pp. 35-46.

Parrinello S., Pettineo A. 2025, *Databases and Information Models for Semantic and Evolutionary Analysis in Fortified Cultural Heritage*, in *Heritage*, 8(1), 29.

Parrinello S., Picchio F., La Placa S. 2024, *The Construction of an Informative 3D Model for the Monitoring of City Heritage Risk*, in *Reviving Aleppo: Urban, Legal and Digital Approaches for Post-War Recovery*, Springer International Publishing, Cham, pp. 243-274.

Picchio F., Parrinello S., Borucka J., Szczepański J. 2023, *Persistences: Analysis of the Image of Gdańsk and Its Cultural Identity Through Survey Processes and Digital Architectural Representation*, in *IMG Journal*, 4(8), pp. 258-283

Woźniakowski A. 2009, *Zarys historii rozwoju fortyfikacji nadbrzeżnych Gdańska w latach 1887-1919 (Brief history of the development of Gdańsk's coastal fortifications between 1887 and 1919)*, in *Fortyfikacje nadbrzeżne Zatoki Gdańskiej*, pp. 47-61.

Fig. 13
Fortifications 19th and 20th Century
A historic photograph of the monument at Westerplatte; the torpedo platform Torpedownia still stands today along the Baltic coast, although in a state of abandonment. In addition, several bunkers and 19th-century watchtowers can still be found along the Baltic coast between Gdynia and Sopot.

Medieval Defensive Systems and the Transformation of Urban Form


D I E M O T T L A V
D E R N E V E G R A B E N
Langer Markt
SCHAEFEREI

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The structure of downtown Gdańsk that still exists today has its origins in the 14th Century. Several units were established during this Century. The most important of them, the Main Town, had full city rights. In addition to the Main Town, there were: the Old Town north of the Main Town, the Young Town even further north, on the Vistula River, and Osiek at the foot of the castle, which had limited self-government. There were also suburbs subordinated to the Main City, including Old Suburb, Long Gardens and islands with warehouse buildings.

Side page, Fig. 01
Reconstruction of Gdańsk from the beginning of the 16th Century on the plan of O. Kloeppel
Source: https://medievalheritage.eu/en/main-page/heritage/poland/gdansk-city-defensive-walls/

The Main Town (*Główne Miasto*) began to be enclosed by defensive brick walls around the mid-14th Century. On the north, west and south sides these were single walls with towers, protected from the outside by a moat[1]. Initially, this circuit wall was relatively low (c. 5 m) and topped with battlements. Towards the end of the 14th and at the beginning of the 15th Century, a second line of defence, referred to as the low wall, was added in front of the south and part of the west walls. As a result of this work, the existing moat was filled in, creating a strip of intramural space, and a new outer moat was dug.

Fig. 02
Gdańsk
General view of Gdańsk from the south-west, seen from Biskupia Górka (reduced version of the large-format view by A. Dickmann), by Matthäus Merian, 1641, etching. Inventory no. 916. PAN Archive

[1] Stankiewicz (1958), *Średniowieczne fortyfikacje Głównego Miasta w Gdańsku*, 'Studia i materiały do historii wojskowzci'; Massalski and Stankiewicz (1969), *Dzieje fortyfikzacji gdańskich*; Bukal (2006), *Fortyfikacje Gdańska*, 1454–1793; Bukal (2012), *Fortyfikacje Gdańska i ujścia Wisły 1454–1793*; Bukal (2016), *Zespół bram ul. Długiej jako element systemu obronnego Gdańska (1343–1612)*, pp. 63-86.

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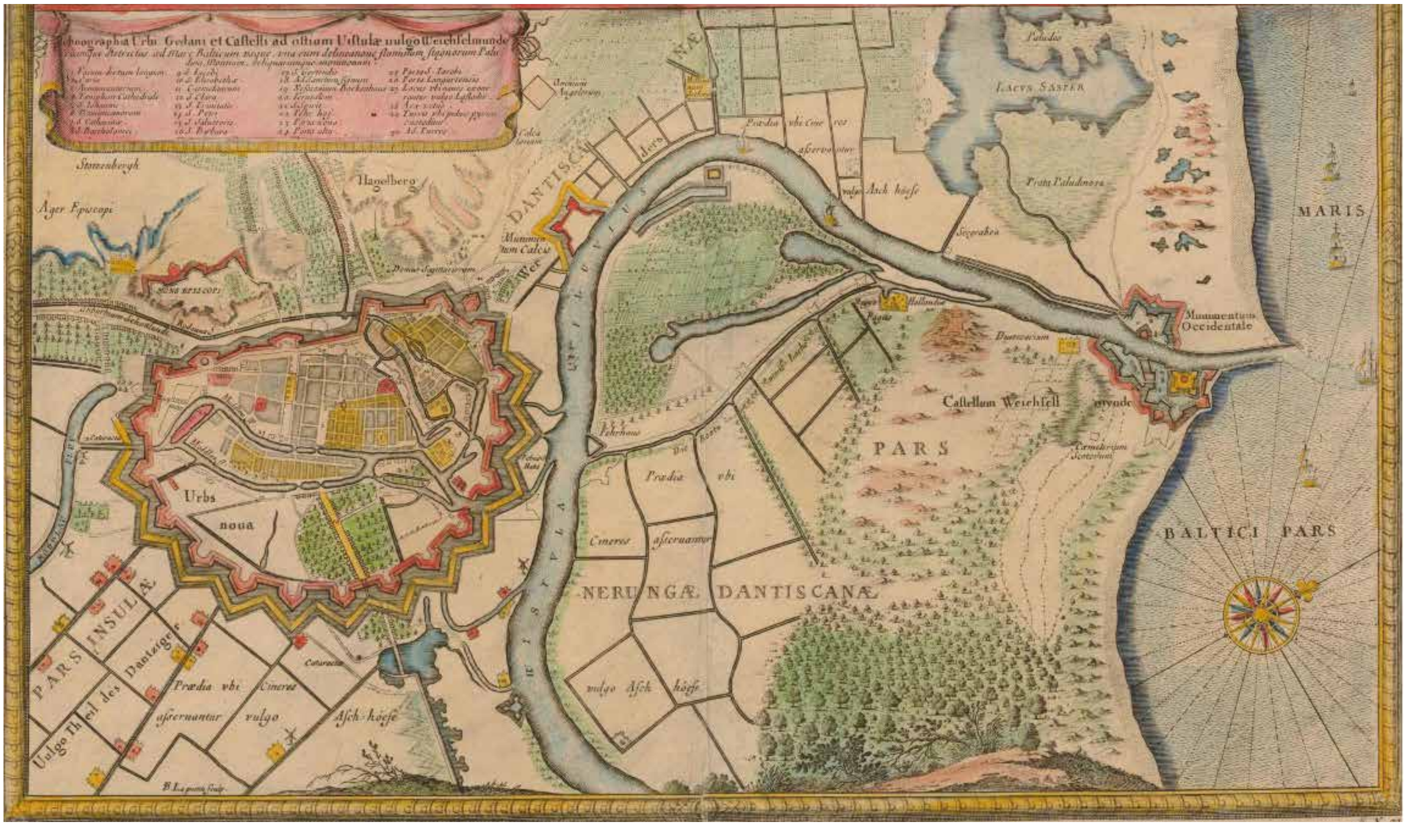


Fig. 03
Plan of the city
View of the territory of Gdańsk with a plan of the city's fortifications and the river way leading to the Wisłoujście Fortress. Engraved by François de Lapointe, likely based on a drawing by Georg Strakowski (c. 1640). The panorama presents a non-realistic southern view of the city. Copper engraving and etching, 1696. Inventory no. 6181. From: Samuel Pufendorf, De rebus a Carolo Gustavo gestis commentariorum..., Nuremberg, 1696. (Source: nr inw. 6181, PAN archive)

In the mid-15th Century the height of the high wall was raised by a further 5 m.

Its battlements featured loopholes, and on the city side it was provided with a brick walkway for guards, which was partially supported on cantilever beams. The high wall featured over 20 towers, connected to the low wall by foregates.

The oldest of these was the *Baszta Narożna* (Corner Tower), which stood at the juncture of the south and west walls.

Originally, the towers were rectangular, projected from the face of the wall, and were open towards the city. Examples include the *Latarniana* (Lantern) and *Na Podmurzu* (Wallside) Towers in the western stretch of the circuit. Over time, they were made taller, covered with roofs and sealed with walls. Slightly later towers were octagonal; these included the *Baszta Słomiana* (Straw Tower), which also served as a powder store, and the tallest tower – *Baszta Jacek* (Jack). There were also cylindrical examples, such as the *Dominikańska* (Dominican) and *Łabędź* (Swan) Towers. Entrance gates stood at the ends of the city's main streets. These included both land gates and water gates – on the *Motława* riverside. By the 14th Century, seven land gates had been built, among them *Brama Kotwiczników* (Anchor-Makers' Gate), *Brama Żabia* (Frog Gate), and *Brama Szeroka* (Broad Gate). The water gates built at this time included the one at the end of *Ulica Szeroka* (Broad Street) – the *Żuraw* (Crane), which was used from the latter half of the 15th Century as a port crane. Initially, most of these gates were simple wickets in the city wall, which were only gradually replaced by gatehouses.

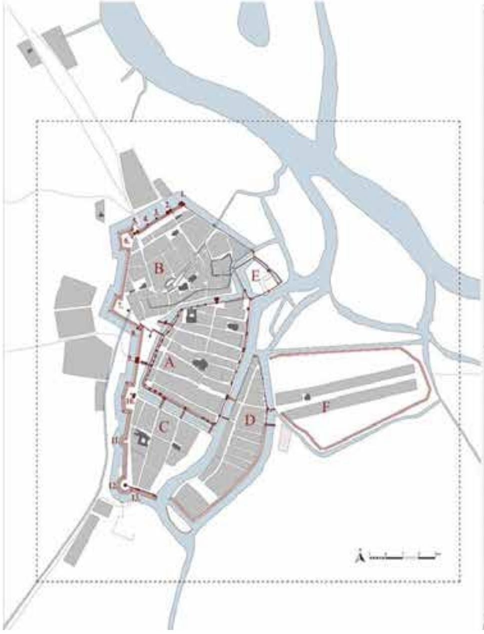
Fig. 04
General view of Gdańsk from the north-west
Unknown engraver, after a drawing by Peter Willer (1687), from: Der Stadt Dantzig historische Beschreibung. Etching. Inventory no. 5640 spurce PAN archive.

In the 15th and early 16th Century further gates were added and existing ones were expanded, sometimes becoming large structures. The last to be built (during 1517–1519) was a twin-towered Gothic gate; known as *Brama Stągiewna* (Milk Vat Gate), it stood at the east end of the route delineated by *Ulica Długa* (Long Street) and *Długi Targ* (Long Market).

Defensive walls also began to be raised around the Old Town (*Stare Miasto*) in 1482, in front of an existing earthen rampart. This circuit featured four gates. Similar fortifications were also built around the Old Suburb (*Stare Przedmieście*). In both cases, there were no walls from the side of the Main Town, and connections were provided by bridges built in front of each main gate.

In the early 16th Century, Gdańsk's fortifications consisted of circuits of walls and moats surrounding each of its three urban centres. With the increasingly widespread use of firearms, the city's medieval fortifications started to become redundant, and its major gates were redeveloped into ornate, prestigious Renaissance buildings that were not defensive in character. This is what happened in the case of *Brama Kogi* (Cog Gate), which was replaced during 1564–1568 by the *Brama Zielona* (Green Gate), with the Gothic *Brama Długouliczna* (Long Street Gate) being superseded by the *Brama Złota* (Golden Gate), built during 1612–1614. As the city developed in the 19th Century, large sections of its medieval walls and towers were dismantled. Today only remnants of these defences survive, significantly altered and partially rebuilt after the Second World War[2].

[2] Hirsch (2003), *Mury obronne Głównego Miasta Gdańska. Ciąg południowy, zachodni i północny. Rozpoznanie architektoniczno-konserwatorskie*.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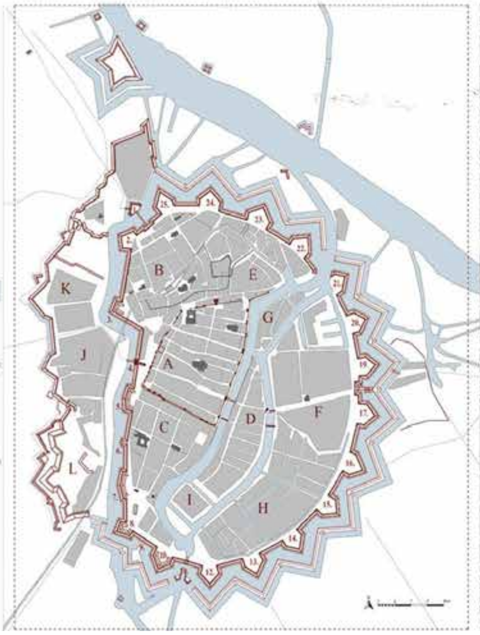
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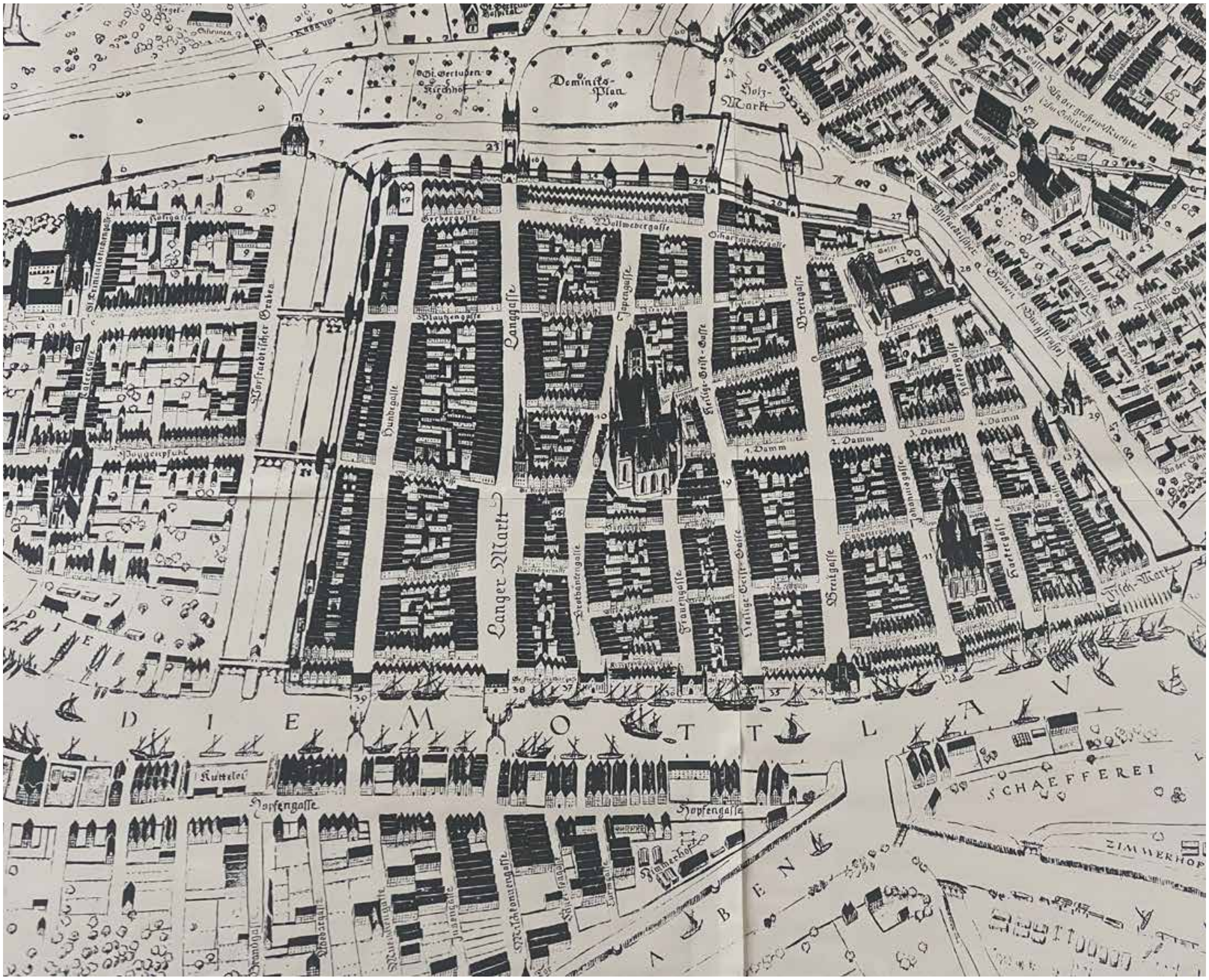
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Kuttelei
Hopfengasse
Hopfengasse
ZIMMERHOF

In many instances, they have been incorporated into new buildings or enclosed within other facilities. Their state of preservation is poor, which further detracts from their historical and educational value and negatively impacts their visibility in the city landscape. Several Gothic gates and towers have survived in varying condition. Some of them have been adapted to serve different functions: the *Żuraw* and *Brama Mariacka* (St Mary's Gate) for museum purposes; the *Baszta Biała* (White Tower) is now the headquarters of the Klub *Wysokogórski* (Mountaineering Club); *Baszta Łabędź* is the headquarters of the *Polski Klub Morski* (Polish Maritime Club); *Baszta Narożna* has become the *Dom Harcerza* (Scout House); and *Baszta Jacek* has been repurposed for commercial use. The extant *Baszta Latarniana*, which was originally open towards the city, and part of the wall adjacent to it, featuring a reconstructed arcade that supported a defensive gallery, are awaiting adaptation as well as conservation and renovation work.

Side page, Fig. 05
City development schemes.
The city of Gdańsk including the fortification city centre system from 1600, 1710 (elaboration by Sz. Kowalski) and current state (source: googlemaps), bottom a drawing of the city.

Fig. 06
Scale model of Gdańsk at the IKM (Institute of Urban Culture).
The exhibition features a detailed 1:500 scale 3D model of the historic city centre, combining physical modelling with multimedia content. The display includes a schwarzplan floor extension, a large-format city map, and a mechatronic reconstruction of the historic Wasserkunst pumping system. Interactive touchscreens enhance the experience, offering educational content and tools to explore urban development, including a comparison between present-day Gdańsk and its layout over 400 years ago. The project was overseen by the Department of Urban Planning and Architecture of the Municipality of Gdańsk. In 2017, the contract was awarded to MAE Multimedia Art & Education, a company specialising in multimedia exhibition design.

References

Bukal G. 2006, *Fortyfikacje Gdańska 1454–1793*, in *Fortyfikacje Gdańska*, ed. G. Bukal, Gdańsk, pp. 20-47.

Bukal G. 2012, *Fortyfikacje Gdańska i ujścia Wisły 1454–1793*, Sopot.

Bukal G. 2016, *Zespół bram ul. Długiej jako element systemu obronnego Gdańska (1343–1612)*, in *Zespół Przedbramia ul. Długiej w Gdańsku. Studium archeologiczne*, ed. A. Pudło, Gdańsk, pp. 63-86.

Hirsch R. 2003, *Mury obronne Głównego Miasta Gdańska. Ciąg południowy, zachodni i północny*. Rozpoznanie architektoniczno-konserwatorskie, Gdańsk, typescript, Museum of Gdańsk Archive.

Massalski R., Stankiewicz J. 1969, *Dzieje fortyfikacji gdańskich, in: Gdańsk jego dzieje i kultura*, (ed.) F. Mamuszka, Warszawa 1969, pp. 142-160.

Stankiewicz J. 1958, *Średniowieczne fortyfikacje Głównego Miasta w Gdańsku*, 'Studia i materiały do historii wojskowości', T. IV, Warszawa, pp. 313-413.


OPTYK

AN ARCHAEOLOGICAL ANALYSIS FOR A DIACHRONIC READING OF THE CITY WALL DEFENCE SYSTEM

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Side page, Fig. 01
Detail of the Stągiewna Gate/ Tower. The tower is located on the outer perimeter of the city's fortifications. This tower serves as a significant testament to the development of the medieval defensive system, which was intricately connected to the city's encircling walls. Its structure provides valuable insights into the architectural and defensive evolution over the centuries.

The mediaeval walls of Gdańsk date back to the 13th Century and are closely linked to the city's development as a strategic commercial hub in the Baltic Sea. Gdańsk, located at the mouth of the Motława River, became a significant trading centre during the Middle Ages thanks to its membership in the Hanseatic League, a powerful alliance of trading cities in Northern Europe. The need to protect the city from external invasions, particularly from pirates and rival powers such as Denmark and Poland, led to the construction of a complex defence system that included not only walls but also moats and towers[1].

The first city walls were primarily made of wood and earth, a common technique in the Middle Ages, but were gradually replaced by more robust and durable brick and stone structures. The growing threat of attacks by the Teutonic Knights, who ruled the surrounding region, spurred further improvements to the fortifications, with the integration of new technologies such as gunpowder and artillery in the 14th and 15th centuries[2]. The architecture of Gdańsk's walls reflects the adoption of advanced construction techniques for the time, such as the *wątek wendyjsk*i, a type of brickwork typical of the Baltic region. The walls were reinforced by defensive towers positioned along the perimeter, many of which also served as observation and lookout points. For instance, the *Wieża Więzienna* (Prison Tower) and the *Wieża Żuraw* (Crane Tower) are two of the most remarkable structures still intact today, functioning both as part of the defences and as symbols of the city's economic power[3] .

The towers were not solely defensive structures but also had civil functions. The *Wieża Żuraw*, for example, also served as a crane for loading and unloading goods from sailing ships moored along the *Motława River*, highlighting the essential role of trade in the city's life. Additionally, the monumental gates, such as the *Brama Długouliczna* and the *Brama Kog*i, served as strategic entry points through the walls, enabling strict control over the movement of people and goods in and out of the city[4].

[1] Chudziak (2012), *Gdańsk: A City of Fortifications*.
[2] Cieślak (1985), *Historia Gdańska*.
[3] Medieval Heritage (2023), *Starogard Gdański - Obwarowania Miejskie*.
[4] Ważny (1999), *Mury miejskie Gdańska w świetle badań archeologicznych*.

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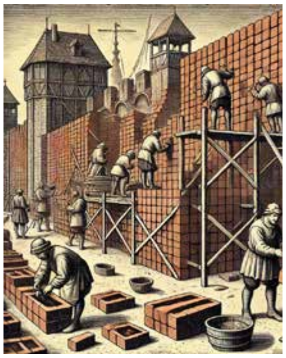

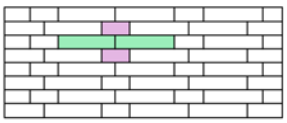

Figs. 02,03
Wątek wendyjski, a type of brick masonry, imagined by AI
Images generated by the author using DALL.E AI

Archaeological excavations have played a key role in understanding the mediaeval walls of Gdańsk, revealing valuable details about construction techniques and materials used. The excavations have uncovered several buried sections of the walls, along with remnants of towers and bastions no longer visible above ground. These digs confirmed that the walls were built primarily with brick, with some sections reinforced with stone in areas more vulnerable to attack[5].

One of the most significant excavations took place around the Brama Kogi, where foundation remains dating back to the 14th Century were uncovered. These excavations also brought to light fragments of pottery and tools, offering insights into the daily life of mediaeval Gdańsk's citizens[6]. Furthermore, recent excavations have uncovered new sections of the walls and towers in the western part of the city, allowing for a better understanding of the complexity of the defensive system[7].

Restoration efforts began as early as the 19th Century and continue to this day, with the aim of preserving these historic structures for future generations. The restoration of the walls has often involved the use of traditional building techniques to maintain the authenticity of original materials and methods[8].

During the Middle Ages, Gdańsk's walls were continuously expanded and reinforced. A turning point in their development came with the introduction of gunpowder in the 14th Century, which necessitated the construction of more massive bastions to withstand new forms of siege. This evolution is clearly evident in the wall expansion projects, which included the addition of gun ports and artillery platforms at strategic points around the city[9]. Additionally, the city's geography—situated on a floodplain surrounded by marshes and waterways—played a crucial role in enhancing its natural defences. The walls were connected to a system of moats filled with water from nearby rivers, creating an extra barrier against land attacks. Defence was further strengthened by fortifications on the surrounding hills, such as Góra Gradowa and Biskupia Górka, which provided a strategic vantage point over the city and its walls[10].

The Hanseatic League had a significant impact on the construction and maintenance of Gdańsk's walls. As a member of this trade alliance, Gdańsk gained the economic and military resources necessary to develop a robust defensive system. The walls were not only a means of physical defence but also a symbol of the League's ideals, which included commercial cooperation, security, and prosperity. Gdańsk's fortifications were crucial for safeguarding goods and the vital maritime routes essential for trade, linking the city with major centres such as Lübeck and Hamburg[11]. The Hanseatic League was concerned not only with maritime trade but also with the defence of its members.

[5] Ważny (1999), *Mury miejskie Gdańska w świetle badań archeologicznych*.
[6] Medieval Heritage (2023), *Starogard Gdański - Obwarowania Miejskie*.
[7] Możejko (2010), *Gdańsk in the Middle Ages: Trade, Defense, and Growth*.
[8] Cieślak (1985), *Historia Gdańska*.
[9] Chudziak (2012), *Gdańsk: A City of Fortifications*.
[10] Medieval Heritage (2023), *Starogard Gdański - Obwarowania Miejskie*.
[11] Chudziak, 2012; Możejko, 2010.

This is evident in the League's direct involvement in financing Gdańsk's fortifications, especially after the 14th Century, when external threats increased. Consequently, the walls were reinforced with what were considered modern technologies at the time, such as artillery platforms and lookout towers[12].

Gdańsk's mediaeval walls were built using advanced techniques for the period, such as the wątek wendyjski, a type of brick masonry common in the Baltic regions and northern Poland. These methods not only enhanced the walls' durability but also allowed for relatively quick and less costly construction compared to stone fortifications. The use of brick, with stone reinforcements in some sections, created a solid and enduring defensive structure that was continuously improved in the centuries that followed[13]. Over time, the walls underwent numerous restoration efforts, especially in the 19th and 20th centuries. During the post-war reconstruction period, a significant portion of the walls was restored to preserve the city's historical heritage, using techniques that aimed to remain faithful to mediaeval materials and methods. Archaeological excavations conducted in various parts of the city have helped uncover new sections of the walls and enhance our understanding of the original construction techniques[14].

Fig. 04
Urban wall of Gdańsk
Along the perimeter of the city, remnants of the original medieval fortifications are still visible today.

Fig. 05
Urban wall of Gdańsk, detail of the Corner Tower (Baszta Narożna, PL)
Still displays its original medieval masonry pattern, now restored and repurposed for contemporary use.

[12] Cieślak (1985), *Historia Gdańska*.
[13] Ważny (1999), *Mury miejskie Gdańska w świetle badań archeologicznych*.
[14] Medieval Heritage (2023), *Starogard Gdański - Obwarowania Miejskie*.

Fig. 06
Urban wall of Gdańsk
Above, a section of walls restored after the IIWW; A fragment of medieval wall visible in a restored section; The interior of a section of wall. The photo reveals the construction technique and highlights the various restoration and renovation interventions.

Archaeological excavations of the mediaeval walls of Gdańsk

The archaeological excavations of the mediaeval walls of Gdańsk have significantly enhanced our understanding of mediaeval construction techniques and the city's urban history. These excavations, which began systematically in the 19th Century and continue to this day, have led to the discovery and documentation of many sections of the walls that had been buried or destroyed over the centuries. One of the earliest major excavations was conducted around the Brama Kogi, one of the city's main gates, where the brick foundations dating back to the 14th Century were uncovered[15]. Finds here include fragments of pottery, everyday tools, and coins that help reconstruct the economic and social life of the city during the Middle Ages. The discovery of architectural elements such as cornerstones and glazed bricks has contributed to a better understanding of the building techniques used to erect the walls. Another important archaeological excavation took place along the western section of the walls, near the Wieża Więzienna (Prison Tower), one of Gdańsk's most iconic towers. Here, archaeologists uncovered multiple layers of the wall, showing that the fortifications were rebuilt and expanded several times over the centuries to adapt to technological and military changes. Some finds in this area include old iron cannons, illustrating the shift from crossbows and handheld weapons to heavy artillery, necessitated by the introduction of gunpowder in the 14th Century[16]. The excavations have also revealed the presence of a vast system of moats running parallel to the walls, filled with water from nearby rivers as an additional defensive barrier. This moat system became particularly evident during excavations along the northern side of the walls, demonstrating the attention mediaeval builders devoted to protecting the city's most vulnerable areas. Finds in the moats, including wood fragments and remains of boats, indicate that these structures also served as part of the city's port system, effectively integrating defence and trade[17]. Excavations conducted since the 2000s have uncovered new sections of the walls and enriched our understanding of mediaeval construction techniques. For example, during renovation work near

[15] Medieval Heritage (2023), *Starogard Gdański - Obwarowania Miejskie.*
[16] Ważny (1999), *Mury miejskie Gdańska w świetle badań archeologicznych*.
[17] Cieślak (1985), *Historia Gdańska*.


Fig. 07
The Western part of northern Walls complex
In the foreground, a series of arches built against the walls can be seen. On the right: a section of wall with a fragment of a darker, medieval wall.

the Motława River, foundations of towers and previously unknown wall sections were discovered. These findings revealed that some of the oldest sections of the walls had been incorporated into later buildings, illustrating how the city expanded and transformed over the centuries[18].

Brick Construction Techniques: The Wendish Bond

The predominant construction technique used for building the walls of Gdańsk was the wątek wendyjski, a type of brick masonry common in many areas of the Baltic and northern Poland during the Middle Ages. This technique is characterised by a specific brick-laying pattern, alternating layers of bricks laid in "header" position (with the short side of the brick facing outward) and "stretcher" position (with the long side facing outward). This masonry system provided greater structural stability and allowed for the rapid construction of long wall sections[19]. The use of bricks for constructing the walls of Gdańsk was not only a technical choice but also a practical necessity. The Gdańsk region is relatively poor in natural stone, making brick the most accessible and economical alternative for constructing monumental buildings. Bricks were produced locally, using abundant clay found around the city, and then fired in specialised kilns. Large-scale brick production became a thriving industry in Gdańsk during the 14th and 15th centuries, driven by the rising demand for walls and other public and private structures[20].

The brick walls were often reinforced with cornerstones in areas most exposed to attacks, such as around city gates or watchtowers. In some parts of the walls, bricks were glazed or decorated, as seen in the Długouliczna Gate, where examples of majolica decorations, a type of high-quality glazed ceramic, have been found[21]. These architectural details not only added strength to the structure but also provided an aesthetic element that reflected the wealth and importance of Gdańsk as a trade city.

[18] Możejko (2010), *Gdańsk in the Middle Ages: Trade, Defense, and Growth.*
[19] *Ibid.*
[20] Ważny (1999), *Mury miejskie Gdańska w świetle badań archeologicznych*.
[21] Cieślak (1985), *Historia Gdańska cit.*.

Figs. 08, 09
The Swan Tower in the historic city of Gdańsk
General and close-up views illustrate the tower's integration into the surrounding urban landscape, highlighting its architectural character and relationship to the medieval city layout.

The evolution of Gdańsk's mediaeval walls reflects a strategic adaptation of construction techniques, shaped by both defensive needs and available materials. Initially, the city's defences were built from wood and earth, consistent with mediaeval norms, but were gradually replaced by brick masonry as Gdańsk expanded its role as a commercial centre. This transition allowed for the adoption of the wątek wendyjski or Wendish bond technique, characterised by alternating headers and stretchers, enhancing structural integrity and accelerating construction[22]. The scarcity of natural stone in the region made brick the most practical choice, with local clay resources enabling large-scale brick production by the 14th Century, as demand surged with the construction of public and private edifices[23]. The design of Gdańsk's walls reflects successive improvements over time, notably the inclusion of defensive towers like the Wieża Więzienna and Wieża Żuraw. These towers served dual roles, offering elevated positions for observation and symbols of economic strength, as seen in the multifunctional crane of the Wieża Żuraw[24]. Additionally, with the rise of gunpowder technology in the 14th Century, the city incorporated artillery platforms and expanded fortifications to withstand new forms of siege weaponry[25]. Reinforcement with stone at vulnerable points, like city gates, added durability where the threat of attack was greatest. Archaeological excavations, particularly around gates such as Brama Kogi, have uncovered wall foundations and artefacts, highlighting the day-to-day life of mediaeval Gdańsk. These discoveries underscore the dual function of the walls as both defence and trade facilitators, a theme reflected in the city's involvement in the Hanseatic League. As a Hanseatic member, Gdańsk received vital support for its defences, aligning the walls with the League's ideals of prosperity, security, and commerce[26]. The significance of Gdańsk's walls thus lies not only in their architectural form but also in their adaptive resilience over centuries. The defensive strategies, choice of materials, and incorporation of the latest technologies of the time underscore how the walls served both as physical protection and as monuments to the city's importance in Baltic trade networks.

[22] Możejko (2010), *Gdańsk in the Middle Ages: Trade, Defense, and Growth*.
[23] Ważny (1999), *Mury miejskie Gdańska w świetle badań archeologicznych*.
[24] Medieval Heritage, 2023.
[25] Chudziak (2012), *Gdańsk: A City of Fortifications*.
[26] Możejko (2010), *Gdańsk in the Middle Ages: Trade, Defense, and Growth*.

Refereces

Cieślak E. 1985, *Historia Gdańska, Wydawnictwo Morskie*, Gdańsk.

Chudziak M. 2012, *Gdańsk: A City of Fortifications, Muzeum Historyczne Miasta Gdańska*, Gdańsk.

Możejko B. 2010, *Gdańsk in the Middle Ages: Trade, Defense, and Growth*, Gdańsk University Press, Gdańsk.

Ważny T. 1999, *Mury miejskie Gdańska w świetle badań archeologicznych*, *Wydawnictwo Naukowe PWN*, Warszawa.

Medieval Heritage 2023, *Gdańsk - Miejskie Mury Obronne*. medievalheritage.eu, 2023.

Medieval Heritage 2023, *Starogard Gdański - Obwarowania Miejskie*. medievalheritage.eu, 2023.

Możejko B. 2019, *Gdańsk w średniowieczu: port i handel*, in Radio Gdańsk.

National Museum of Gdańsk 2000, *Fortifications and Defenses of Medieval Gdańsk*, National Museum, Gdańsk.

Medieval Heritage 2023, *Gdańsk - Ratusz Głównego Miasta* medievalheritage.eu, 2023..

The Hanseatic League and the Defense of Gdańsk 2018, in *Journal of Hanseatic Studies*, 32(2), pp. 112-129.

Fig. 10, 11
Gateways and Strongholds: Traces of Medieval Gdańsk Along the Vistula
From the river-side perspective in Gdańsk, it is possible to admire the Straganiarska Gate seamlessly woven into the city's riverside skyline. Below the Jacek Tower – a historic symbol anchoring the medieval fortification network within the urban landscape.

DATA ACQUISITION PROCEDURES BETWEEN PHOTOGRAMMETRY AND LASER SCANNER SURVEYS

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Side page, Fig. 01
Corner tower

Gdańsk's medieval walls and fortifications stand as widespread and defining monuments of the city, steeped in architectural and engineering complexity, evidence not only of medieval military ingenuity but also of urban adaptations throughout history[1]. As seen in the previous sections, the very fabric of Gdańsk's medieval walls reflects the passage of time, incorporating various phases of construction, renovation, and adaptation. The architectural complexity is intrinsically linked to the materials used, the construction techniques employed and the functional needs of the city[2].

The significant integration of defensive and architectural elements into these structures requires a detailed representation, which through geometric/formal and textual quality, is often the basis for expert study of the degree of damage and deterioration, but at the same time can also serve as the formal basis on which to set up actions for knowledge, enhancement and protection of such historical heritage[3].

In this context, the utilization of integrated survey methods for data acquisition enables the precise digital replication of buildings and their distinctive features. The current era has witnessed an exponential increase in the availability of 3D datasets, driven by tools facilitating survey operations across various scales, from macroscale to microscale. However, these tools show notable differences in resolution, accuracy, acquisition time, and the availability of RGB texture points. Because of this reason, in the 3D data acquisition process, it is imperative to consider technological solutions that complement each other, rather than merely duplicating the acquired geometry of the object[4]. Within this perspective, the data acquisition phase demands meticulous analysis and strategic planning of procedures to address critical issues arising from the specific characteristics of the object being represented. It involves optimizing and integrating the technological specificities of the survey tools.

One effective solution lies in the synergistic application of terrestrial and aerial surveying techniques. Integrated surveying, incorporating both range-based methods - using laser scanner instruments - and image-based ones - with ground-based and UAV photography - , facilitates the acquisition of comprehensive and metrically reliable information.

[1] Tölle (2008), *Gdańsk*, pp. 107-119.
[2] Januszajtis (1999), *Fortifications of Old Gdańsk*, pp. 361-374.
[3] Trizio et al. (2021), *Digital environment for remote visual inspection and condition assessment of architectural heritage*, pp. 869-888.
[4] Remondino et al. (2014), *State of the art in high density image matching*, pp. 539-546.

Referee List (DOI 10.36253/fup_referee_list)
FUP Best Practice in Scholarly Publishing (DOI 10.36253/fup_best_practice)
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Fig. 02, 03
The tower census
Diagram of the preserved elements surveyed in detail; on the right, a photograph of the White Tower..

This approach optimizes on-field acquisition time and allows the integration of different data in order to represent the object in its entirety, capturing its formal and material characteristics, as well as its relationship to the urban and environmental context[5].

Terrestrial laser scanning (TLS) has become a prevalent method for acquiring 3D cultural heritage (CH) data, driven by the increased availability of scanning technologies. This approach yields dense point cloud models, facilitating the effective mapping of monuments, serving as a primary tool for archiving architectural details, historic buildings, and their complexities. Mobile laser scanning (MLS) systems complement TLS by offering the advantage of acquiring data from dynamic perspectives and efficiently covering large areas, but they have lower resolution and metric reliability. These gaps are successfully implemented by data obtained from unmanned aerial vehicles (UAVs), which provide better image geometry of the entire area, but lack accuracy in terms of both metric and textural information compared to, for example, data from digital terrestrial photogrammetry, which, on the other hand, is better at capturing textural details (of accessible areas) with greater accuracy but more time consuming.

If from a purely practical point of view terrestrial photography was very rapid and direct, on the other hand it proved insufficient with regards to the acquisition of the upper parts of the remains of the urban fortifications (city walls). Therefore it was necessary to use a drone to be able to take images of the crests of the walls of the roofs of the Towers and the upper parts of all those elements that are not visible from the ground.

[5] Parrinello et al. (2022), *Drones and Drawings - methods of data acquisition, management, and representation*, pp. 1-7.

Figs. 04, 05, 06
Survey of defensive wall remains
The traces of masonry textures along the city perimeter were identified and thoroughly documented. In some cases, embedded towers are still visible within the wall structures, while in others crenellations survive, highlighting the original defensive features and construction techniques of the fortification system.

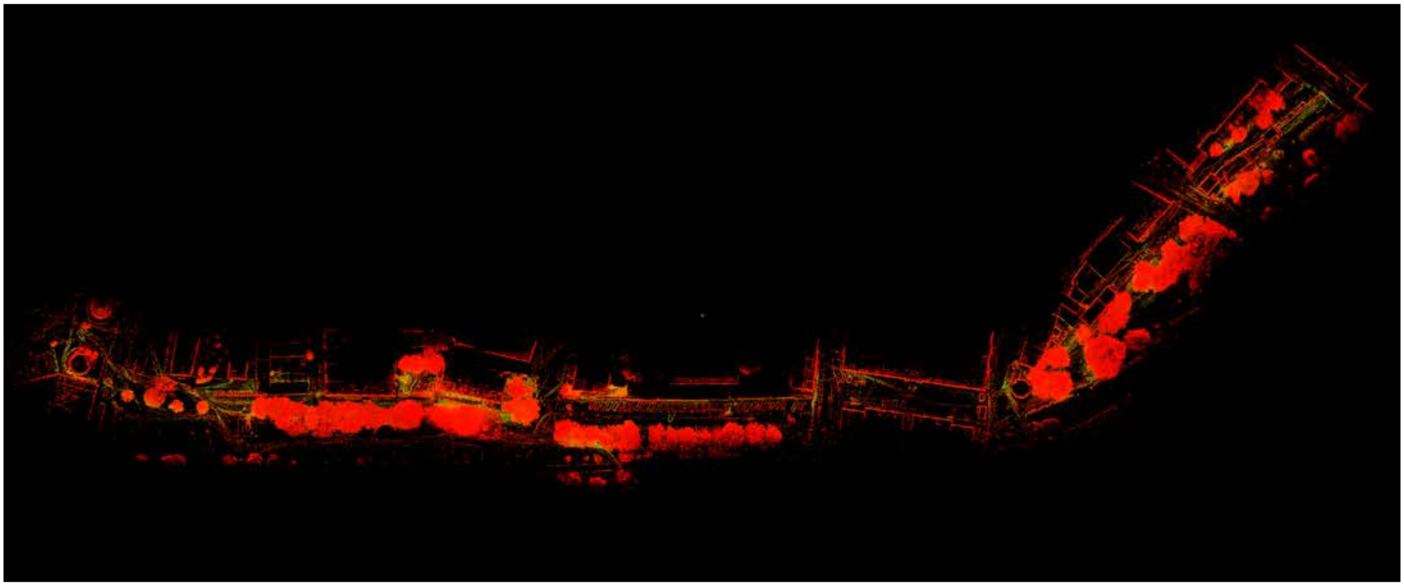
The scans were then linked to those carried out from the ground thanks to the use of homologous points with the scans from the ground. It was often not possible to use markers due to the context in which we found ourselves operating.

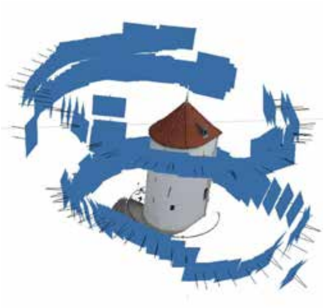
Also in this case there are three phases of acquisition of images from a drone which then lead to the creation of a three-dimensional model:

- the acquisition phase, in which the images are captured, filtered and developed from the raw formats;
- the orientation of the cameras and the creation of a geographical space in which the frames can be reprojected;
- the three-dimensional reconstruction and the possible export of two-dimensional outputs which will then follow for the generation of the deterioration map and two-dimensional surveys.

There were many significant problems associated with this type of intervention. What proved to be the most impeding was certainly the presence of colonies of birds nestled under the roofs of the towers and present in the various squares of Gdańsk. To solve this problem it was enough to carry out scans at different times of the day, however, significantly prolonging the survey operations. The second significant problem, however, was the low temperature and strong winds which began to be an obstacle to the stability of the drone and consequently its safety from an altitude of 7-8 m. Finally, thanks to the presence of a network of GNSS points detected by the DAda-LAB laboratory, the point clouds generated both from the ground and from the drone were recorded on a common topographic mesh[6].

[6] Guidi et al. (2003), *Fusion of range camera and photogrammetry: a systematic procedure for improving 3D models metric accuracy*, pp. 667-673.





Figs. 07, 08
Fortifications of Gdansk, database devolopment
Plan view of a urban path acquired by mobile laser scanner, and UAV acquisition og White tower and Corner tower.

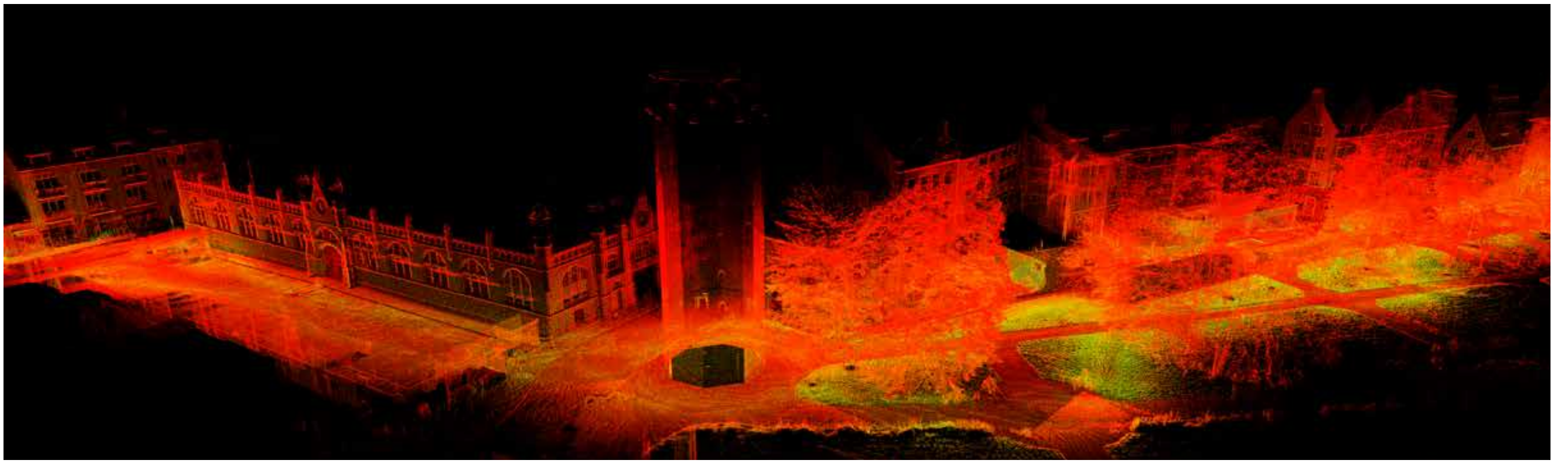
Next pages *Figs. 09, 10, 11, 12, 13, 14, 15*
Point cloud view
The point cloud illustrates the survey of the boundary walls. The mobile mapping acquisition was integrated with detailed, high-resolution surveys carried out around the towers included in the CH Route, ensuring a more accurate documentation of architectural features and construction details.

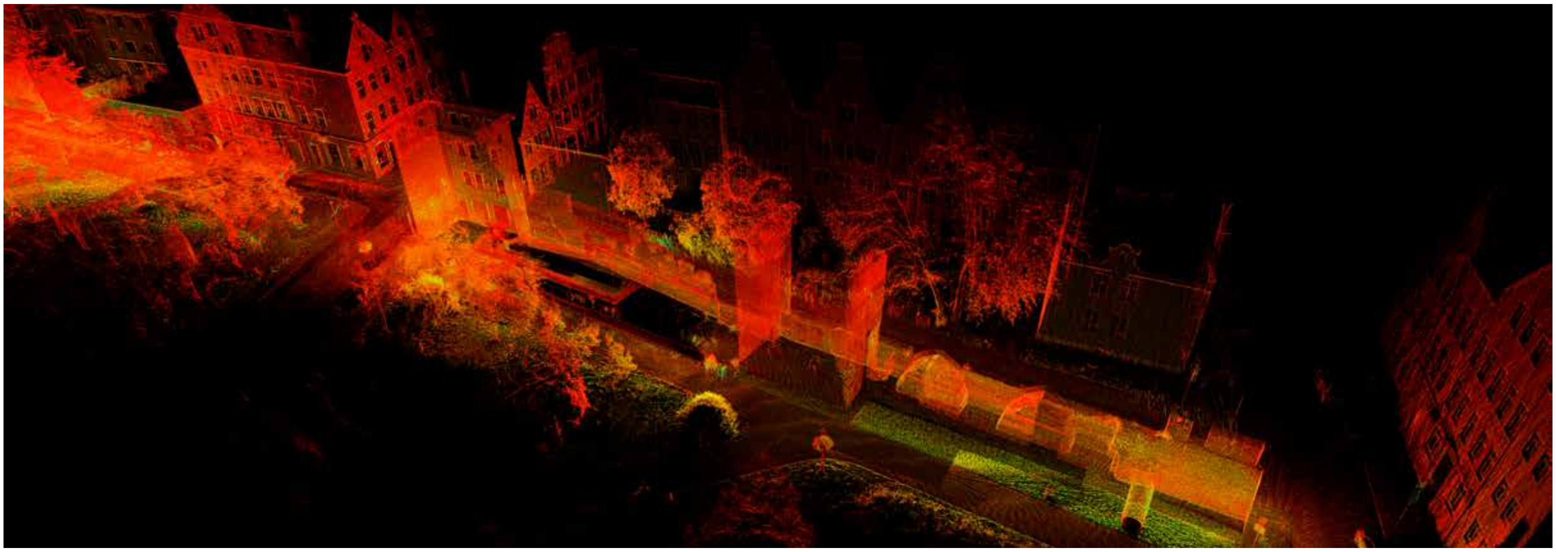
The results obtained have made it possible to generate point clouds that can be integrated into other workflows and 3D models, which can morphologically and visually describe geometries with an absolutely reliable material and colorimetric appearance.

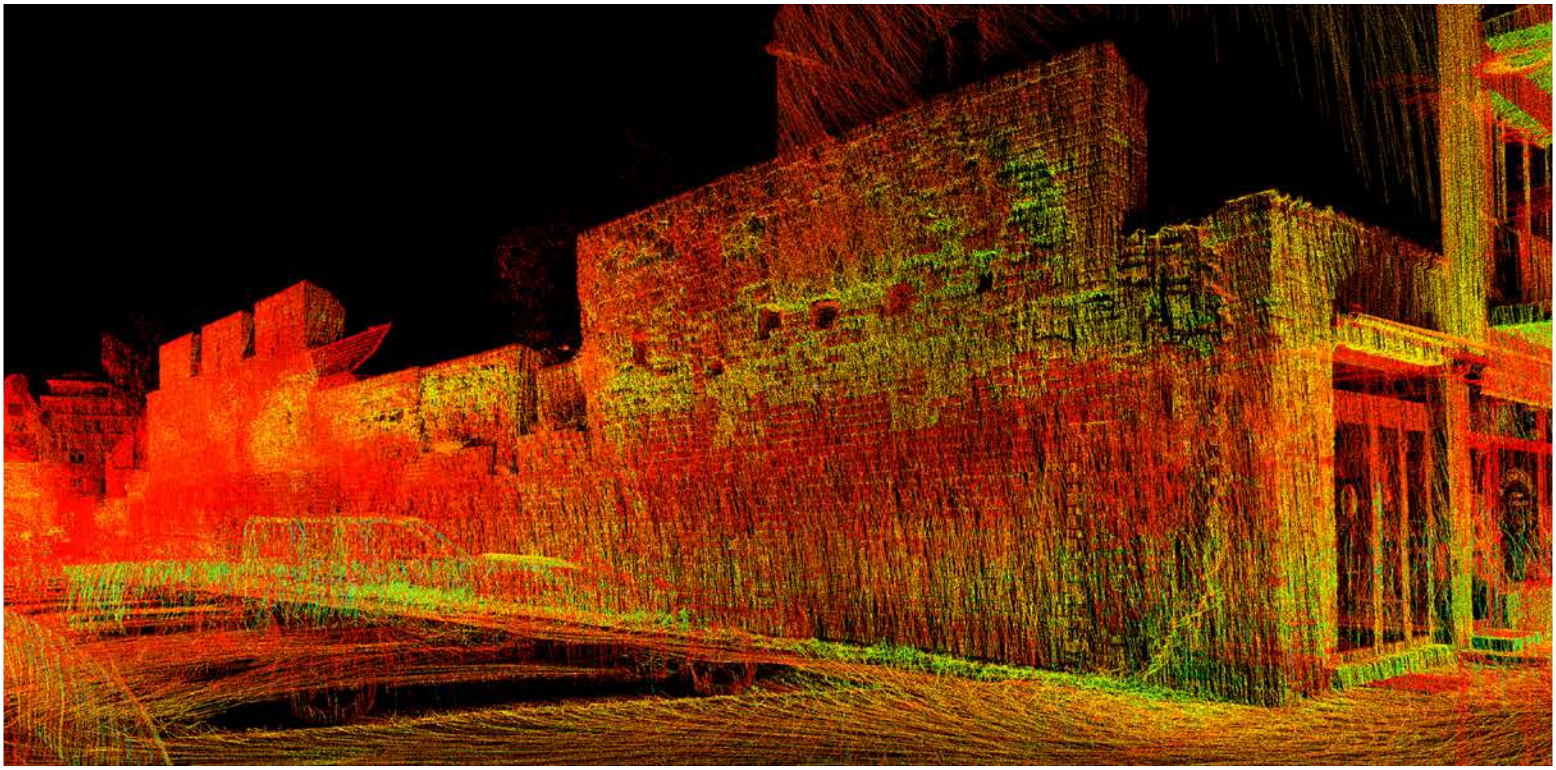
The integrated use of UAV photogrammetry and mobile laser scanning (MLS) technologies has proven to be particularly effective for the systematic representation of the outer edges and boundary lines of Gdańsk's medieval fortification system. These edge conditions—where vertical masonry, earthen ramparts, and later urban additions often meet in complex, irregular geometries—are especially challenging to capture using a single surveying method. By combining UAV-based image acquisition with the dynamic, close-range scanning capabilities of the Leica BLK2GO, it becomes possible to obtain a unified and continuous 3D representation of both the vertical development and the horizontal articulation of the city walls.

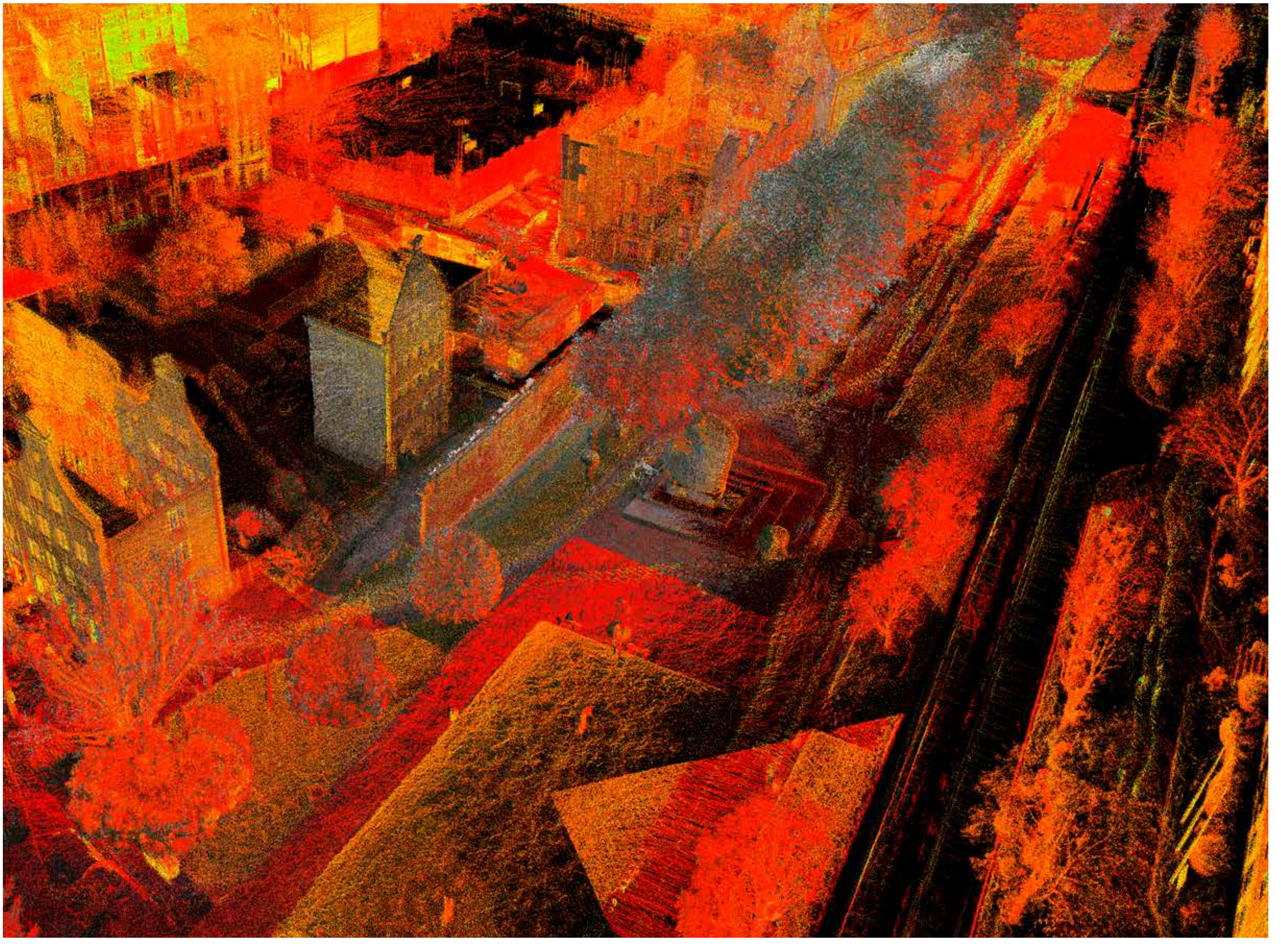
UAVs, equipped with high-resolution cameras, were employed to acquire overlapping imagery of the wall tops, crenellations, and parapets—areas that are otherwise difficult or dangerous to reach from the ground. These aerial datasets provided comprehensive visual coverage and were instrumental in reconstructing the elevation profiles of the walls in their entirety. However, aerial data alone lacks the close-range accuracy and detail needed for representing the base zones of the walls and their contact with the surrounding urban fabric, especially in narrow alleys or partially buried sections.

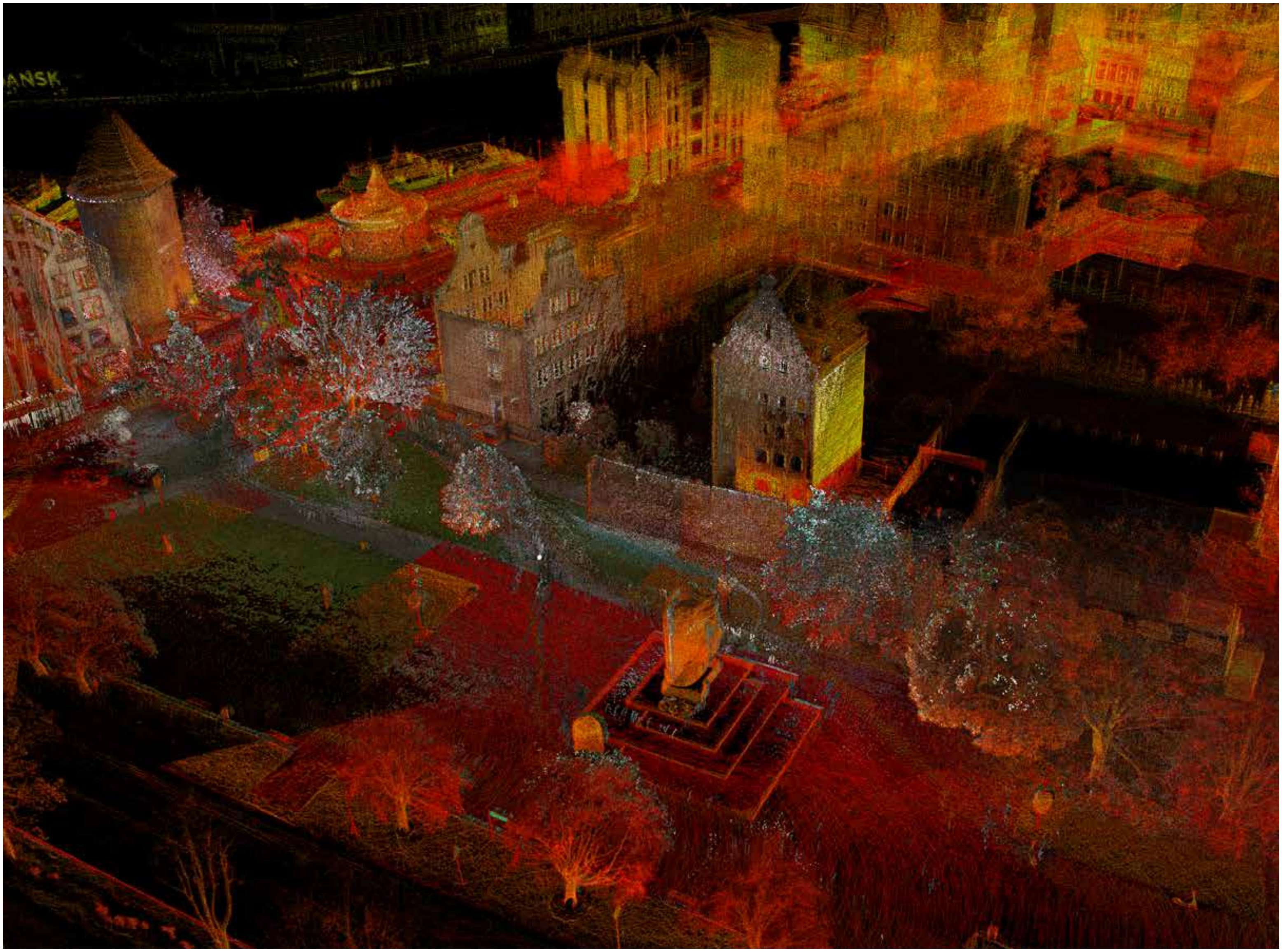
To address this limitation, the BLK2GO mobile laser scanner was used to walk along the perimeter of the walls, capturing dense point cloud data from street level. This approach allowed for high-resolution documentation of the wall foundations, niches, gateways, and interface points where the historic structures abut modern constructions. The real-time SLAM technology of the BLK2GO enabled flexible movement across uneven terrain and congested areas, making it ideal for capturing the "lower edge" of the fortification system with both speed and precision.

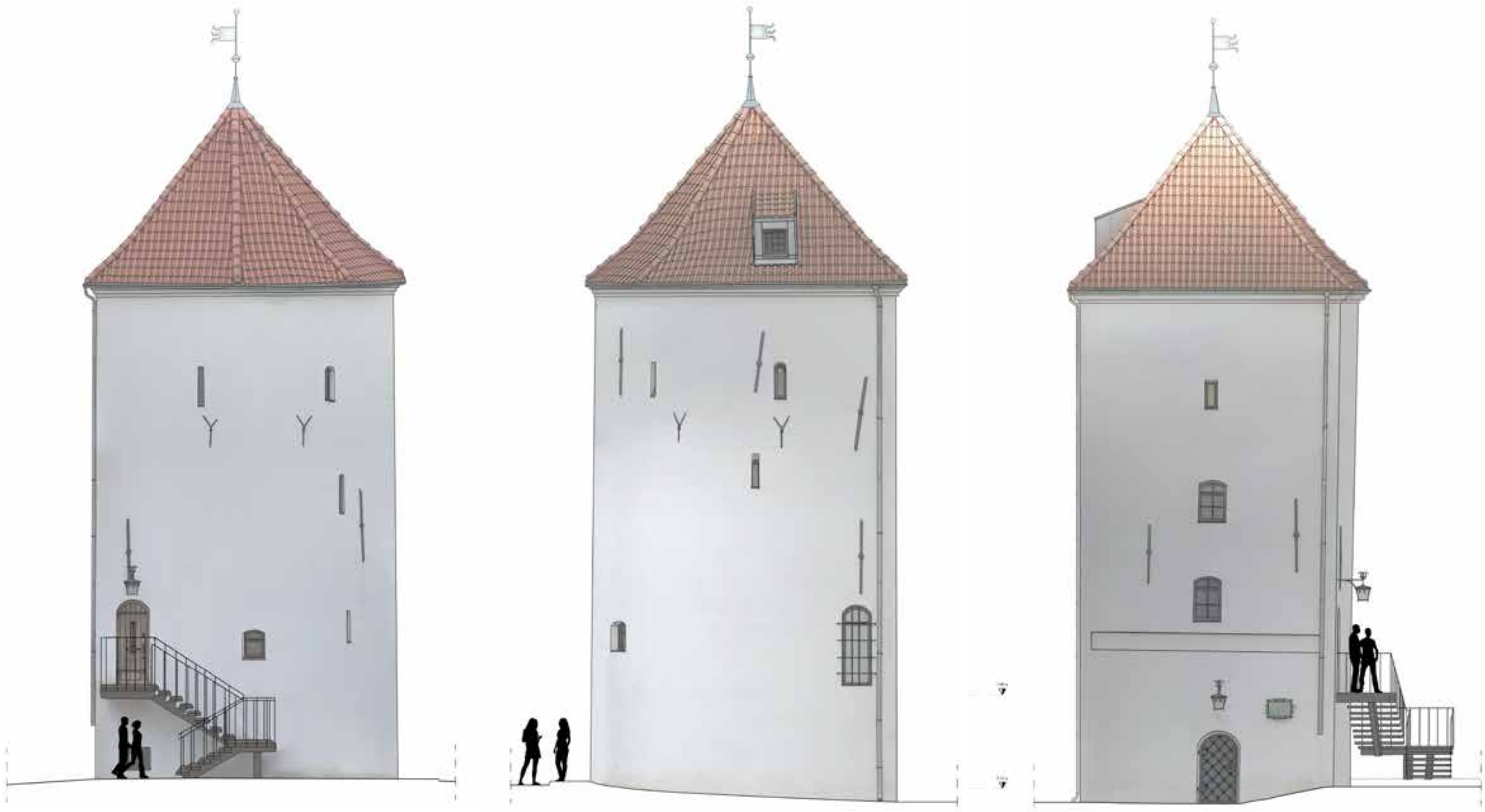


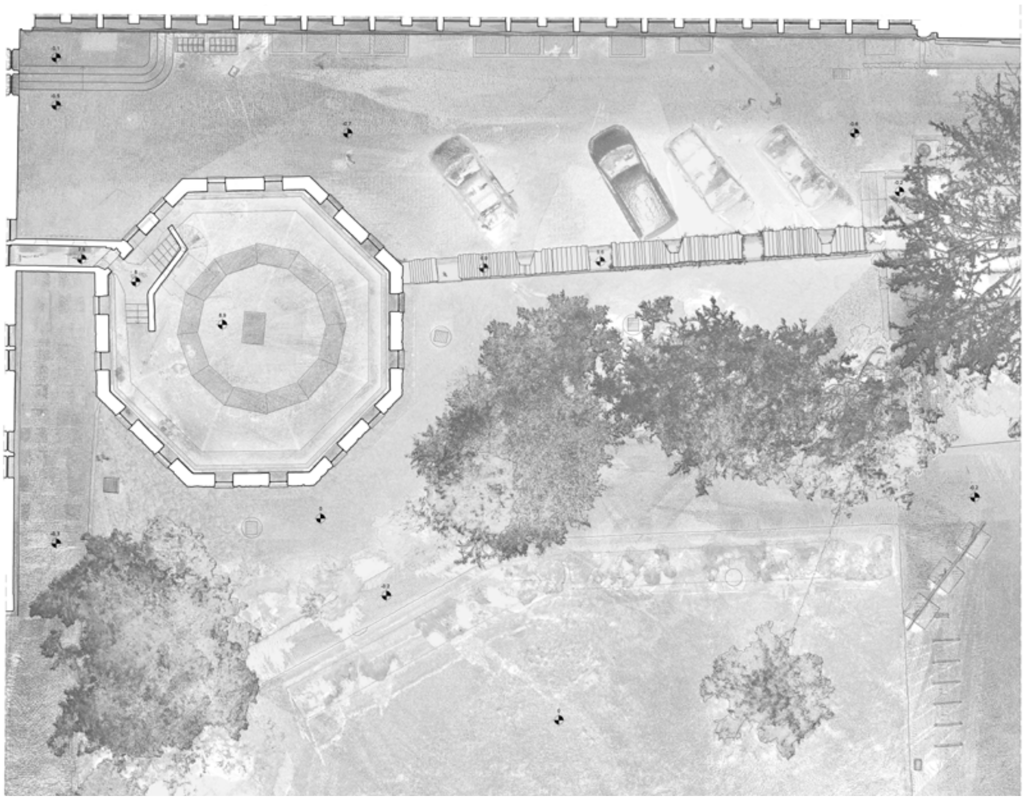


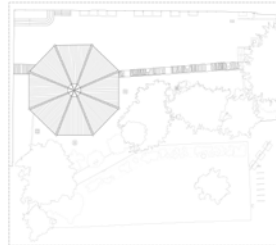


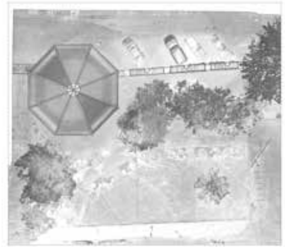


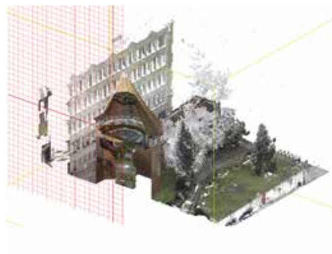






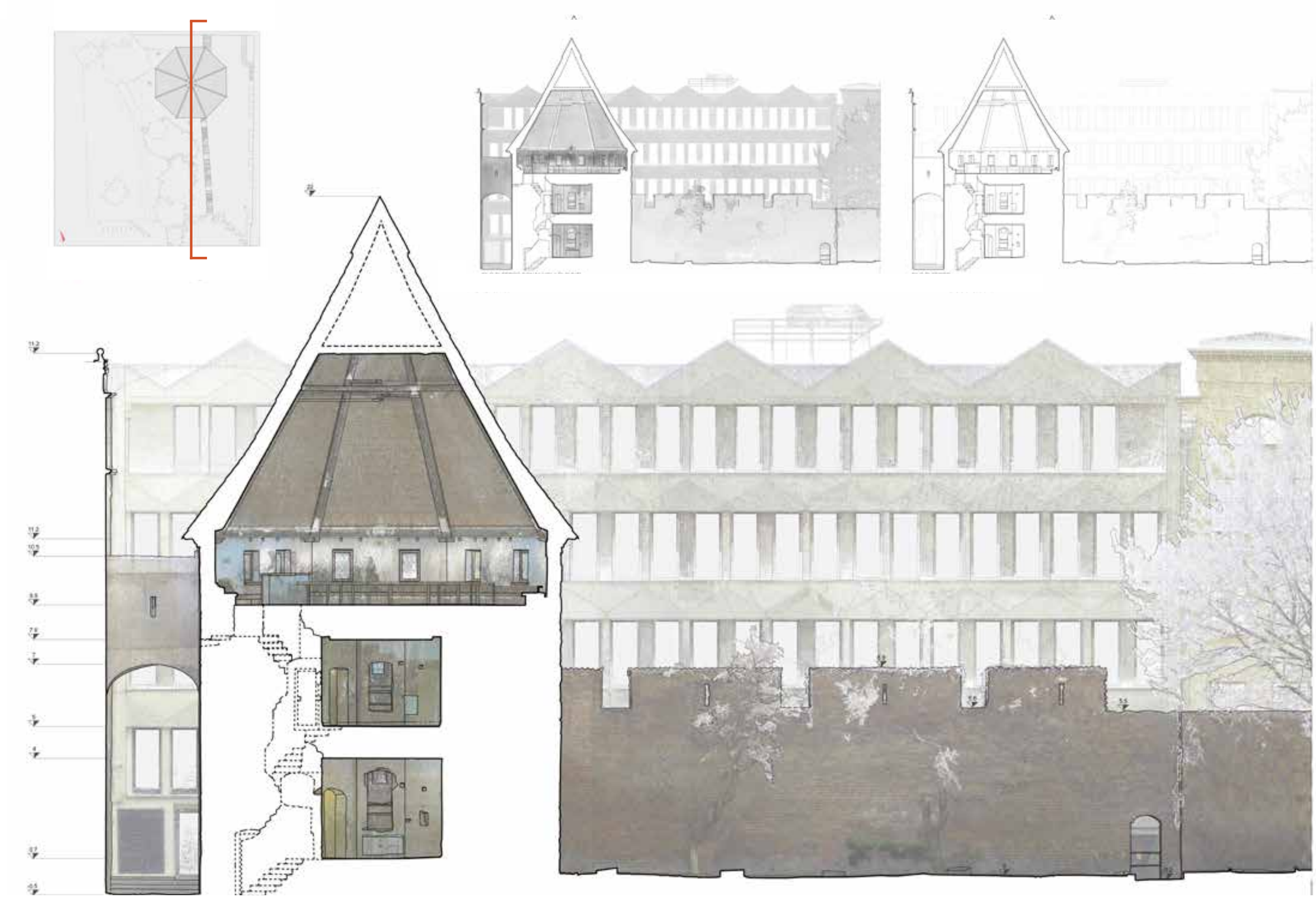


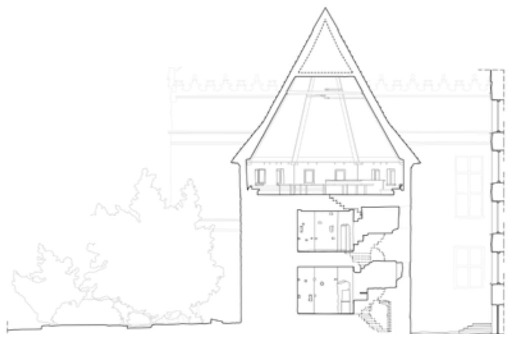




Side page, *Fig. 16*
White tower
External elevation drawings and sectional views of the tower, illustrating its architectural configuration, structural layout, and vertical organisation.

Fig. 17
Straw tower
Roof plan and first-floor plan of the tower, illustrating the spatial layout and organisation of the upper and intermediate levels.





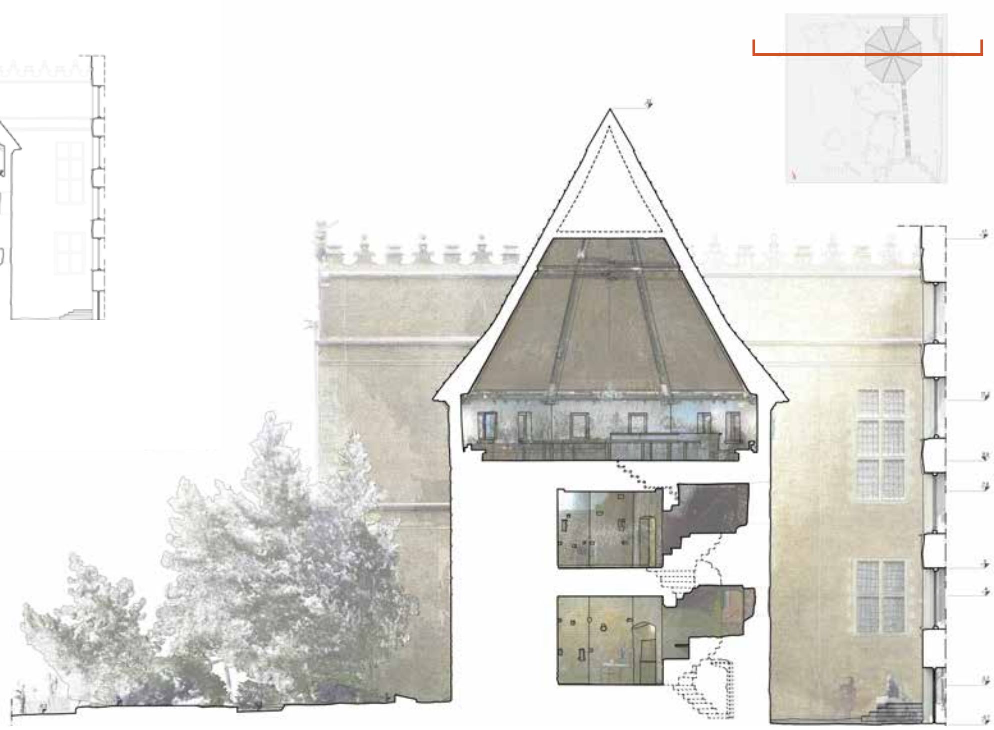
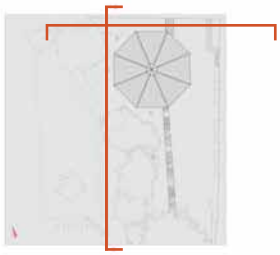
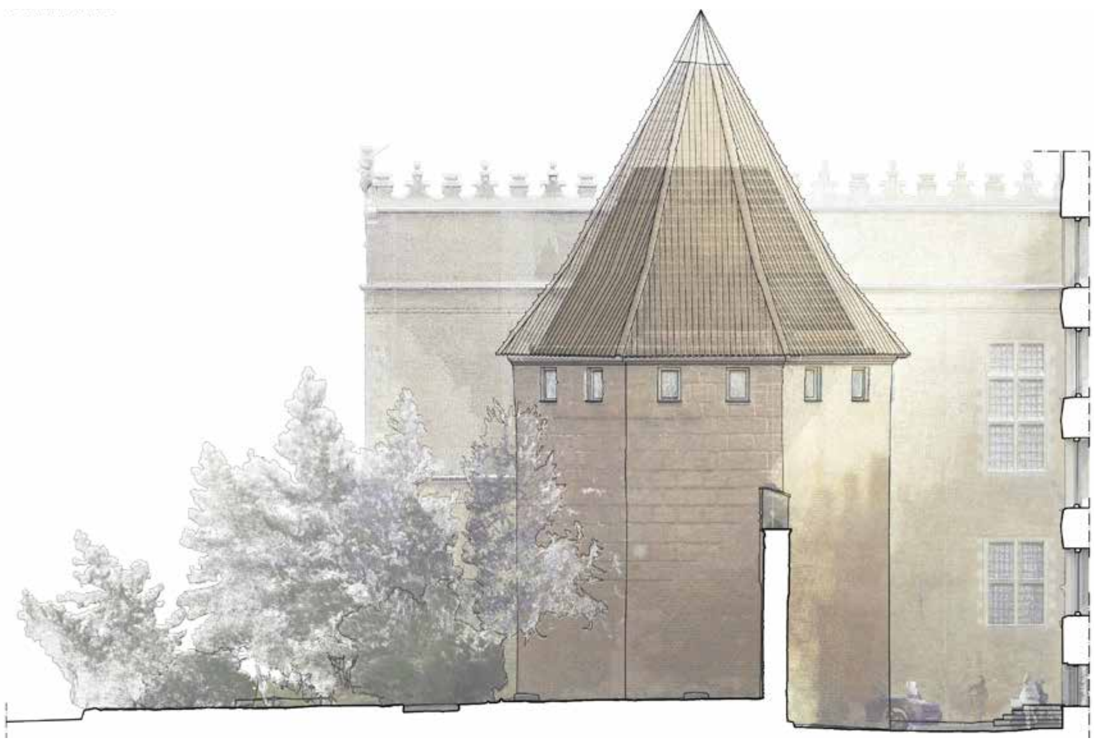


Fig. 18
Straw tower
Sections architectural configuration, structural layout, and vertical organisation.

Next page Fig. 19
Straw tower
External elevation (urban front).





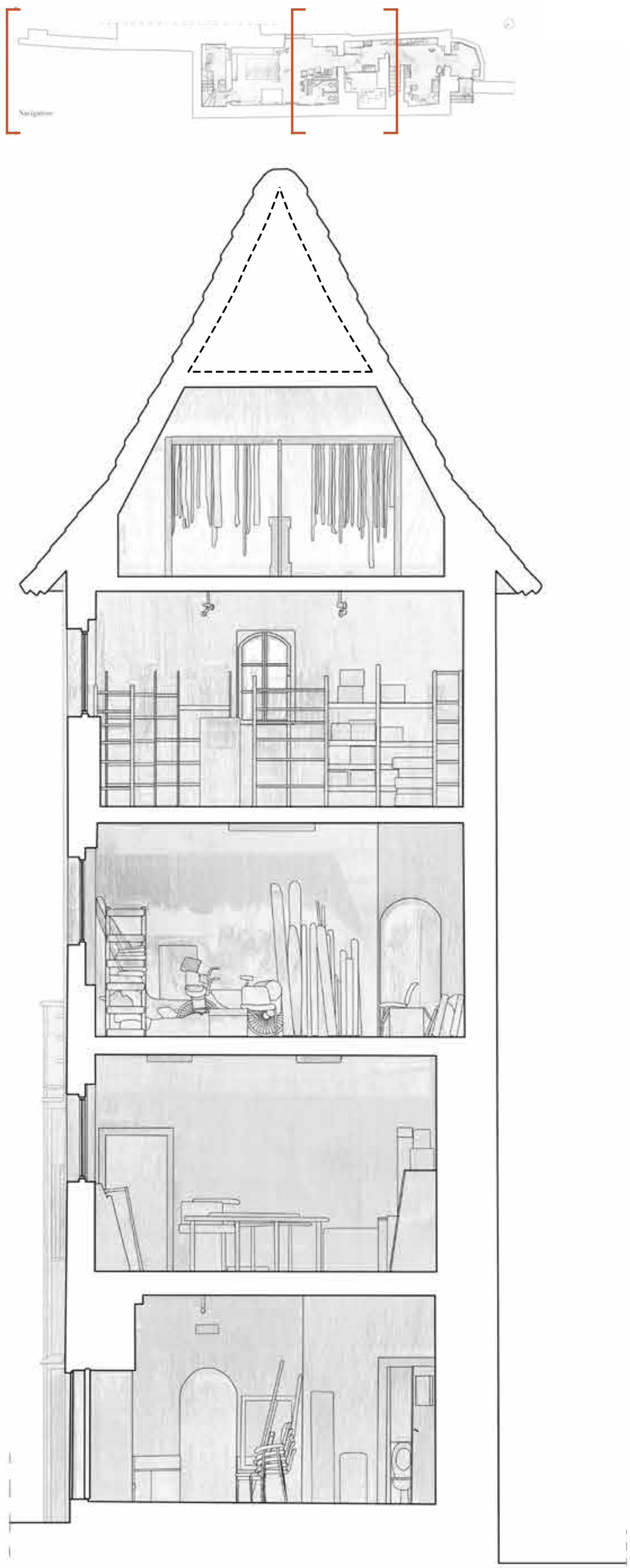
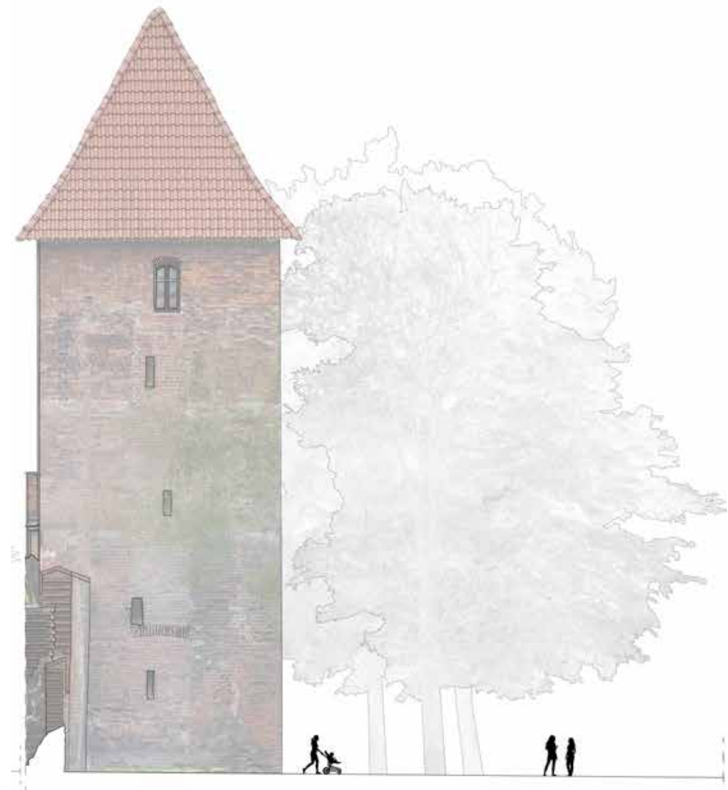
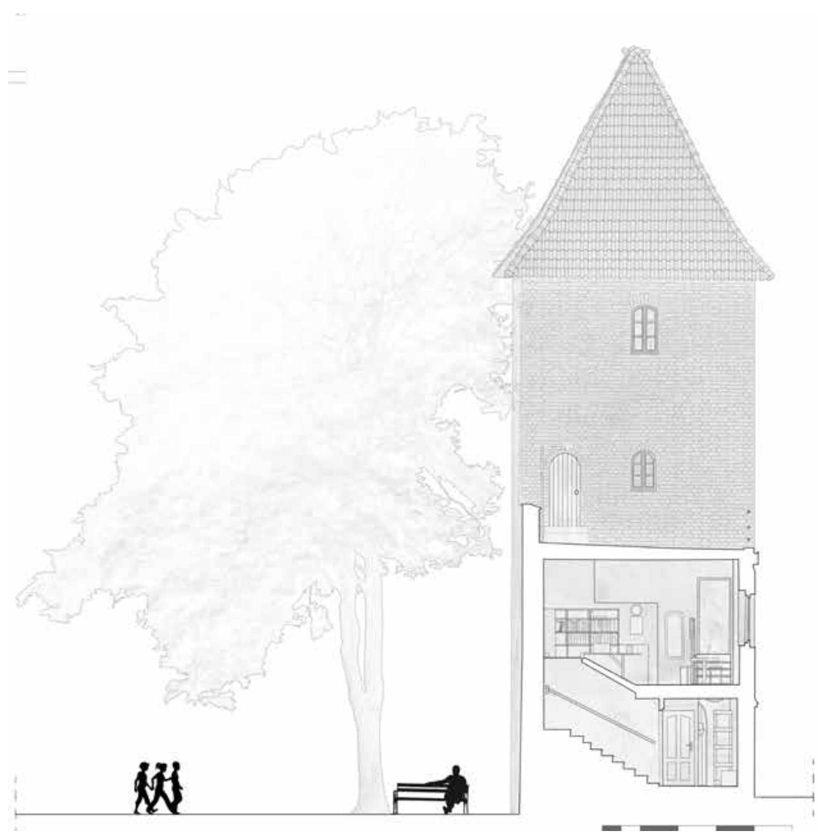


Fig. 20
Tower on the Behind/under Walls
2D Drawing and sections.





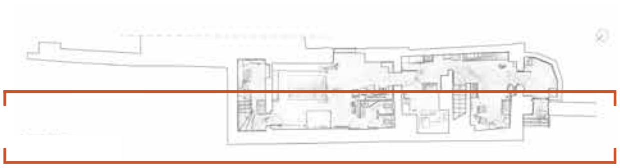


Fig. 21
Tower on the Behind/under Walls
The drawings not only describe the internal spaces but also illustrate the main spatial constraints, including the placement and volume of materials and furnishings within the tower.

Once processed, both UAV and MLS datasets were aligned and georeferenced within a shared topographic framework using ground control points and common features. The resulting integrated point cloud offers a holistic representation of the walls' boundaries, not only in geometric terms but also in terms of surface texture, material variation, and spatial context. This dataset serves as a base layer for analytical studies—such as deformation mapping, structural diagnostics, and urban growth modeling—and forms the foundation for interpretive and communicative outputs including orthophotos, 3D sections, and virtual reconstructions.

Cultural Significance and Visual Memory

Beyond the technical and methodological aspects of the survey, the act of reconstructing and visualizing Gdańsk's medieval fortifications carries a deeper cultural significance. Reclaiming the form, texture, and spatial context of these historical structures is not merely a question of data capture—it is an act of cultural reactivation. Digital models, generated through high-resolution point clouds and photogrammetric reconstructions, become instruments of collective memory, re-inscribing in the present the traces of a complex and often fragmented urban past.

By restoring visibility to these architectural remnants, the digital survey allows the broader public and scholars alike to engage with layers of history that are otherwise hidden, degraded, or inaccessible. These models serve as interpretative tools through which narratives of defense, transformation, and urban identity can be revisited and reinterpreted[7]. They also offer a foundation for future conservation strategies, educational outreach, and urban regeneration projects, reinforcing the role of heritage as a living component of the contemporary city.

In a time when historical environments are increasingly subject to neglect, transformation, or oblivion, the ability to digitally document and visualize cultural assets becomes a form of resistance—a way of affirming that the past still speaks, and that its signs, however weathered, still have the power to shape our sense of place and continuity.

Fig. 22
UAV 3D model
Result of the UAV photogrammetric acquisition.

[7] Fassi et al. (2015), A *multi-sensor approach for the 3D survey and the semantic analysis of the Pavia Cathedral*, pp. 261-268.

Fig. 23
Boundaury wall 3D database
On the left, the point cloud model acquired through mobile mapping with the BLK2GO system, providing a rapid and continuous capture of the urban environment. On the right, the 3D model generated from UAV photogrammetric acquisition, offering a more detailed and textured representation of surfaces. The comparison highlights the complementary nature of the two survey methodologies, combining speed of acquisition with geometric accuracy and visual richness. photogrammetric acquisition.

Fig. 24
White tower
UAV texured model.

Refereces

Agugiaro G., Remondino F., Girardi G., von Schwerin J., Richards-Rissetto H., De Amicis R. 2011, *A web-based interactive tool for multi-resolution 3D models of cultural heritage sites*, in *ISPRS Journal of Photogrammetry and Remote Sensing*, 66(2), pp. 136-147.

Fassi F., Achille C., Mandelli A., Rechichi F. 2015, *A multi-sensor approach for the 3D survey and the semantic analysis of the Pavia Cathedral*, in *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XL-5/W7, pp. 261-268.

Guidi G., Beraldin J.-A., Ciofi S., Atzeni C. 2003, *Fusion of range camera and photogrammetry: a systematic procedure for improving 3D models metric accuracy*, in *IEEE Transactions on Instrumentation and Measurement*, 52(4), pp. 667-673.

Januszajtis A. 1999, *Fortifications of Old Gdańsk*, in *TASK Quarterly*, 3(3), pp. 361-374.

Parrinello S., Picchio F., Barba S. 2022, *Drones and Drawings - methods of data acquisition, management, and representation*, in *DisegnareCON*, 15(29), pp. 1-7.

Remondino F., Spera M. G., Nocerino E., Menna F., Nex F. 2014, *State of the art in high density image matching*, in *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XL-5, pp. 539-546.

Scaioni M., Longoni L., Melillo V., Papini M. 2014, *Remote sensing for landslide investigations: An overview of recent achievements and perspectives*, in *Remote Sensing*, 6(10), pp. 9600-9652.

Tölle A. 2008, *Gdańsk*, in Cities, 25(2), pp. 107-119.

Trizio I., Savini F., Ruggieri A., Fabbrocino G. 2021, *Digital environment for remote visual inspection and condition assessment of architectural heritage*, in *International Workshop on Civil Structural Health Monitoring*, Springer International Publishing, Cham, pp. 869-888.

FAST SURVEY PROCEDURES FOR THE DOCUMENTATION OF GDAŃSK HISTORIC CITY CENTER

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Side page, Fig. 01
Dluga street
Type of visualization shows a 3D point cloud generated through laser scanning.

Describing Gdańsk involves examining a historical rupture that fundamentally redefined urban authenticity. The near-total destruction during the Second World War resulted not only in material loss but also in a void subsequently addressed through a deliberate cultural initiative. Entire blocks were eliminated, civil and religious architecture was reduced to rubble, and the urban fabric was fractured. Amid this devastation, a collective decision emerged: to reconstruct both the city's physical structures and its symbolic continuity. The post-war reconstruction of Gdańsk resulted from a collective decision to restore not only buildings but also the urban form, facade rhythms, and a spatial grammar developed over centuries. Architects, historians, and citizens collaborated by integrating archival research with imaginative projection. This process was characterised by tensions and negotiations: architects prioritised formal order and stylistic consistency; historians emphasised fidelity to sources and historical layering; citizens regarded reconstruction as an opportunity to assert a renewed civic identity. The debate over the reconstruction of façades along Long Street (*Ulica Długa*) exemplified these dynamics, with some advocating for the restoration of lost Baroque elements and others proposing the preservation of war scars as memorials. Ultimately, a solution emerged that balanced philological rigour with aspirations for renewal: historical decorative motifs were reintroduced and reinterpreted through contemporary perspectives. Ancient views, engravings, and pre-war photographs served as key references. Gdańsk was thus reborn as both a faithful interpretation of its past and a declaration of shared memory. Digitisation represents a 'third phase' in Gdańsk's urban development. Following its historical origins and reconstructive renewal, the city is now undergoing a digital transformation. This phase incorporates advanced acquisition technologies: the survey campaign utilised terrestrial laser scanning (TLS), Mobile Laser Scanning for rapid documentation of main streets, and aerial photogrammetry with drones to record roofs and inaccessible areas[1]. Data processing and integration were achieved through point cloud processing and three-dimensional modelling software, ensuring precise alignment and high geometric fidelity across sources. Digital surveying extends beyond surface capture to document the projective intentions underlying reconstruction. Each scan integrates coordinates, reflectance values, and textures, converting visual experience into numerical data. Bricks laid in the 1950s, modeled after medieval and Renaissance iconographies, serve as vectors of continuity

[1] Tysiac et al. (2023), *Combination of terrestrial laser scanning and UAV photogrammetry for 3D modelling and degradation assessment of heritage building based on a lighting analysis: case study—St. Adalbert Church in Gdańsk.*

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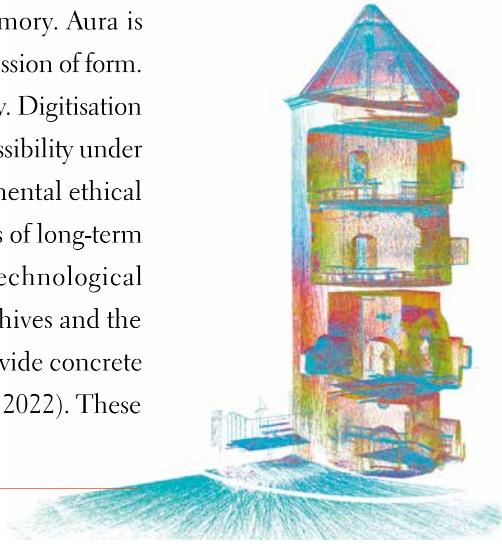
Fig. 02
Fortifications of Gdansk, tower digitalisation
3D point cloud registration of the Tower, located behind and under the defensive walls, captured through mobile mapping with the Leica BLK2GO laser scanner.

that transcend their historical period. This digital phase surpasses mere documentation: the digital model offers practical tools for conservation and public engagement. Accurate three-dimensional replicas facilitate emergency planning and the reconstruction of damaged structures following natural disasters, enabling informed, timely responses [2]. The digital city thus functions not only as an archive but also as a dynamic platform for decision-making, training, and participatory engagement, allowing citizens, researchers, and administrators to interact directly with urban heritage. Within the three-dimensional model, the distinction between materials from the fourteenth and twentieth centuries dissolves: what persists is the urban configuration, the sequence of solids and voids, the measure of heights and the weave of proportions. The city manifests itself as a system of spatial relations. The facades along Long Street align in a harmonious composition that time has transformed, yet not dissolved. Although seemingly abstract, the point cloud preserves the persistence of urban form. This process detaches the city's identity from material fragility, situating it within a dimension where it endures as a relational structure. Each point represents a surface fragment, yet collectively they form a living organism that embodies the city's memory. In this context, authenticity is defined not by the age of materials but by fidelity to a shared urban design. The third birth of Gdańsk can therefore be understood as an ontological transformation: the city now exists as a mathematical configuration, a replicable scheme, and a formalized memory. This condition extends the city's existence beyond physical vulnerability, enabling the transmission of form and identity with unprecedented precision. The survey was organised into concentric macro-blocks with Long Street as the generative axis, transforming the acquisition campaign into a narrative process. The route was both technical and symbolic: traversing the city's backbone helped restore its spatial continuity. Each acquired segment reinforced connections between squares, city gates, and building frontsJorge Luis Borges envisioned a map so detailed that it became indistinguishable from the Empire it depicted. Similarly, in Gdańsk, three-dimensional modeling fulfills this vision: the Digital Twin serves as both representation and operational environment. It enables exploration through innovative methods, integrating urban scale and architectural detail within a unified informational space. Using Mobile Laser Scanning, TLS, and aerial photogrammetry, the historic centre is reconstructed as a navigable, queryable, and sectionable environment. Users can virtually traverse streets, isolate buildings, analyse architectural details, and examine masonry irregularities. Researchers study wall stratigraphy, urban planners simulate transformations, and conservators assess deformations and structural instabilities without physical intervention. During a sudden structural failure caused by heavy rainfall, historians, planners, and conservators collaborated on a digital platform. The historian offered comparative insights into earlier stratifications, the planner simulated the effects of temporary traffic interventions, and the conservator

[2] Liao et al. (2025), *Reconstruction of existing buildings for evacuation assessment under emergency situations using 3D Gaussian splatting and machine learning.*

measured crack amplitudes in real time. This coordinated response prevented the loss of a monumental building[3] . The digital city thus serves as an operational meeting ground for diverse expertise, enabling heritage protection through concrete action. The digital map constitutes an alternative territory governed by its own rules of exploration. Within this space, the city can be observed from multiple perspectives simultaneously. It is possible to view both aerial and detailed aspects at once, combining perspectives that would otherwise require separate tools and extended time in the physical world. This transformation redefines the relationship between reality and representation. The digital model accommodates future scenarios, comparative analyses, and volumetric verifications. It serves as a design platform, a three-dimensional archive, and an urban laboratory. In this parallel dimension, the city is insulated from material decay and temporal change, becoming a dynamic archive. Digital Gdańsk enhances the experience of the physical city. The map evolves from a navigational tool to an analytical space where memory and transformation coexist. Walter Benjamin argued that mechanical reproduction dissolves the aura of a work of art, defined as its unique presence in time and space[4] . However, the case of Gdańsk indicates a different trajectory. The post-war reconstructed city was shaped by iconographic mediation: paintings, engravings, and photographs informed its architectural rebirth. In this process, imagery preceded construction, and interpretation preceded reconstruction. In this context, aura was generated through the transmission of images. Reconstruction did not diminish urban meaning; rather, it consolidated it. Each reinstated façade served as evidence of identity-driven decisions, transforming the city into a testament to cultural perseverance. Digitisation continues this tradition as an additional act of preservation. Three-dimensional surveying documents not only façade geometry but also the collective intent underlying its realisation. Each cornice, pediment, and portal reflects a deliberate cultural decision to reaffirm continuity after destruction. The laser scanner converts these features into numerical coordinates. The resulting data preserve proportions, alignments, and curvatures. Binary code thus becomes the custodian of urban memory. Aura is redefined: it is no longer limited to physical presence but extends to the faithful transmission of form. Drones and SLAM systems enhance the capacity to preserve and restore urban memory. Digitisation acquires ethical significance by safeguarding collective commitment and ensuring accessibility under uncertain future conditions. However, this promise of continuity introduces a fundamental ethical question: who is responsible for safeguarding binary code, and under what guarantees of long-term access? To prevent digital memory from becoming exclusive or vulnerable to technological obsolescence, open protocols and non-proprietary standards are essential. Public archives and the publication of datasets in open formats, such as civic-managed digital repositories, provide concrete protection against loss or privatization (National Archives and Records Administration, 2022). These

Fig. 03
Fortifications of Gdańsk, tower digitasation
3D point cloud registration of the White Tower, acquired through mobile mapping with the Leica BLK2GO. The dataset consists of two separate scan blocks enlighted by different colors (interior and exterior), subsequently aligned and merged during the registration process.



[3] Barba et al (2021), *A SLAM integrated approach for digital heritage documentation*.
[4] Benjamin (1997), *Sul concetto di storia*.

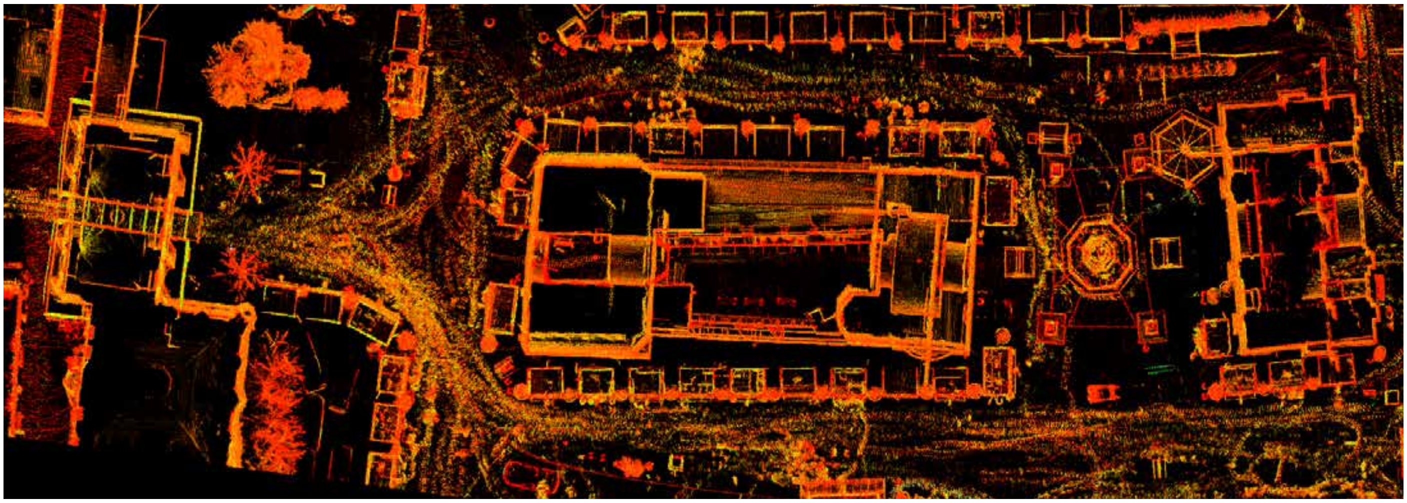


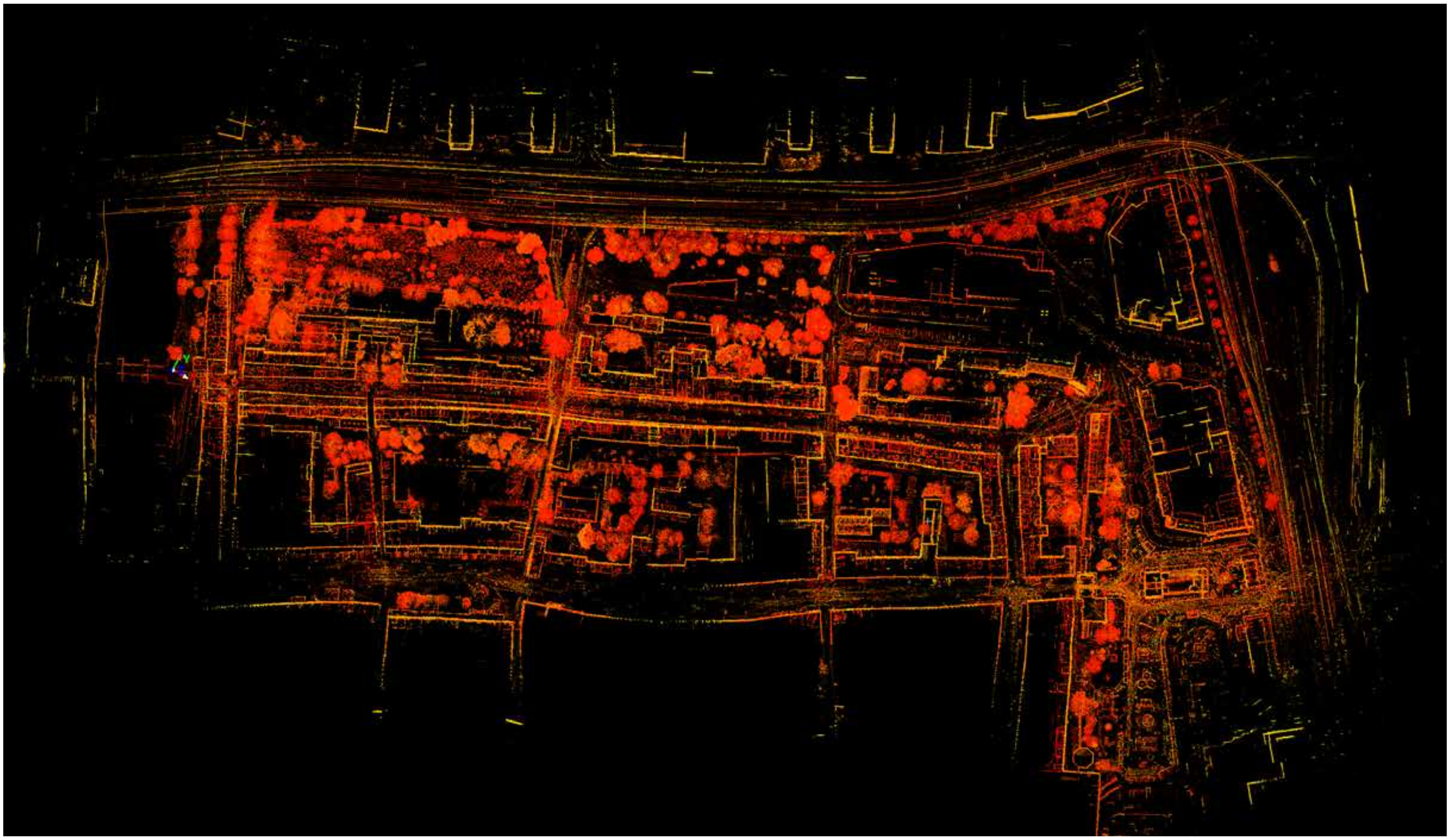
Fig. 04
City centre, point cloud
Top view of the point cloud illustrating the sequence of main access points: the Three Gate on the right, the High Gate at the center, the Prison Tower, and the Golden Gate on the left.

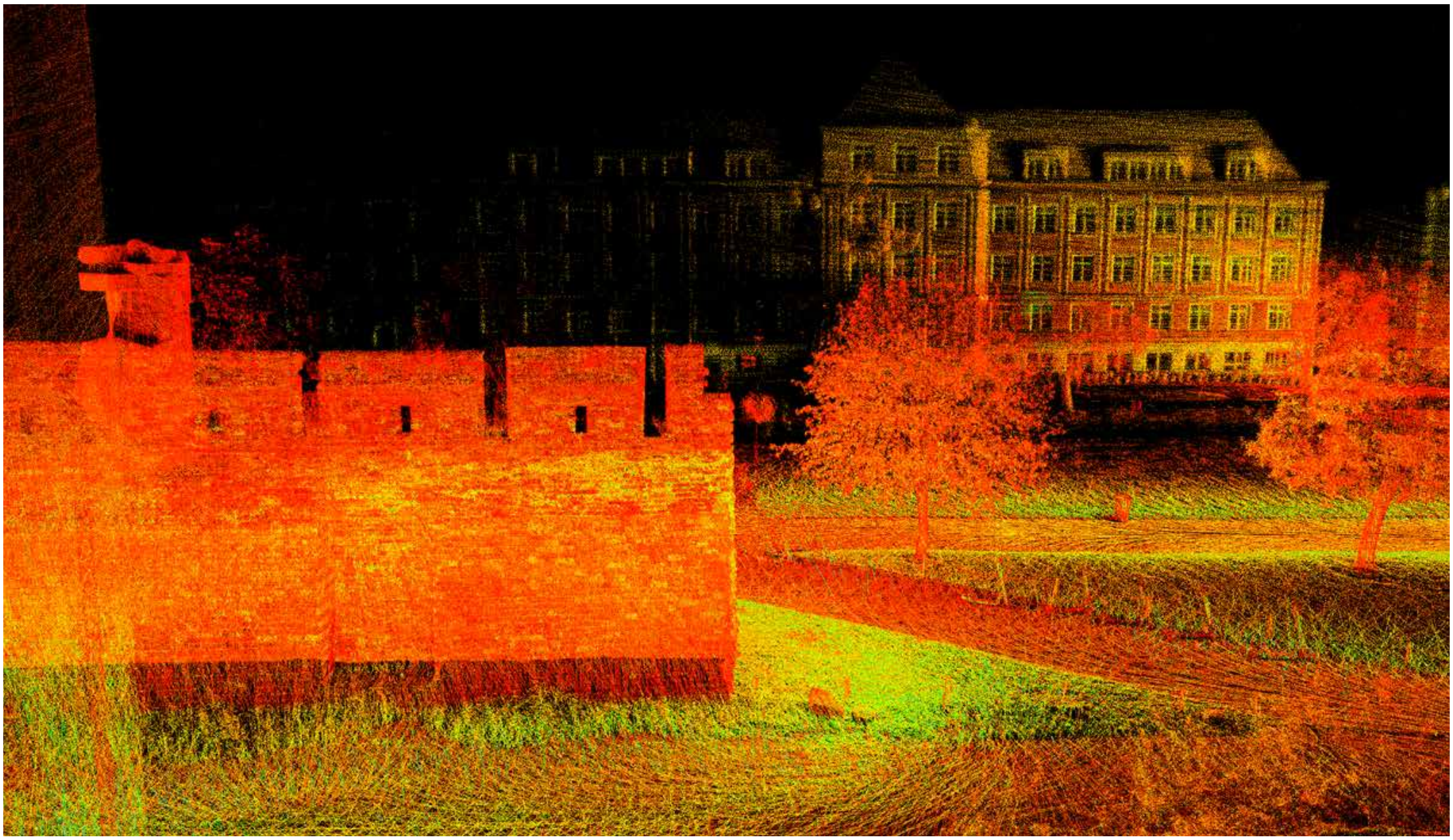
Next page, Fig. 05, 06
City centre, point cloud
The survey of the historic centre was organised into separate acquisition blocks. In the upper portion, the fortification walls and their medieval remains around the Corner Tower are visible. The lower image shows a close-up of the wall, illustrating the detail of the point cloud captured through mobile laser scanning.

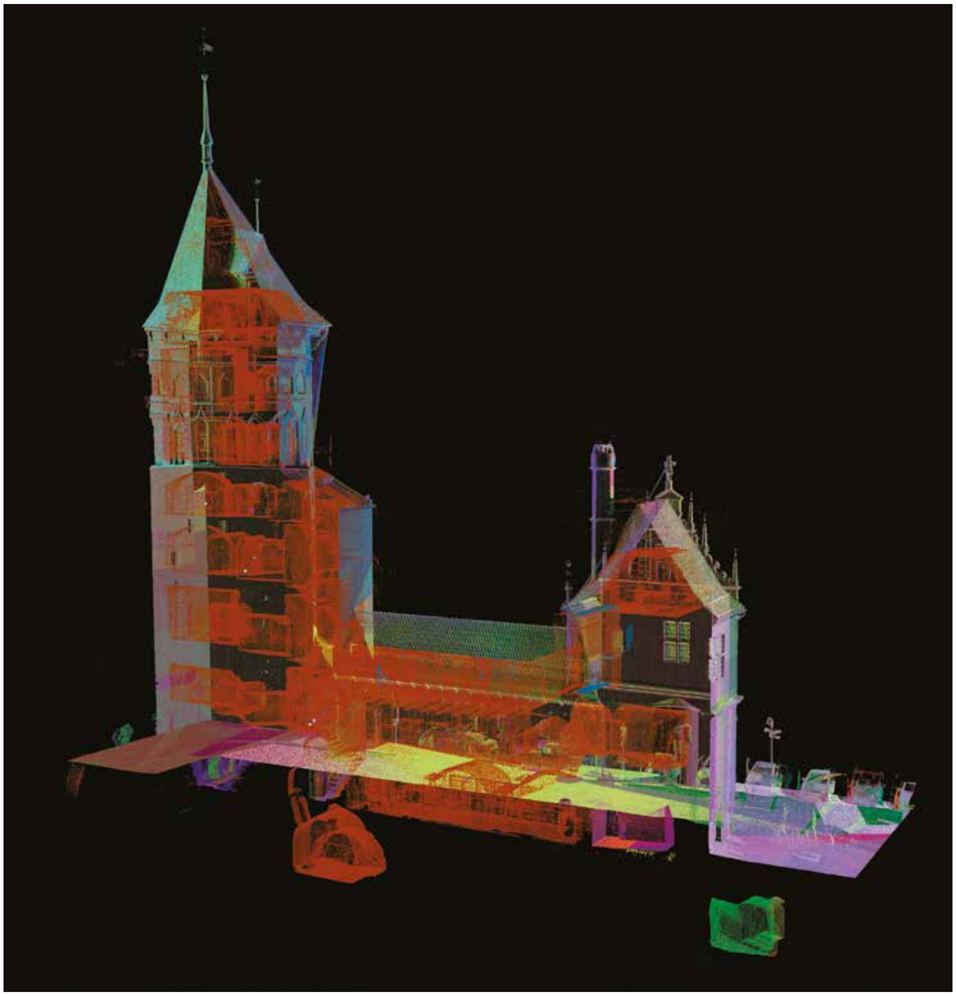
practices strengthen the relationship between the city and its inhabitants, reaffirming the collective and accessible nature of memory. In this context, the digitised city embodies a commitment not only to technical continuity but also to ethical and public responsibility.The Prometheus 2023 project documented the entire historic centre in four days using a single operator[5]. This achievement prompts reflection on the temporality of surveying. In earlier centuries, documenting a city required years of observation, manual measurement, and labour-intensive graphic restitution. Each representation reflected the duration of its creation.

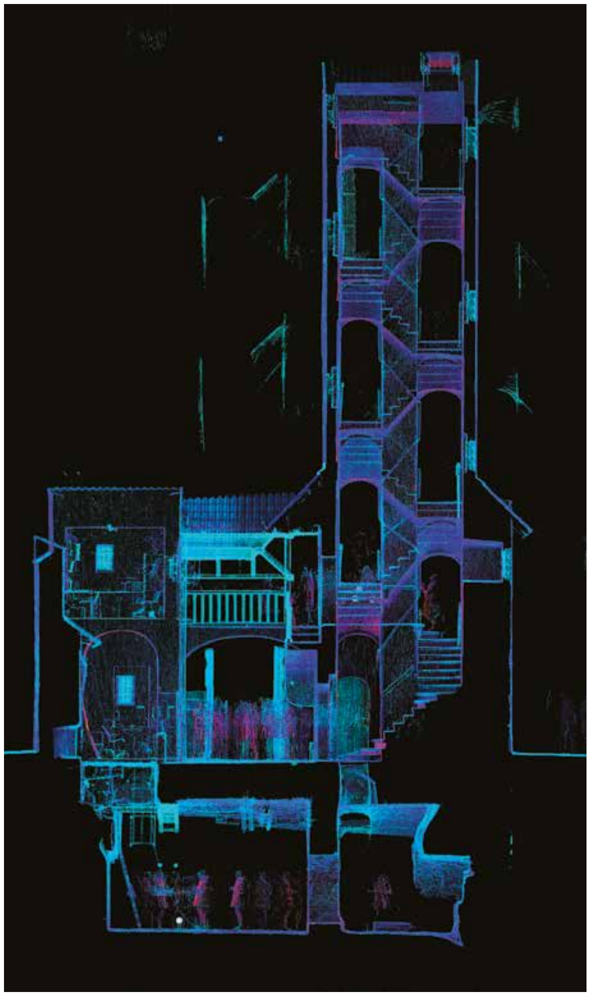
Contemporary technology enables data acquisition within a highly compressed timeframe. Millions of points are recorded in seconds, producing a synchronous image of the city. The outcome is a comprehensive three-dimensional snapshot of Gdańsk at a specific moment in 2023. This temporal compression transforms approaches to urban interpretation. Machine-mediated perception reveals alignments, curvatures, and millimetric deviations that are barely perceptible to the human eye. Structural deformations and compositional regularities become distinctly observable. The rapid pace of data acquisition enhances analytical capacity. Urban planners compare successive datasets to identify changes, conservators monitor micro-movements, and historians overlay different historical periods. While time is compressed during acquisition, it is expanded during interpretation. Machine-mediated perception extends human observation by providing simultaneity, depth, and comprehensive detail. The city becomes legible as a whole without compromising the precision of individual decorative elements.The integration of TLS, photogrammetry, and mobile scanning has established an information ecosystem where architectural detail and monumental scale coexist without hierarchy. Historic gates, defensive walls, and sequences of facades along the market form a coherent digital continuum, with each element interacting within a unified system. Gdańsk demonstrates how urban memory can be preserved using advanced technological tools. In an era characterised by climate change, conflict, and rapid transformation, the existence of a comprehensive three-dimensional

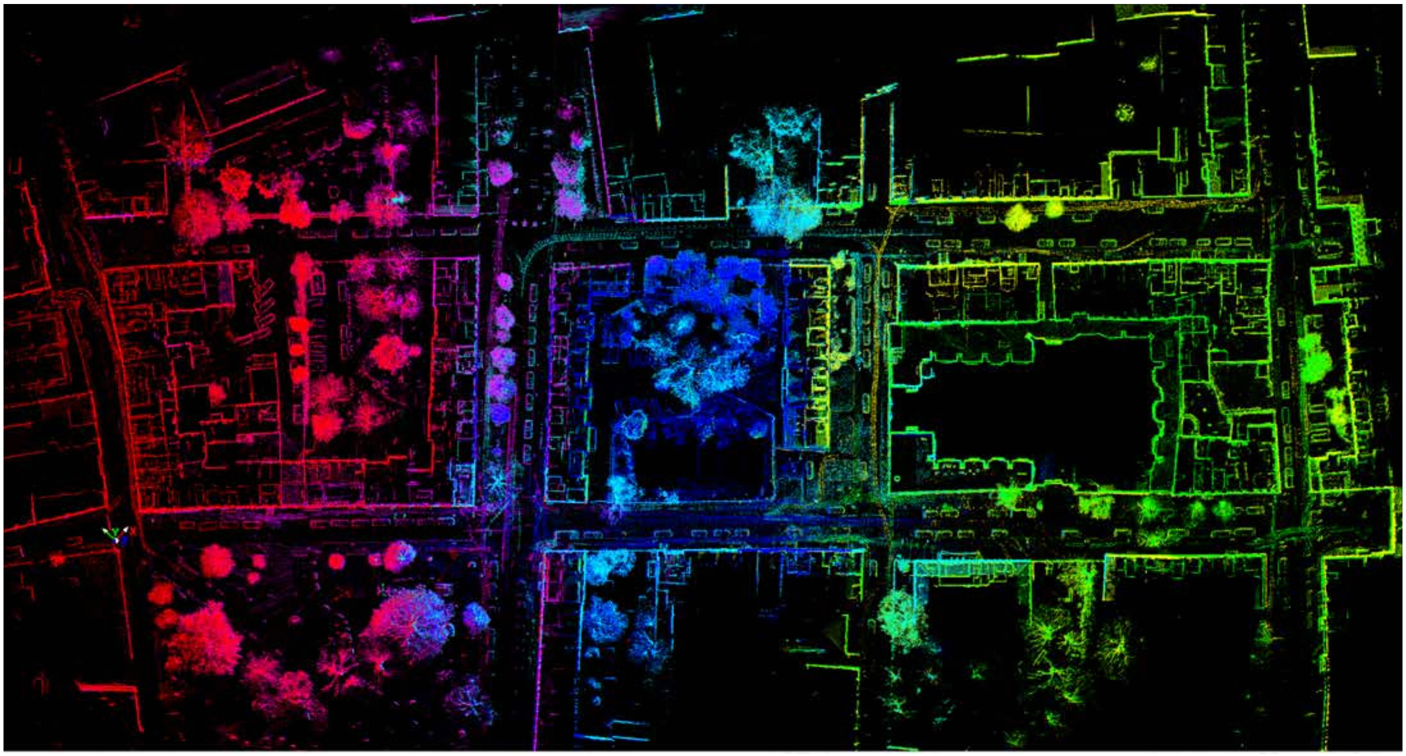
[5] Bursich, Parrinello (2024), *The "PROMETHEUS" European Project: Gdańsk Fortress Route (Poland)*.











model serves as a form of preventive protection. Heritage is not only observed but also structured as data, prepared for analysis and intervention. Safeguarding urban memory requires more than the expertise of a single professional group. The stewardship and development of the city's digital model demand collective participation: scholars, administrators, technicians, and citizens must collaborate to maintain, update, and enrich this shared heritage. The challenge is to foster an open community that engages new generations and presents Gdańsk as a living laboratory for memory, research, and identity. Through public initiatives, collaborative projects, and participatory platforms, the three-dimensional model can remain accessible, inclusive, and continuously evolving. The objective extends beyond conservation to include the potential for reconstruction, understanding, and reinterpretation.

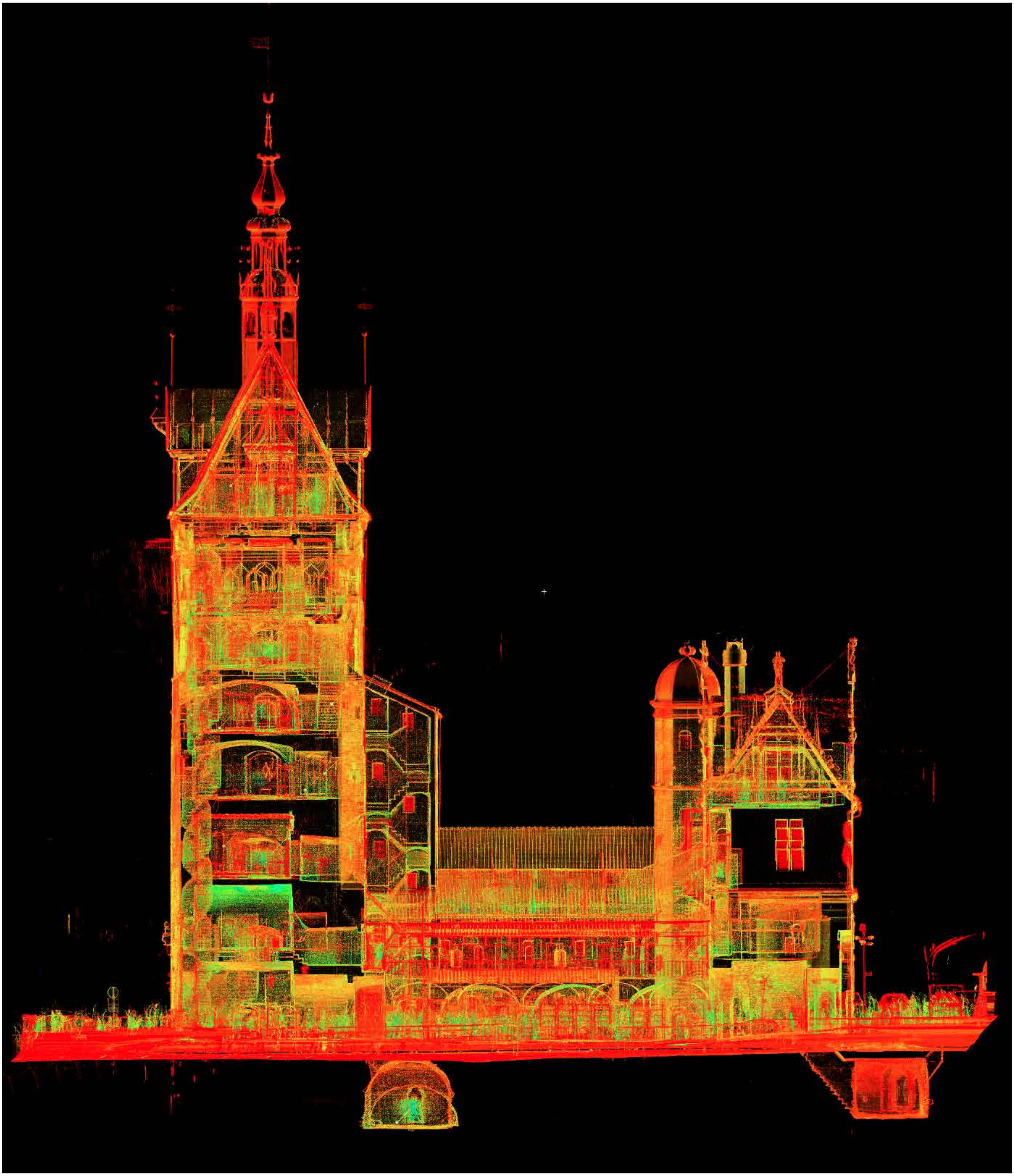
The digital model serves as the foundation for future restorations, historical research, and educational initiatives. The city thereby acquires an additional dimension alongside its physical form. Gdańsk, having experienced destruction and rebirth, illustrates that collective identity can adopt new forms of expression. The digital model becomes its vigilant counterpart: a mathematical entity that accompanies the physical city, prepared to sustain, document, and project its memory beyond temporal boundaries. In 1945, Gdansk and its historic centre within the former fortifications were destroyed by almost 90%. Thus, the warfare of the Second World War led to the destruction of one of the most beautiful historic complexes in northern Europe. Next to Warsaw and Wrocław, Gdańsk suffered the greatest destruction of all cities currently within Poland's borders[6]. The most architecturally significant and distinctive

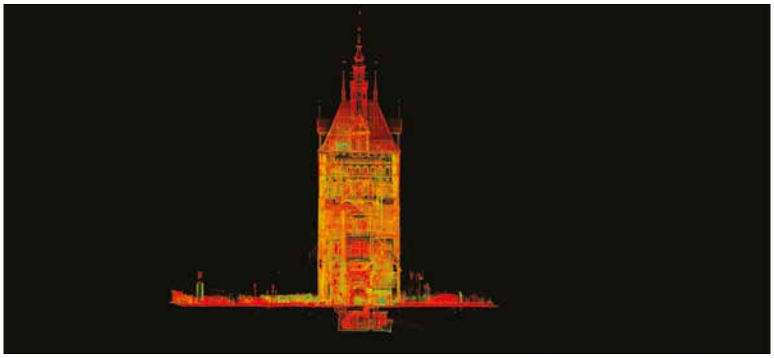
[6] Gruszkowski (2012), *Ruiny. Fotografie Wiesława Gruszkowskiego.*

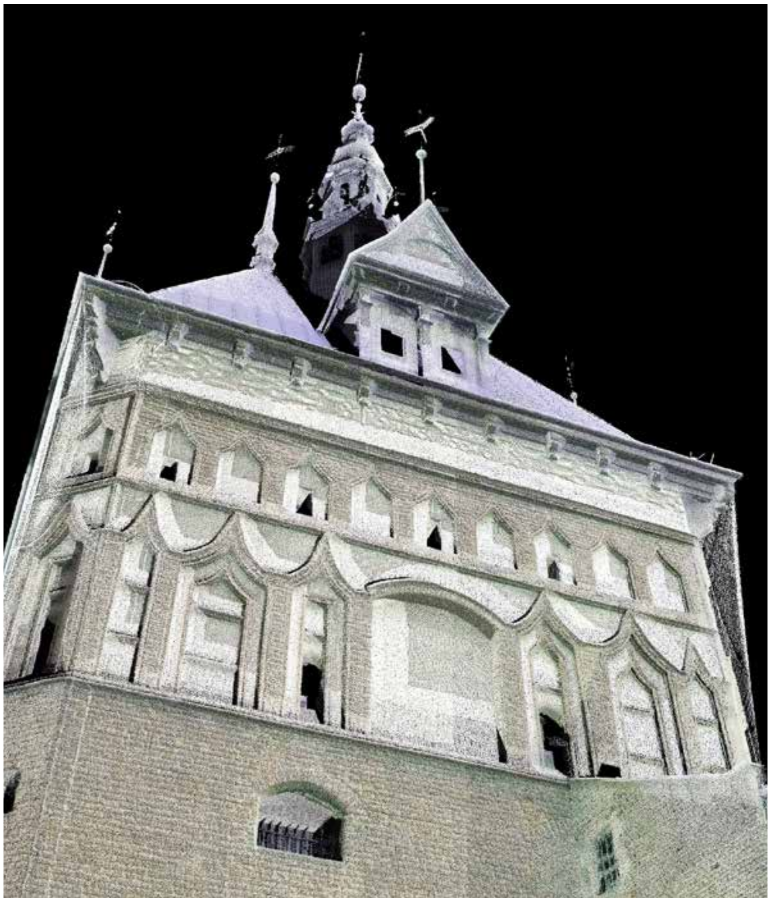
Side page, Fig. 07, 08, 09
The Prison Tower survey
As shown in the images, presents the registered point cloud resulting from integrated acquisition strategies. The exterior was captured with a static terrestrial laser scanner (Leica RTC360), while the interiors were surveyed via mobile laser scanning, structured into vertical trajectory-based blocks. The resulting datasets were aligned and merged using cloud-to-cloud registration algorithms.

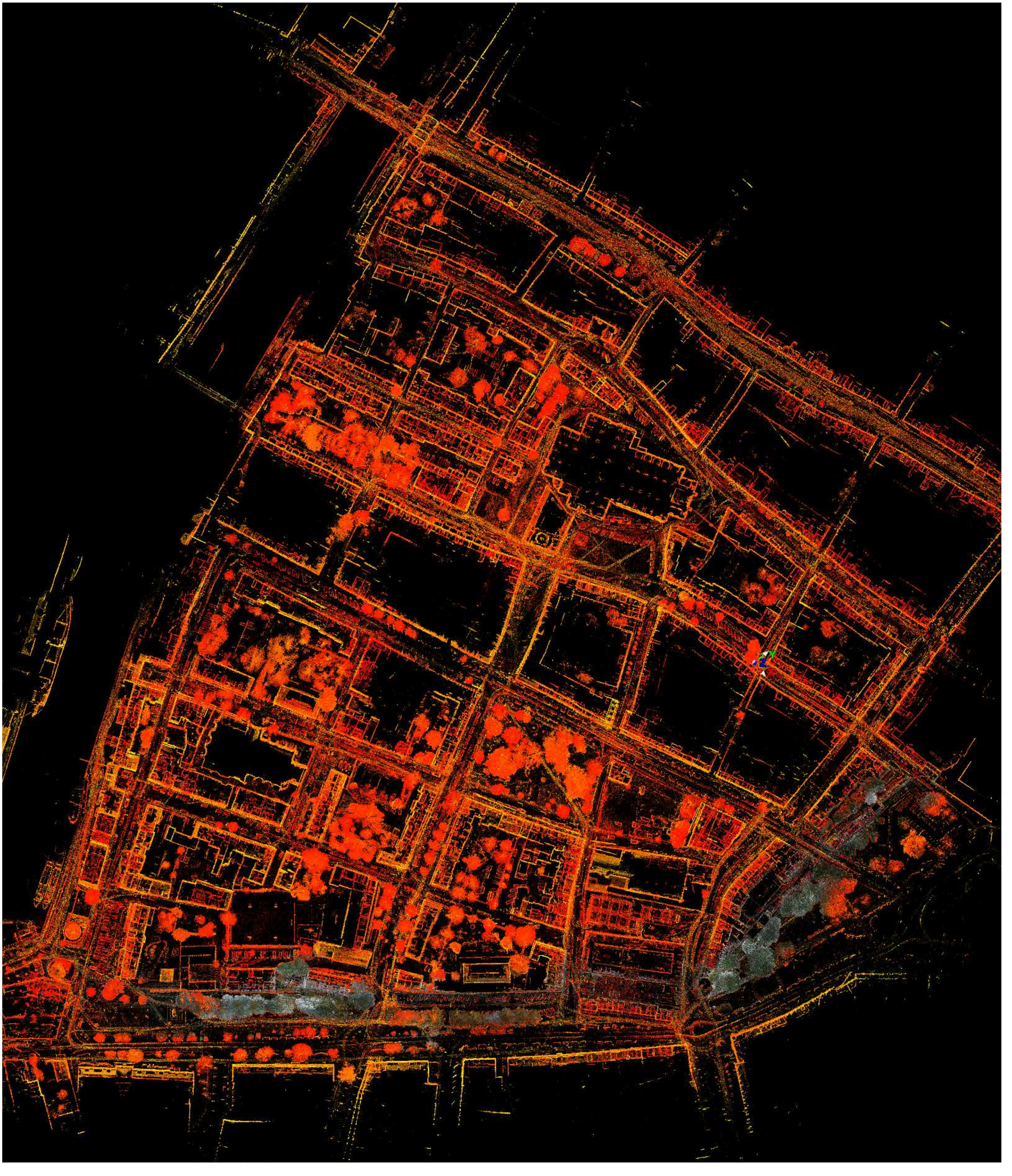
Fig. 10
The city centre mobile survey acquisition
The scheme illustrates the acquisition strategy applied to the historic centre. The districts were divided into closed acquisition paths, designed to overlap in contiguous areas, ensuring about 40% overlap between neighbouring blocks.

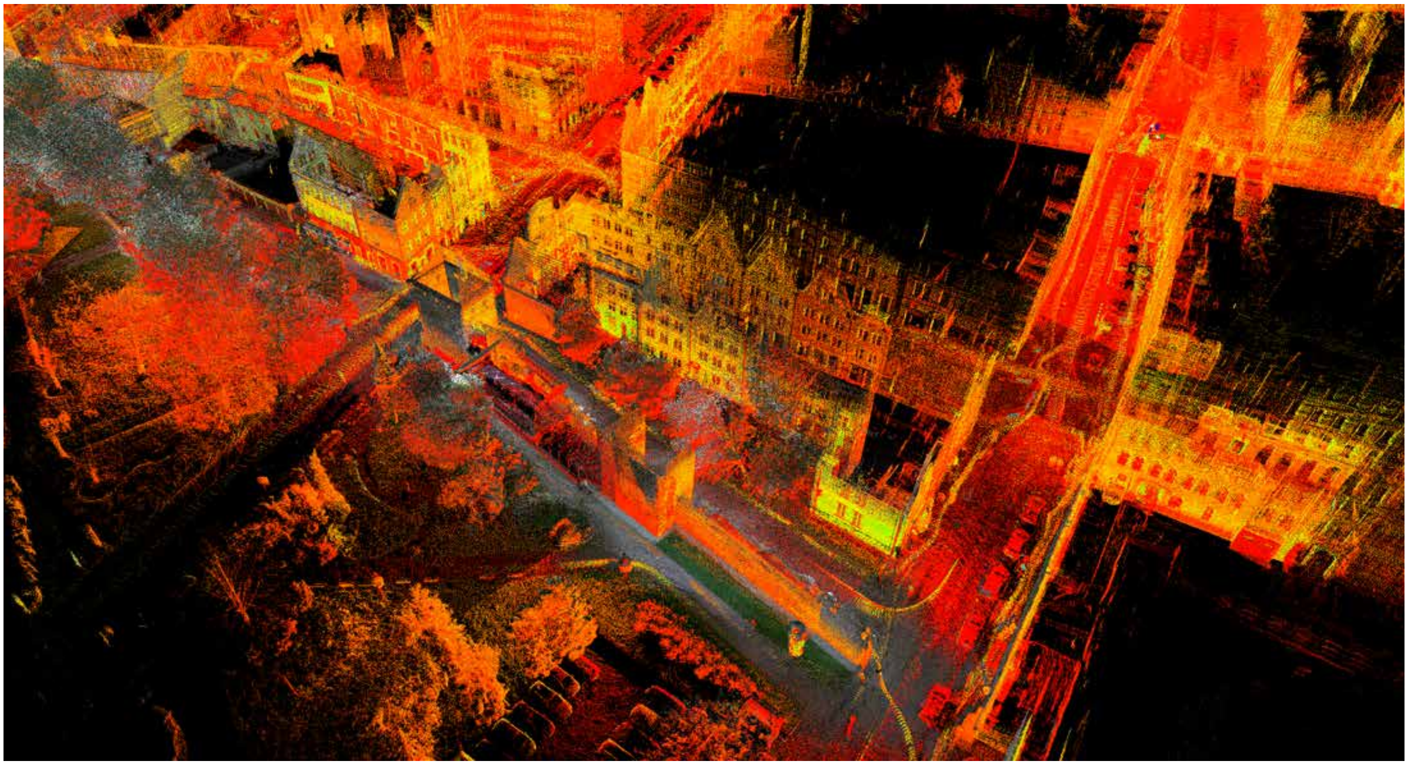
Next page 11, 12 , 13, 14, 15
Prison tower
Point cloud representation of the Prison Tower 3D dataset, illustrating how the survey delivers a complete and integrated model of the building's overall structure.

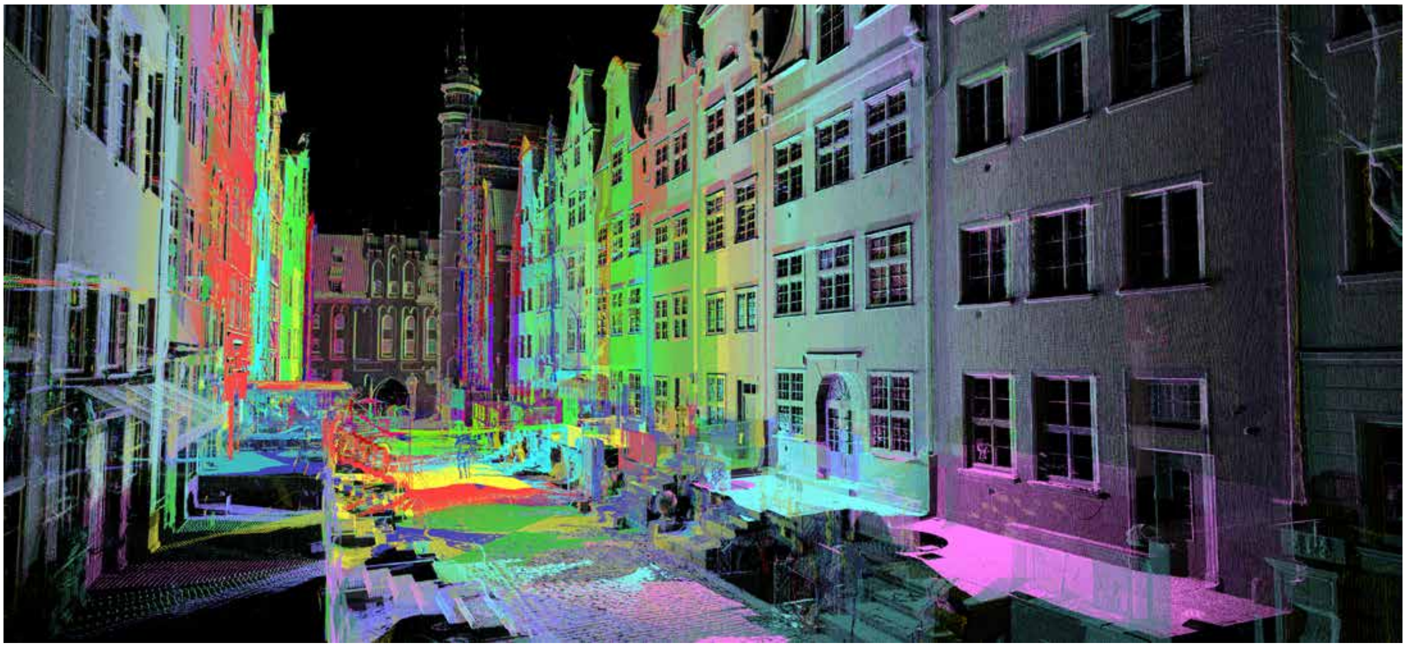












Side Page, Fig. 16
Top view of Gdańsk city point cloud database

Fig. 17, 18
The city centre mobile survey acquisition
The acquisition strategy applied to the historic centre, highlighting the integration of local datasets captured with the Leica BLK2GO into the global point cloud database generated with the Kaarta Stencil.

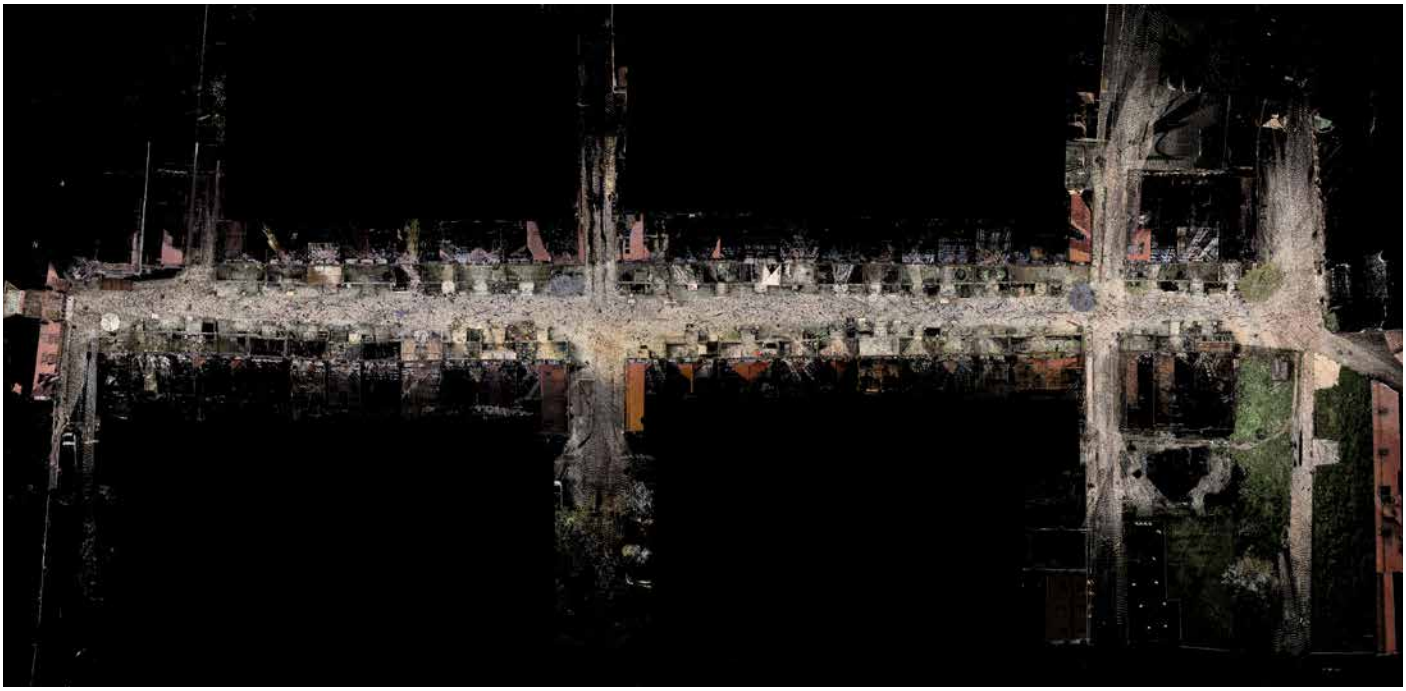


Fig. 19
The city centre mobile survey acquisition
In specific areas, this database was complemented by TLS surveys – such as Mariacka Street – acquired using terrestrial laser scanners like the FARO Focus. Top view of the point cloud database RGB color.

Next page, Figs. 20, 21
Mariacka street point cloud database views
In specific areas, this database was complemented by TLS surveys – such as extracted from point cloud digitization results provide a virtual image of the street, opposing views along the Mariacka Street street axis: one directed towards the gate, the other towards St. Mary's Church. (April 2024).

buildings were reduced to ruins, with only a few surviving in the city centre.Gdańsk, particularly its historic downtown, underwent extensive reconstruction similar to other cities affected by World War II. Between 1949 and 1960, the Main Town was comprehensively rebuilt, while the Old Town was modernised in a manner consistent with its historic architecture[7]. Despite these transformations, the city boasts an open-air architectural heritage that preserves remnants of its past[8]. The city's unique architectural elements, technical innovations, masonry walls, and colour usage provide a rich catalogue of references to its historical identity[9]. Every component of urban ornamentation has been meticulously reconstructed and reimagined based on the historical representations of the city. The proponents of the reconstruction of Gdansk had convincing arguments, given the historical context. After research and planning, the following principles were adopted:

- the medieval street grid and the old building fronts should be preserved
- to reconstruct the facades of houses for which architectural elements and archive material were available
- damaged historic buildings should be rebuilt strictly according to historical sources
- the remaining buildings were to be designed in such a way that, together with the preserved or reconstructed buildings, they would create the characteristic image of a Gdansk street.)

Mariacka Street, in the centre of Gdańsk's recostructerd structure (Main Town), is one of the city's most emblematic and intriguing thoroughfares. Prior to its devastation during World War II,

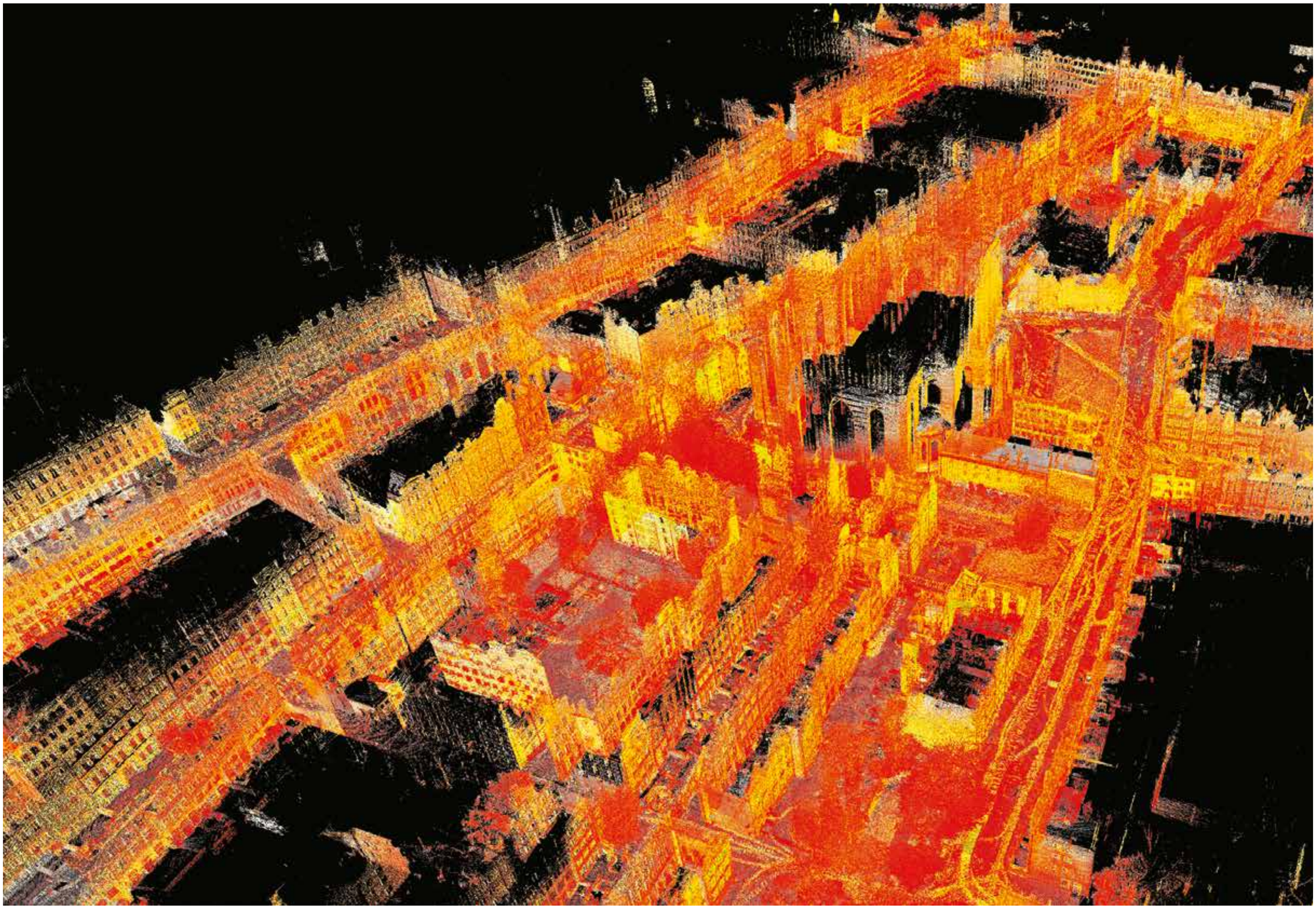
[7] Friedrich (2015), *Odbudowa głównego miasta w Gdańsku w latach 1945-1960, Wydawnictwo Słowo/obraz Terytoria.*
[8] Porcheddu et al (2025), *Recoleta: the dual threshold between the city of stone, the represented city, and the digital city*
[9] Borucka, Gatermann (2016), *Architekturführer Danzig: Gdańsk Sopot Gdynia.*

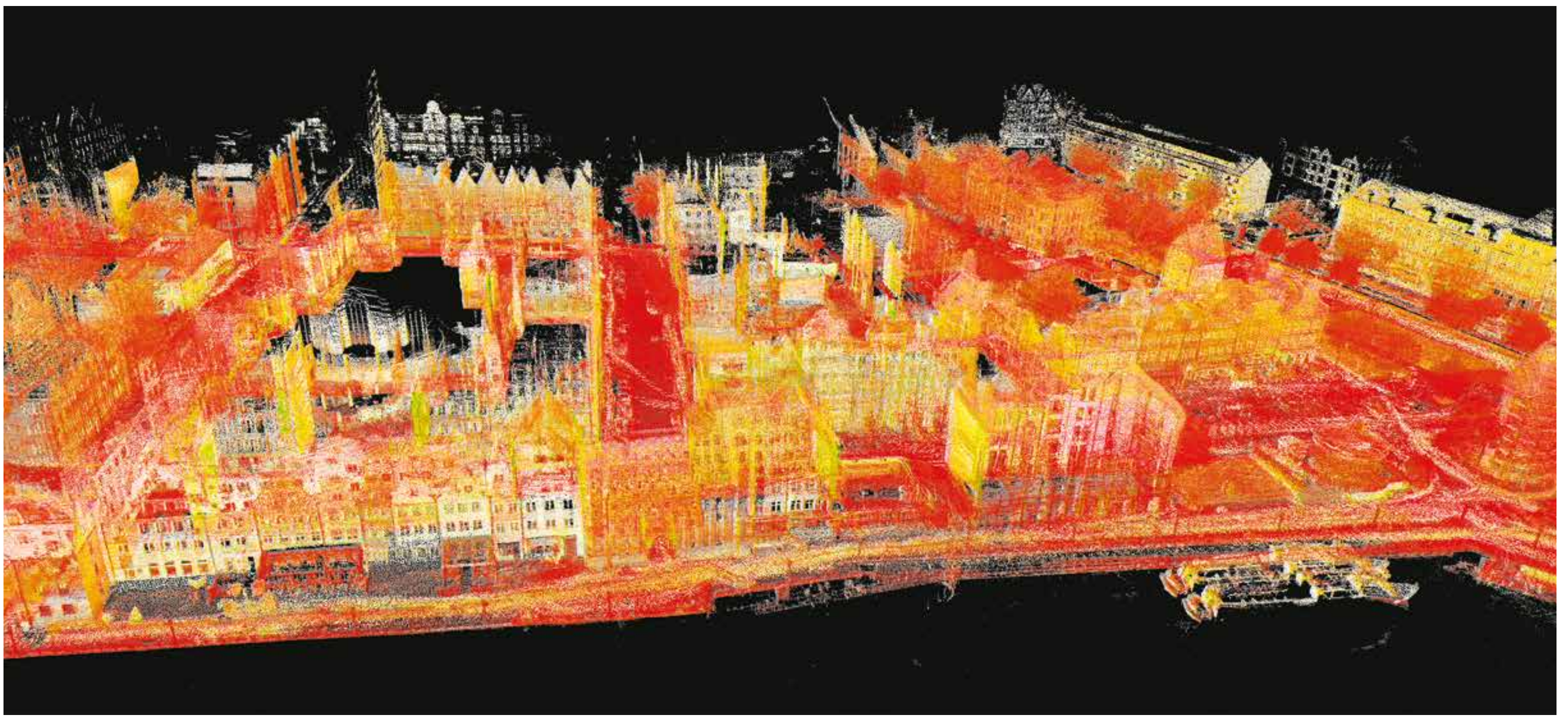
Figs. 23, 24
3D data acquisition of the exthrnal urban front of dluga street

Mariacka Street served as a vibrant centre of cultural and economic activity. Renowned for its Gothic and Renaissance architectural styles and its association with craftsmanship, the street constituted a vital element of Gdańsk's heritage identity. After the war, the Polish government prioritised the reconstruction of Mariacka Street as an essential aspect of restoring Gdańsk's cultural legacy. Architects meticulously restored façades, terraces, and defining features using historical photographs, maps, and artworks. This process relied heavily on written records, requiring archivists and architects to interpret incomplete or damaged documentation to achieve the most accurate reconstruction possible. However, the reconstructed Mariacka Street did not constitute an exact replica of its pre-war state. Instead, it embodied a curated interpretation of the past, shaped by post-war cultural and political ideologies. The reconstruction was influenced not only by historical sources but also by contemporary values and resource constraints. Mariacka Street dates back to the 13th century as a "*platea Dominae Mariae*" when Gdańsk became a vital trading centre on the Baltic Sea. Initially named Frauengasse (till 1945), it received its name Mariacka street from the Basilica of St. Mary (*Bazylika Mariacka*), a key city symbol at the street's western end. In the Middle Ages, Mariacka linked the religious heart and commercial downtown of Gdańsk.The residences along the street were initially constructed of timber, a prevalent practice in Hanseatic cities at the time. As the Hanseatic League expanded, the merchant families of Gdańsk experienced increased prosperity, which culminated in a gradual architectural transformation: the wooden houses were supplanted by robust brick structures in the Gothic style. This architectural advancement not only enhanced the fire resistance of the edifices but also imparted the street its distinctive medieval charm. In the 16th and 17th centuries, Mariacka Street experienced a period of great splendour. Gdańsk, rich from the grain and amber trade, attracted craftsmen, artists, and merchants from all over Europe. The facades of the houses were embellished with elaborate decorations, while characteristic terraces with stone balustrades (known as '*przedproża*'), became a distinctive feature of the street. It was the most characteristic element of the Danzig house and street.

As an architectural form, it consists of a balustraded terrace protruding in front of the building's façade, stairs leading up to the terrace and a cellar descent located at their side. They constituted the building line protruding in front of the facades forming the walls of the street's urban interior. The origin of the Gdansk stoops has not been fully explained. These terraces were used as intermediate spaces between the street and the house entrance, where business activities often occurred. The gargoyles that embellish the street and terraces serve a dual purpose: firstly, they act as a decorative element; secondly, their principal function is to ensure efficient water drainage. During this time, Mariacka Street was home to small merchants, craftsmen and functioning tenement houses. Between the 18th and 20th centuries, as the Hanseatic League declined and Gdańsk's commercial significance waned, Mariacka Street experienced economic hardship. Nonetheless, it preserved its residential and artisanal functions despite a decline in its previous significance glory. World War II marked a dark time for Mariacka. The 1945 siege of Gdańsk destroyed much of the historic part of the city (Main Town), including Mariacka. Historic houses became rubble, losing many artistic and architectural treasures lost. The starting point for the reconstruction project was the reconstruction of the entire façade sequences based on measurements of the surviving remnants, on iconographic records dating back to the 16th century and on Building Police records carried out since 1815, and on photographic documentation carried out since the 1960s. Post-war reconstruction was a priority for the Polish government. Mariacka Street was restored with careful attention to historical details from pre-war documents, photographs, and paintings. During the reconstruction, the principle was adopted to reconstruct the façade on the basis of the most ancient and at the same time most reliable archival and iconographic sources without any 20th and 20th century influences. Post-war architectural research facilitated the reconstruction and thus authentic Gothic elements were incorporated into the reconstruction. Most of the elements and details excavated from beneath the ruins were used for reconstruction of the historical city without any knowledge of their original location. The exception here is Mariacka Street, where the fully restored stoops are authentic in form and substance.

Buildings were reconstructed in historical styles, restoring Gothic and Renaissance facades and creating terraces with stone balustrades.These façades serve as models for the city's historical memory, with grotesque decorations like gargoyles and allegorical figures as symbols of its past. The street has been rebuilt with the restoration of all the stoops and stone terasses, the structure of which is mostly original.Following the comprehensive reconstruction of the 1950s and 1960s, Mariacka Street has most fully retained the character of a traditional Danzig street. The reconstruction process redefined the street as a symbolic site, emblematic of Gdańsk's cultural resilience. Today, Mariacka Street is renowned for its galleries, distinctive pubs, and especially its amber shops and studios. It has evolved beyond a tourist attraction to become a significant landmark for the city's artistic and cultural heritage community. Despite extensive destruction, Mariacka Street continues to thrive, contributing to the





Side page, Figs, 25,26
View of 3D point cloud database of city center of Gdańsk

Figs. 27
Mariacka street 2D drawings

city's identity and reviving the traditions of the historic merchant centre. Mariacka Street is currently considered one of the most popular destinations for tourists in Gdańsk. The street preserves its historical character, offering unique insights into the city's history and the craft of amber processing. Additionally, Mariacka hosts various cultural events and festivals, including the prominent Gdańsk Amber Festival, which celebrates the city's longstanding tradition with this valuable resin. As media offerings expand, a burgeoning archive is preserved within online usage systems, enabling the virtual consultation of historical images. The media serve to 'liberate' these images from the confines of specific locations and the limitations imposed by direct interpersonal interactions[10]. This implies that these images, by integrating themselves into their users' memories, evolve into resources that can facilitate the construction of reality by various subjects whose identities and memories consequently transform. Maricka's case study prompts reflection on how images can serve as the cornerstone for preserving a city's identity and creating its corresponding 'model' across various eras and with different technologies[11].

The two-tier model of representation connects source-based abstractions with their tangible or visual forms. This process encompasses two essential steps and core concepts of 'modelling': The 'written model', encompassing historical sources such as texts and archival materials, provides essential interpretative guidelines. However, these sources are frequently incomplete or ambiguous, necessitating meticulous contextualisation synthesis. The 'represented model' encompasses both physical and digital reconstructions, which translate the new physical portrayal of the city into a spatial and sensory experience that is not tangible in the context of the digital environment.The interaction between these levels highlights the dual function of reconstructions: they provide accurate representations of the past while also serving as contemporary reinterpretations shaped by current technologies, aesthetics, and priorities.

[10] Kockel (2019), *Culture and Economy*.
[11] Bocconcino (2024), *La dimensione collaborativa della città immaginata: ciberspazio e disegno*, pp. 52-63.

In 2024, a collaboration among the Gdańsk University of Technology, the University of Pavia, and the University of Florence initiated educational programmes and research projects focused on digitising Mariacka Street and developing its use in virtual environments.The digital reconstruction of Mariacka Street involved the use of survey systems enhanced by advanced digital technologies. Methods such as Terrestrial Laser Scanning (TLS) and photogrammetric recording with remotely operated Unmanned Aerial Vehicles (UAVs) enabled the capture of imagery using digital reflex and 360-degree cameras.The images collected in this context support the development of a new digital model of Mariacka Street, opening new possibilities for knowledge acquisition through various methodologies. Virtual tours enable interactive exploration, allowing users to view authentic representations of the street. These tours integrate informative elements and archival documents accessible during the experience, thereby enriching the immersive educational environment with historical detail. Additionally, digital models enabled comparative analyses of Mariacka Street's pre-war, post-war, and contemporary conditions. This approach allows for a deeper investigation of historical changes and an assessment of the consequences of reconstruction decisions. Modelling systems use images to reconstruct environments digitally. Data from survey campaigns are processed and integrated into three-dimensional models, facilitating the study of decorative features on building façades. This process supports discussions on the relationship between digital representation systems and the various outputs that contribute to the city's narrative. The case of Mariacka Street establishes a foundation for a two-tier approach to cultural heritage construction. The documented model preserves historical knowledge even when physical structures are lost, while the represented model, in both physical and digital forms, ensures this knowledge is accessible to a broad audience. Each level requires interpretative decisions that shape the final outcome. The written model provides the basis, while the represented model reflects current perspectives, technologies, and constraints. Digital reconstruction transforms representation by making static records dynamic and interactive, thereby increasing user engagement. Furthermore, this innovation encourages public participation through immersive and customisable experiences. These developments enhance the relevance of cultural heritage in the digital era, ensuring its continued significance and adaptability.

Refereces

Barba S., Ferreyra C., Cotella V. A., Di Filippo A., Amalfitano S. 2021, *A SLAM integrated approach for digital heritage documentation*, in *International Conference on Human-Computer Interaction*, pp. 27-39.

Benjamin 1997, *Sul concetto di storia*, Einaudi, Torino.

Bocconcino M. 2024, *La dimensione collaborativa della città immaginata: ciberspazio e disegno*, in TRIBELON. *Journal of Drawing and Representation of Architecture, Landscape and Environment*, 1(2), pp. 52-63.

Borucka J., Gatermann H. 2016, *Architekturführer Danzig: Gdańsk Sopot Gdynia*, DOM Publisher, Berlin.

Bursich D., Parrinello S. 2024, *The "PROMETHEUS" European Project: Gdańsk Fortress Route (Poland)*, in *Proceedings*, 2024, 96, 18.

Friedrich J. 2015, *Odbudowa głównego miasta w Gdańsku w latach 1945-1960, Wydawnictwo Słowo/obraz Terytoria*, Fundacja Terytoria Książki, Gdańsk.

Gruszkowski W. 2012, Ruiny. Fotografie Wiesława Gruszkowskiego, Vintage Galeria, Toruń.

Kockel U. 2019, *Culture and Economy*, Routledge, Oxfordshire.

Leserri M., Rossi G. 2023, *The digital documentation of the cultural heritage between public interest versus private property. Survey and research on the Immacolata square in Martina Franca (Apulia, Italy)*, in *SCIRES-IT - SCIentific RESearch and Information Technology*, 13(2), pp. 27-42.

Liao X., Zhou B., Liu Y., Zhang L., Zhou Z., Chong H. 2025, *Reconstruction of existing buildings for evacuation assessment under emergency situations using 3D Gaussian splatting and machine learning*, in *Reliability Engineering & System Safety*, 222.

Porcheddu G., Barba S., Parrinello S. 2025, *Recoleta: the dual threshold between the city of stone, the represented city, and the digital city*, in *DISEGNARECON*, 8(35).

Tysiac P., Sieńska A., Tarnowska M., Kedziorski P., Jagoda M. 2023, *Combination of terrestrial laser scanning and UAV photogrammetry for 3D modelling and degradation assessment of heritage building based on a lighting analysis: case study—St. Adalbert Church in Gdańsk*, Poland, in *Heritage Science*, 11.

Figs. 28
Mariacka street 2D drawings


Hampton

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Gate access system as a part of the collective system

Entrances to the city have always been, and still are, one of the most important elements of the urban structure. They shape the first impression, the initial image and atmosphere of the city for visitors, and are also important for residents as an integral element of the fortification structure, and a military facility protecting access to the city. In Gdańsk, the main entrance, access to the city is strictly related to the main axis, the so-called The Royal Route. This axis between the Foregate Complex and the Green Gate, together with its significant buildings, especially at both ends, constitutes the most important and representative, recognizable part of the reconstructed historical structure. Along the urban fortification system in the city of Gdańsk, the Foregate Complex and the Green Gate are the key entrances to the city. Access from the west is highlighted by the buildings of the Gate Complex and from the east by the Green Gate. These buildings clearly describe and mark the end and start points of the main axis. It is not only about the urban and visual significance of these buildings. Both of them perform very important and prestigious functions today.

The buildings now serve public purposes, dedicated to visitors, citizens of the city of Gdańsk and people involved in creating the current image of the city. The Foregate Complex houses the Municipal Tourism Office, the Museum of Gdańsk (pol. Muzeum Gdańska), the Pomeranian Chamber of Architects (pol. Pomorska Okręgowa Izba Architektów RP) and the Association of Polish Architects (pol. SARP o. Wybrzeże). Currently, the Green Gate serves a very important function as a branch of the National Museum (pol. Muzemu Narodowe w Gdańsku o. Zielona Brama).

Two main gate structures of the axial urban layout constitute an integral part of the Gdańsk fortification system. Due to their special location, the buildings are intended, above all, to be a showcase of the city. Protection of this urban heritage is therefore the city's priority. The aim of this research dedicated to Complex Gate and Green Gate is to address the critical need to preserve and understand these monuments by creating a comprehensive 3D digital model and digital drawings.

Foregate Complex and the Green Gate - Understanding by history

Foregate Complex: From the 14th Century onwards, the main gateway into Gdańsk from the west was the Foregate Complex (pol. Zespół Przedbramia), which gave entrance to Długa Street (pol. *Ulica Długa*).

Side page, *Fig. 01*
Gdańsk
A city view from the Prison Tower bell.

Fig. 02
The gate of Long Street. Fragment of the painting 'Homage to Money' by Anton Möller, 1601. Collection of the Gdansk Museum.

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Built in several stages, initially this complex was part of Gdańsk's defences and was integrated into the mediaeval city walls encircling the Main Town (pol. *Główne Miasto*).

The complex was connected to the city by a bridge that led across a moat and by the neck of the no longer existing Długa Street Gate (pol. *Brama Długouliczna*), which was later replaced by the Golden Gate (pol. *Brama Złota*), built during 1612–1614. At the opposite end of this axis, the eastern entrance to Gdańsk was originally defended by a Gothic water gate, now gone, named Cog Gate (pol. *Brama Kogi*), dating from 1378. After 1564 the prestigious new Green Gate (pol. *Brama Zielona*) was built in its place.

The Foregate Complex, currently rectangular in plan, comprises three interconnected above-ground structures: the seven-storey Tower, the Neck, and the three-storey building of the former Front Gate (pol. *Brama Przednia*). Together they create an internal courtyard of sorts (on the site of the bridge that used to cross the moat). Parts of the underground structures have also survived: the brick culverts of a three-span medieval bridge, casemates beneath the Torture House (pol. Katownia) and a chamber beneath the Tower – probably once a cell referred to as the Viper's Lair (pol. Nora Żmii). The oldest part of the Complex is the Tower, the construction of which probably began around 1331[1]. Originally, this was a single-storey building featuring a central gateway with a pointed arch. In 1380, a brick-built bridge was installed over the second line of moat defences, and the walls of the Neck, featuring two rows of loopholes at different levels, were built on its spans. On the west side, the Neck was sealed off by the single-storey Front Gate. During 1416–1420 two fortified towers were added to it. The height of the Tower was raised on several occasions by adding successive storeys (in the 1370s (or in 1345) after 1433, and during 1506–1509), and it came to be known as the High Gate (pol. *Brama Wysoka*).

Fig. 03
Fortifications of Gdańsk, 1809. The Long Street Gate (High Gate) and adjoining fortifications in winter, Gdańsk, early 20th century. Right: The Prison Gate and foregate complex showing wartime damage, Gdańsk, mid-20th century.

Fig. 04
Complex of the Foregate of the Long Street Gate, from the south, Gdańsk. Inv. no. Gr Al. 4091/5. (from the collection of the Polish Academy of Sciences Gdansk Library).

[1] Białko at al. (2002), *Badania historyczne, architektoniczne i konserwatorskie Wieży Więziennej Zespołu Przedbramia ulicy Długiej w Gdańsku*; Jung-Migalska at al. (2004), *Badania architektoniczne w obrębie Szyi i Katowni Zespołu Przedbramia ul. Długiej w Gdańsku, Analiza wyników badań*; Bukal (2016), *Zespół bram ul. Długiej jako element systemu obronnego Gdańska (1343–1612)*; Pudło (2016), *Rozwój Zespołu Przedbramia ul. Długiej na podstawie badań archeologicznych prowadzonych w latach 2001–2004.*

The loopholes were adapted to accommodate new firearms and cannons. In 1540 modern earthwork defences began to be built in Gdańsk. In effect, both mediaeval moats were filled in and the neck connecting *Długa Street* Gate with High Gate was dismantled.

In 1574 the Upland Gate (pol. *Brama Wyżynna*) was built on the west side of the existing gatehouse complex, thus making it possible to enter the city without passing through the Foregate. In view of these changes, in 1586 the Complex was converted into a prison. The High Gate was known from then on as the Prison Tower (pol. *Wieża Więzienna*), and the Front Gate as the Torture House. Because of its height, the Tower still served as a lookout post.

The Foregate continued to be used as a prison until 1861, after which time it served as a headquarters for various institutions. In 2006 a branch of the Museum of Gdańsk was opened there. It currently houses an exhibition about how Gdańsk was rebuilt following its destruction during the Second World War. Over the centuries, the Foregate Complex has suffered deterioration and damage but has also undergone several episodes of building and conservation work[2]. Despite this fact and the numerous times the Foregate has been repurposed, its original defensive role is still clearly visible in its architectural structure. During the course of conservation work carried out in the early 21st Century, all of the key evidence that testifies to the complicated history of this remarkable historic building was recorded and preserved.

The Green Gate, also known as Grünes Tor (ger.), stands at the eastern exit of the Long Market, marking the conclusion of the Motława Royal Route at the Green Bridge. Replacing the Gothic Kogi Gate, it was constructed in three stages, beginning in 1564 and concluding in 1568, under the supervision of the builders Master Regnier and Hans Kramer. Built in the Dutch Mannerism style, the gate features fine Amsterdam brick (brought to Gdańsk as ballast for cargo ships) and stone elements. The structure includes a basement and four stories (with the southwestern wing boasting five stories), displaying

Fig. 05
The Green Gate
Gdańsk, early modern engraving. Right: The Green Gate after wartime damage, Gdańsk, mid-20th century.

Figs. 06,07
Reconstruction of the Green Gate after the Second World War
The successive phases of the reconstruction of the Green Gate (Gdańsk) after the damage sustained during the Second World War. A view of space of the street. A.L. Randt. Painting, 1856. Polska Akademia Nauk Biblioteka Gdańska, Archive.

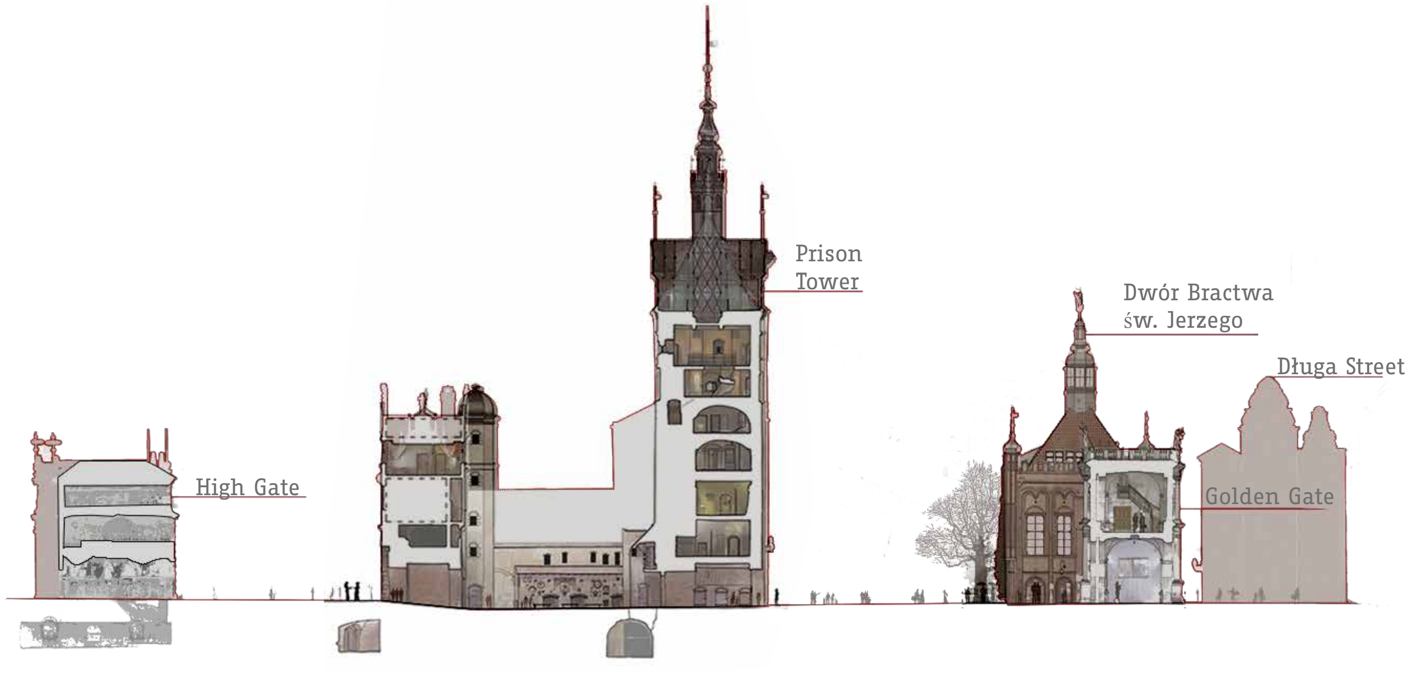
[2] Bigoś-Bojarska, Darecka (2010), *Zespół Przedbramia ulicy Długiej w Gdańsku. Prace konserwatorskie i adaptacyjne.*

Fig. 08
View of the Long Market (Długi Targ) with the Main Town Hall and St Mary's Church, Gdańsk.
Aerial view of the Long Market (Długi Targ), with the Main Town Hall at its centre and St Mary's Church to the right, Gdańsk.

four passage arcades, adorned with rustic military-evoking elements. The lower part is divided into six equal fields with pilasters, and the gable roof, crowned with statues, encompasses two- and three-story dormitories. Dutch with stone details: pilasters, cornices, window frames and rich sculptural decoration. The ground floor in the passage section was faced with stone carvings. From the beginning, the gate had more representative than defensive functions. Renowned as the largest, oldest, and most decorative building of its kind in Gdańsk, the Green Gate underwent 19th-Century reconstructions but retained its original appearance through restoration efforts. In 1879, the West Pomeranian Natural History Museum was established there. Initially, it served diverse purposes, housing the Natural Society and, until World War II, the Natural History Museum. Post-war reconstruction transformed it into the seat of the Monument Conservation Workshop. Presently, the Green Gate hosts a branch of the National Museum and the Gdańsk Photo Gallery.

Foregate Complex and the Green Gate - Understanding by survey

The study aimed to create a comprehensive 3D digital model consolidating the current condition of the monuments —a detailed representation intended for further research, fostering a deeper understanding of the facility's functionality. Additionally, the study sought to explore the potential afforded by digital tools in acquiring architectural and urban monuments on a city scale for research purposes.



The integrated digital survey of the gate access system: the axis Foregate Complex - Green Gate followed the established protocols also employed for the documentation of the other cultural routes analysed through the project. In the specific case of this urban axis, the preliminary study of the site made it possible to systematize a specific strategy to realise a digital duplicate capable of describing, with different appropriate levels of detail, the main architectural elements that constitute the gate system, that is existing: the Upland Gate, Prison Tower, Torture House, Golden Gate and the Green Gate o the other side, and their relationship in space and with urban space. The study aimed to develop a comprehensive three-dimensional digital model capable of consolidating the current condition of the monuments: a detailed representation intended to support further research and to foster a deeper understanding of the complex's functionality. In addition, the research sought to explore the potential offered by digital tools for the acquisition of architectural and urban monuments at an urban scale for research purposes. The integrated digital survey of the access system — along the Foregate Complex–Green Gate axis — followed established protocols already adopted for documenting the other cultural routes analysed within the project. In the specific case of this urban axis, the preliminary site study made it possible to define a targeted strategy for creating a digital duplicate capable of describing, with appropriate levels of detail, the main architectural elements of the existing gate system: the Upland Gate, the Prison Tower, the Torture House, the Golden Gate and, on the opposite side, the Green Gate, as well as their spatial relationships and their connection with the urban context. A further primary objective of the study was to demonstrate the effectiveness of the techniques applied in the conservation of architectural heritage and in the preparation of data for subsequent research activities. During the various phases of the study, educational workshops were organised to apply integrated techniques for capturing the built environment, including photography, laser scanning, and drone use. Through these activities, a complete, highly detailed model was obtained at true 1:1 scale.

Fig. 09
Concept of the fortified axis
The section schematically shows the relationship between the different architectural elements that make up the urban fortified axis. Below, general overview of the city center in relation to the gate's complex.

This approach encouraged knowledge exchange among researchers and enabled students at different levels to directly experiment with advanced digitalisation practices. The tools and methods adopted proved fundamental for the analysis of historical architectural objects, extending beyond individual buildings to a wider range of elements. The possibility of using photographs, including those taken with simple digital cameras or mobile devices, significantly enhances data processing and model creation. This flexibility facilitates the application of photogrammetry and other techniques to produce detailed 3D models, enriching the understanding and analysis of architectural heritage. The integration of different techniques — from photographic acquisition to point cloud generation, from solid modelling to texture mapping — proves highly versatile. These methods can be applied at various stages of the 3D modelling process, contributing to the creation of an accurate digital representation of historic structures.

Side page Fig. 10
Current photographs of the monuments of the fortified complex
From above, the Prison Tower monument; below, the Golden Gate and High Gate city monumental gates.

References

Białko P., et al., 2002, *Badania historyczne, architektoniczne i konserwatorskie Wieży Więziennej Zespołu Przedbramia ulicy Długiej w Gdańsku*, T. I. Opis i wnioski badań historycznych, architektonicznych i konserwatorskich, Gdańsk, typescript, MG, ZP/2002-5,6.

Bigoś-Bojarska M., Darecka K. 2010, *Zespół Przedbramia ulicy Długiej w Gdańsku. Prace konserwatorskie i adaptacyjne*, in: Spotkania Malborskie im. Macieja Kilarskiego, ed. A. Dobry, Malbork, cz. 1–3, pp. 225-242.

Bukal G. 2016, *Zespół bram ul. Długiej jako element systemu obronnego Gdańska (1343–1612)*, in: Zespół Przedbramia ul. Długiej w Gdańsku. Studium archeologiczne, ed. A. Pudło, Gdańsk, pp. 63-86.

Dell'Amico A. 2021, *Mobile laser scanner mapping system's for the efficiency of the survey and representation processes*, in *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 46, pp. 199-205.

Jung-Migalska H., Ilska W., Kamińska P., Pastewka M. 2004, *Badania architektoniczne w obrębie Szyi i Katowni Zespołu Przedbramia ul. Długiej w Gdańsku*, *Analiza wyników badań*, Warszawa–Gdańsk, typescript, MG, ZP/2004-38.

Parrinello S., Picchio F. 2023, *Digital Strategies to Enhance Cultural Heritage Routes: From Integrated Survey to Digital Twins of Different European Architectural Scenarios*, in *Drones*, 7(9), 576.

Pudło A. 2016, *Rozwój Zespołu Przedbramia ul. Długiej na podstawie badań archeologicznych prowadzonych w latach 2001–2004*, in *Zespół Przedbramia ul. Długiej w Gdańsku. Studium archeologiczne*, ed. A. Pudło, Gdańsk, pp. 13-62.

Sammartano G., Spanò A. 2018, Point clouds by SLAM-based mobile mapping systems: accuracy and geometric content validation in multisensor survey and stand-alone acquisition, in *Applied Geomatics*, 10, pp. 317-339.

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Side page, Fig. 01
Digital survey database of the Main Town Hall, Gdańsk
Image from the database obtained by TLS laser scanner acquisition.

In the contemporary context of research on architectural heritage, digital surveying is increasingly seen as a complex, stratified process in which data acquisition is only one phase within a broader knowledge pathway. Surveying is understood as a cognitive act involving actions aimed at translating and investigating architectural artefacts. Data acquisition, though technologically advanced (via methodologies such as 3D laser scanning, digital photogrammetry, or drone use), is not the ultimate goal but instead initiates a trajectory toward deeper knowledge. Surveying thus transcends geometric recording to become a critical investigation uncovering material history, construction techniques, temporal stratifications, and spatial relationships inherent in architectural artefacts. This process involves synergistic actions: analysis and interpretation, wherein raw data are processed and structured into dense 3D models. Such work demands advanced computational and representational skills, as well as architectural historical knowledge, to correctly interpret surveyed geometries and identify anomalies or decay. Digital surveying operates as a translation mechanism, converting tangible reality and material properties into usable digital models—choices regarding representation scales, levels of detail (LOD), and intended applications (documentation, conservation, restoration, virtual access) all influence this process. The outcomes serve as essential bases for later protection, conservation, or scientific dissemination, whether in traditional graphic drawings, BIM models, or virtual environments. The precision and completeness afforded by digital surveying support non-invasive, reversible documentation of existing states, which is vital for structural diagnostics and material identification. Ultimately, contemporary digital surveying bridges physical heritage and its digital representation, casting the professional as a critical mediator in understanding architecture.

The evolution of surveying and modelling technologies has profoundly transformed the relationship between object, representation, and interpretation, shifting the focus from geometric restitution to the construction of integrated, dynamic information systems. In this perspective, the digitalisation of heritage serves as a cognitive action aimed, on the one hand, at making the physical object virtual and, on the other, at opening it up as a knowledge device capable of integrating heterogeneous data that can be updated and interrogated over time[1]. The digital model thus becomes an open infrastructure, in which geometric, material and, potentially, historical and managerial information converge,

[1] Picchio et al. (2025), *Narrare il patrimonio dei borghi: linguaggi grafici per la rappresentazione delle aree a rischio*, pp. 3141-3164.

Referee List (DOI 10.36253/fup_referee_list)
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Fig. 02
Field survey and data processing
Some photographs showing the field acquisition phases with range-based and image-based instrumentation, and the recording operations of the integrated point cloud at University. Below, top view screenshot from Leica's Cyclone Field application.

Side page, Fig. 03
Point cloud view of Długa Street and Green Gate
Screenshot from the terrestrial laser scanner of the colored point cloud.

configuring itself as an active tool in processes of analysis, conservation and enhancement[2]. The definition of the acquisition strategy plays a central, non-neutral role in this framework, as it directly affects the quality and nature of the data produced. The integration of different techniques — such as fixed-position laser scanning and mobile surveying — addresses the need to balance accuracy, continuity, and operational speed. Alongside these, photogrammetry is employed using a multiscale approach: on the one hand, for close-range analysis of detailed elements; on the other, from aerial platforms for documenting inaccessible parts such as roofs. Combining different tools lets us create detailed information sets where point clouds and 3D photo models work together as a single digital system. Here, the 3D model is not just a picture of the building, but also a tool for sorting and understanding the data, enabling deeper study. The acquisitions carried out at the main Gates along the city access axis (High, Golden, Green and Prison Tower) required careful attention to connections between internal and external portions due to restoration scaffolding, which partially limited visibility. For surveying the main road axis, wider scanning paths were organised. To minimise drift error caused by the linearity of the investigated system, high-resolution scans were performed at the four corners of each intersection and within the first 20 metres of streets orthogonal to *Long Lane* (*ul. Długa*). Data acquisition focused on key nodes of urban and architectural heritage, adapting survey methods to each context. The main challenge at these sites was ensuring continuity and accuracy in connecting interior and exterior spaces, made more difficult by scaffolding necessary for ongoing conservation, which limited visibility and instrument positioning.At the same time, to map the main road, especially *Long Lane* (*ul. Długa*), was decided to use a wide-scanning plan to efficiently cover the entire length. But because the street is long and straight, small mistakes are likely to add up, which can affect the

[2] Borucka, Picchio (2026), *Transforming urban experience through virtual tours: a digital storytelling of Gdańsk and its heritage*.

full model's accuracy. To mitigate this potential error and ensure high metric accuracy, a targeted integration and calibration strategy was adopted.

Specifically, very high-resolution scans were carried out at strategically defined points along the road axis. These points included the four corners of each intersection encountered along Long Lane. Furthermore, to ensure accurate connection with the secondary urban grid, high-resolution scans were also performed within the first 20 metres of all streets orthogonal to Long Lane. This system of high-density, high-precision "control nodes" firmly constrained the three-dimensional model of the main axis, significantly reducing drift error and ensuring the reliability of the acquired data for subsequent analyses and documentation[3]. The built fabric of *ul. Długa*, with the exception of the Town Hall tower, has an average height of four storeys. Although the system in plan may conceal it, the street is wide, allowing information about the crowning decorations to be obtained from the ground. However, to obtain a complete database of the system, the laser survey campaign was complemented by an aerial survey to integrate data on roofs and characteristic decorative elements at the top of the facades. The creation of integrated 3D models of Gdańsk's monuments is not merely a technical surveying operation, but a true act of "digital heritage". In a city that has experienced the fragility of matter and the burden of historical reconstruction, translating architecture into data means freeing urban identity from the tyranny of time and events. These models do not merely describe forms; they archive the very essence of the structures that define Gdańsk's skyline. By transforming the physical monument into a "digital twin", conservation shifts from the plane of bricks to that of pure information: a process that ensures millimetric precision for future restoration while also democratising heritage, making it accessible and navigable beyond physical boundaries. In this way, the digitised building ceases to be a static object and

[3] Bigongiari (2025), *Beyond the module: measuring adaptation in the Laurentian palimpsest*, pp. 66-75.

Fig. 04
Study of details
Analysis and acquisition of decorative details through sketches, field drawings and the application of photogrammetric techniques.

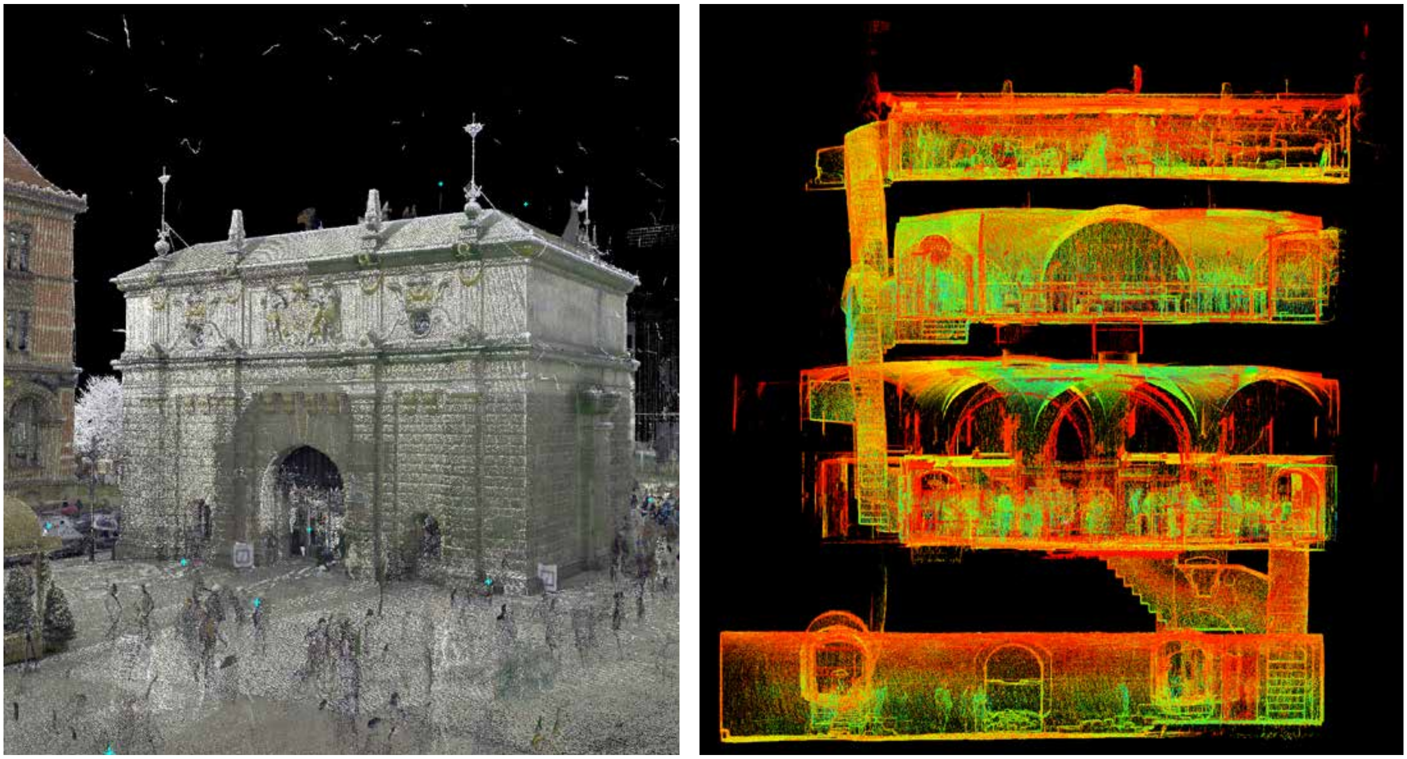


Fig. 05
High Gate laser scanner database
Point cloud visualisation of the exterior and interior of High Gate.

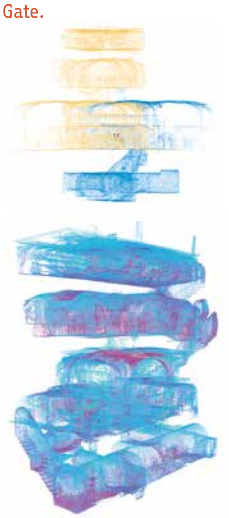
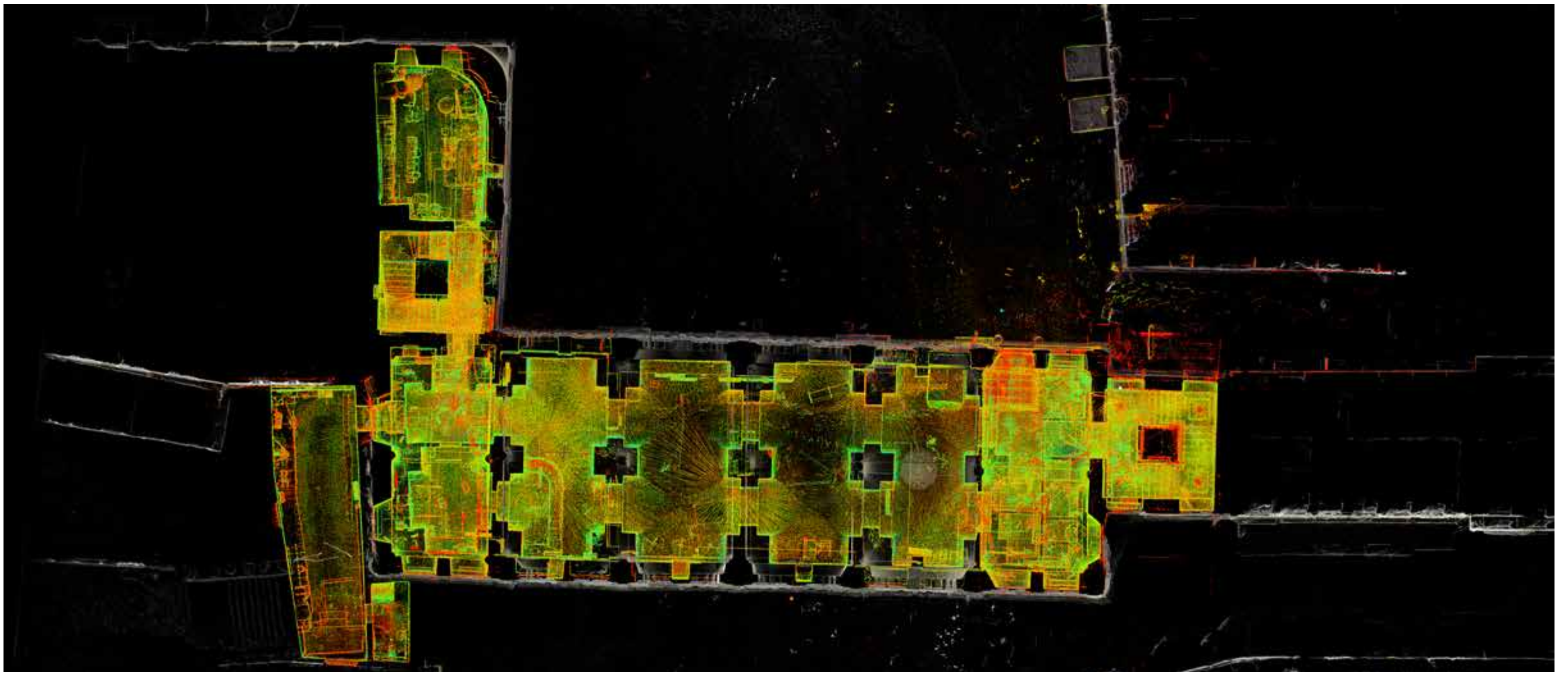


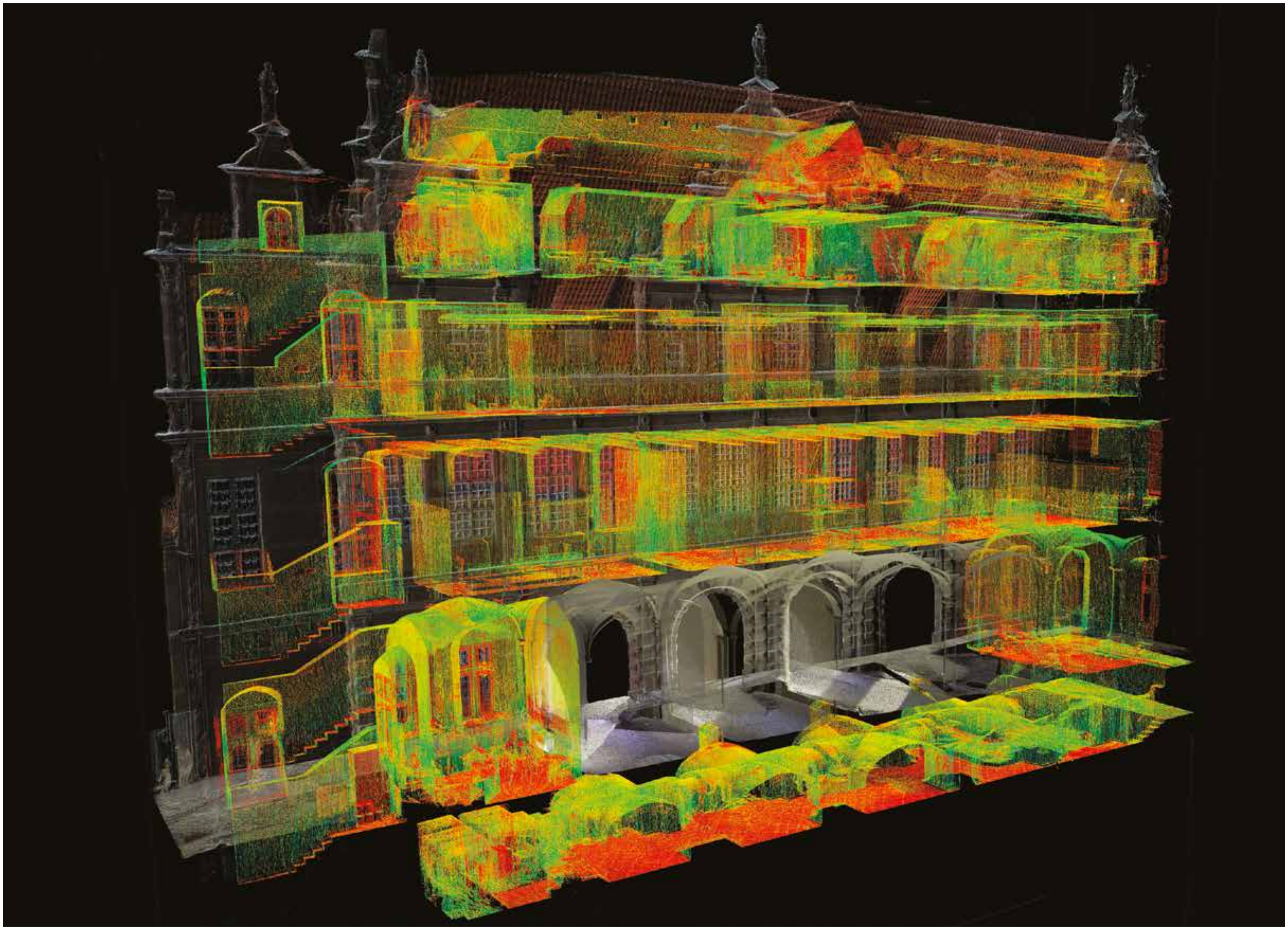
Fig. 06
High Gate laser scanner database
The process of recording the scans to obtain the overall point cloud of the monument.

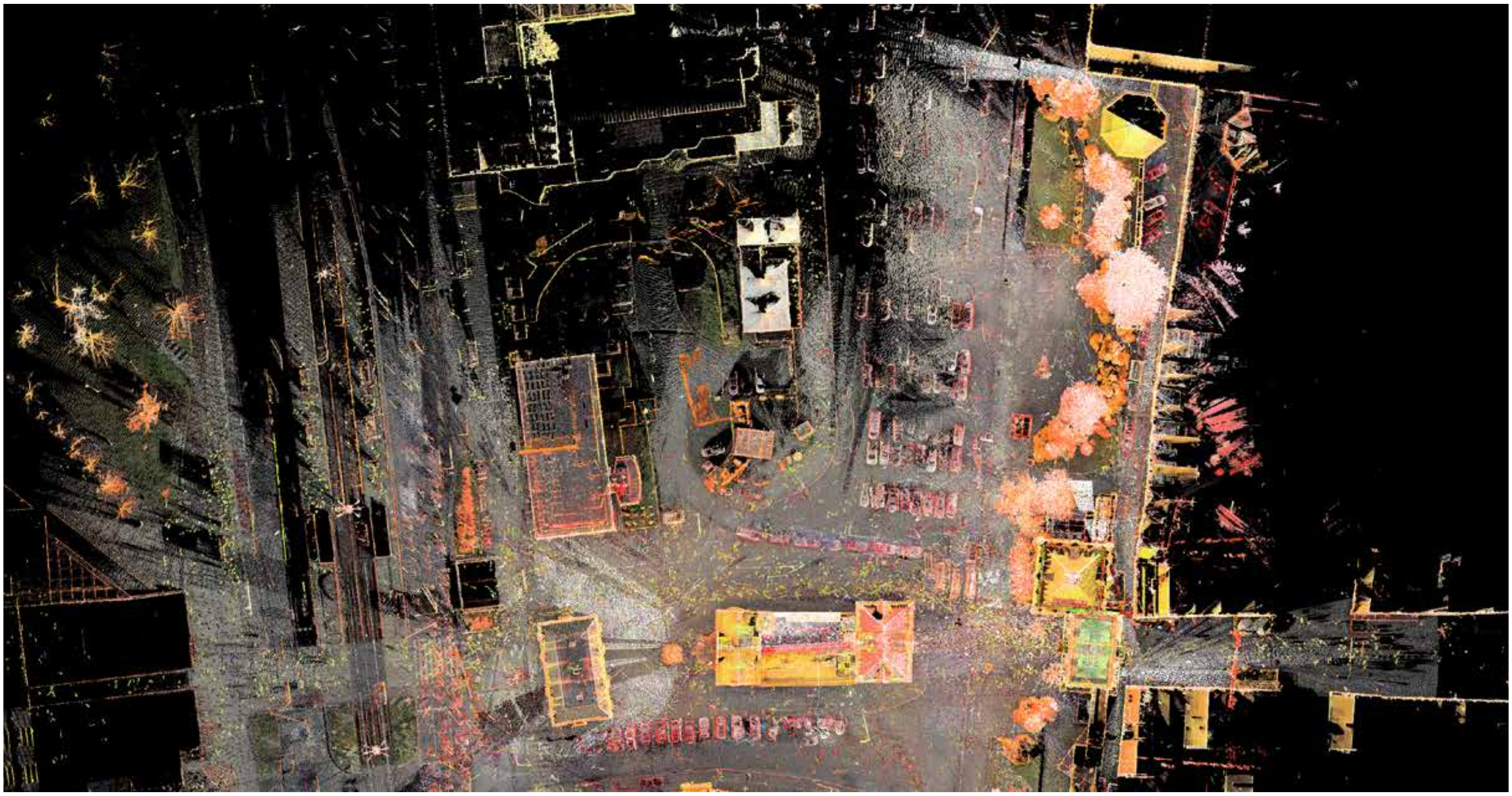
Side page, Fig. 07, 08
3D point cloud of Green Gate monument
Image from the database obtained by mobile laser scanner acquisition.

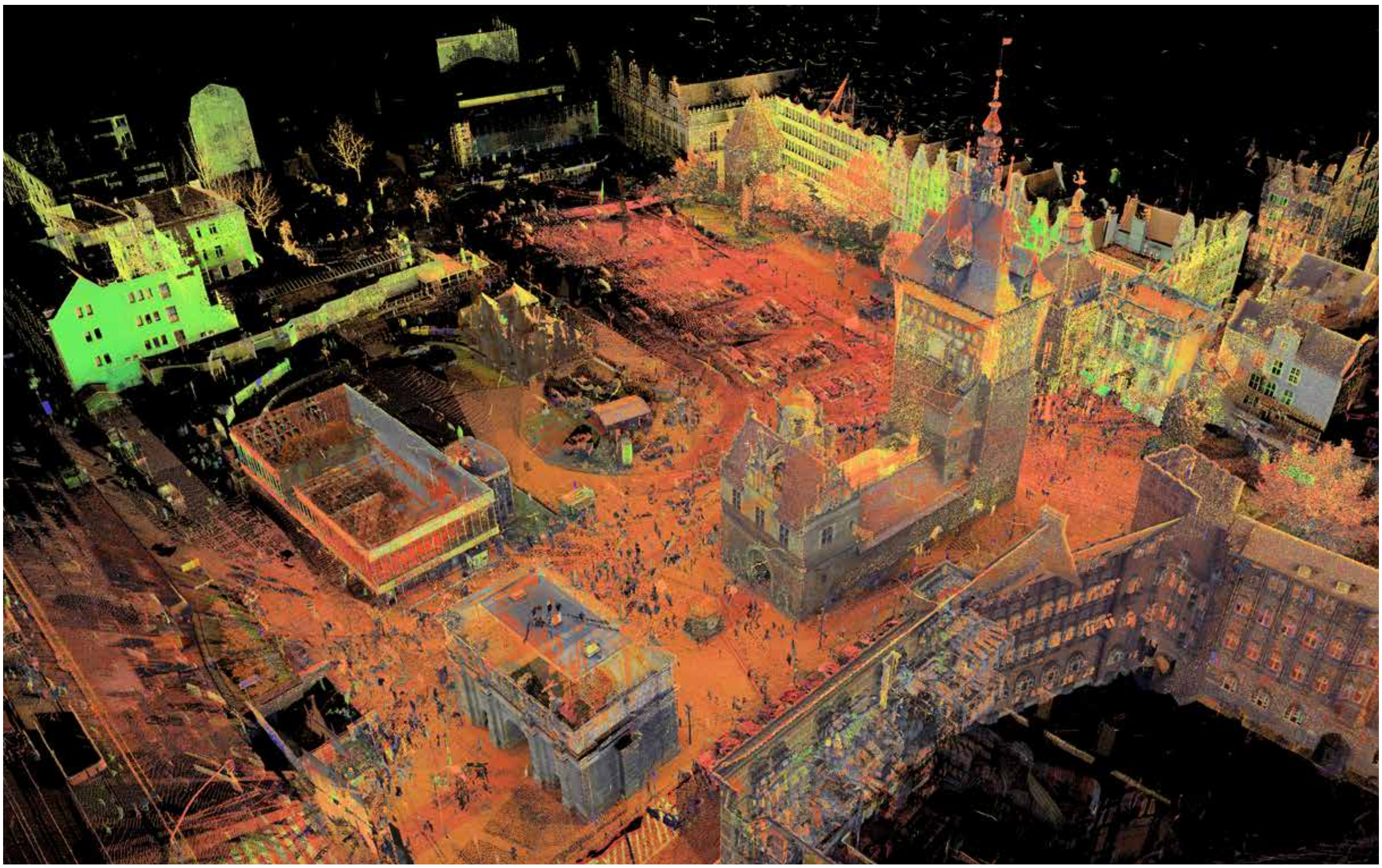
becomes a dynamic informational organism, capable of telling its own story and structural complexity to future generations, preserving forever the collective memory that is the beating heart of the city. However, within this highly digitalised process of documentation and analysis, based on advanced technologies such as 3D laser scanning and photogrammetry, drawing — both freehand and technical, in its various forms — maintains not only a fundamental but an irreplaceable role. Far from being an anachronistic residue or something superseded by faster automatic acquisition technologies, it is configured as a true critical tool for selection, deep interpretation and conceptual synthesis. Drawing acts as a powerful cognitive filter. It forces the observer to actively engage with the subject's complexity, rather than passively record physical reality[4]. When the designer or analyst decides what to include and what to omit, which lines to emphasise and which spatial relationships to highlight, they are performing an act of deep interpretation and hierarchical organisation of information. This process of abstraction becomes fundamental for understanding architecture, especially when digital models, although faithful to reality, produce an abundance of data that is often noisy and lacks explicit conceptual structure. Drawings derived from complex digital databases — whether traditional plans, sections and elevations, or more interpretative outputs such as exploded axonometries, analytical diagrams or hypothetical reconstructions — are not simple outputs or 'prints' of the 3D model. Rather, they are essential moments in the construction of knowledge. At this stage, the extensive geometric dataset is actively interrogated, filtered through disciplinary lenses (architectural, archaeological, engineering)

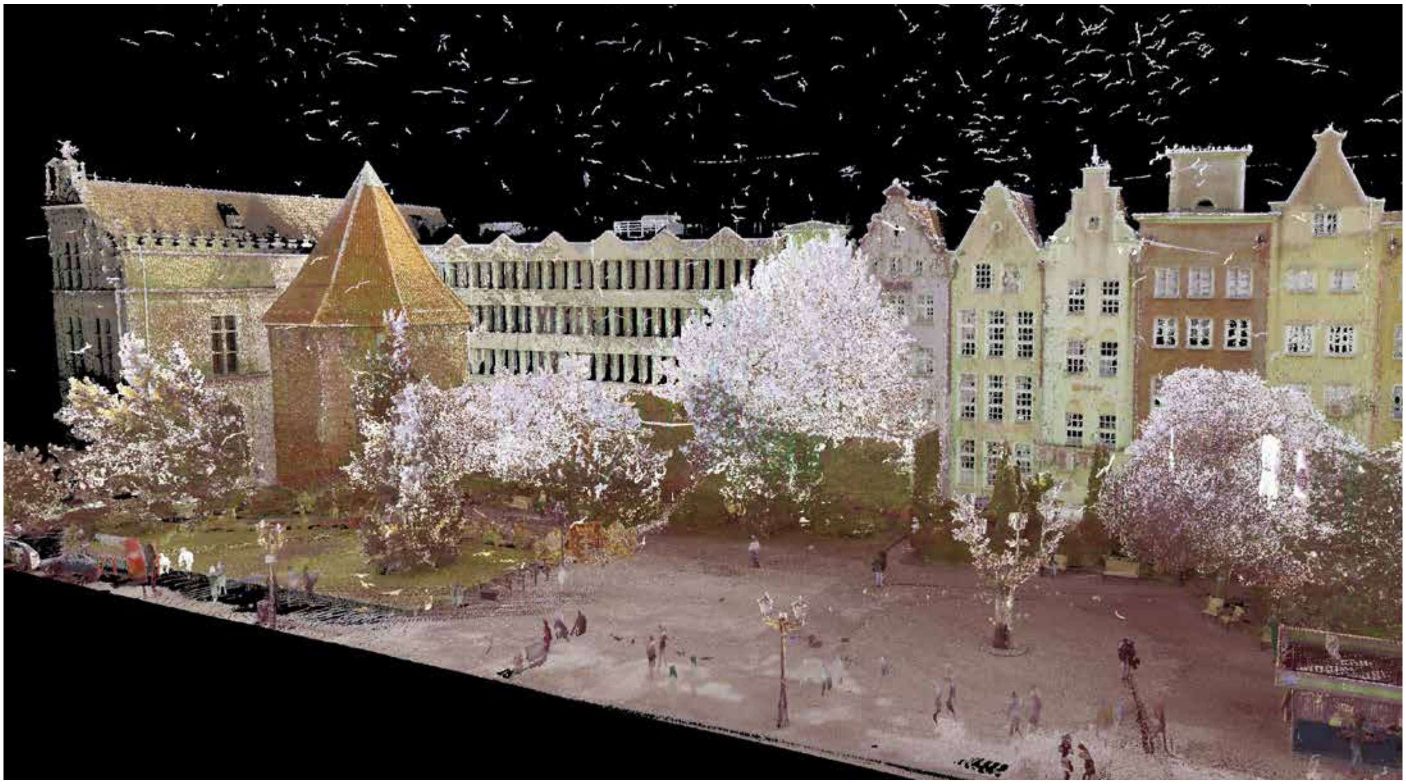
[4] Varol, Öksüz (2025), *Use of advanced measurement and reality technologies in cultural heritage sites from the perspective of technology and tourism*, pp. 585-603.











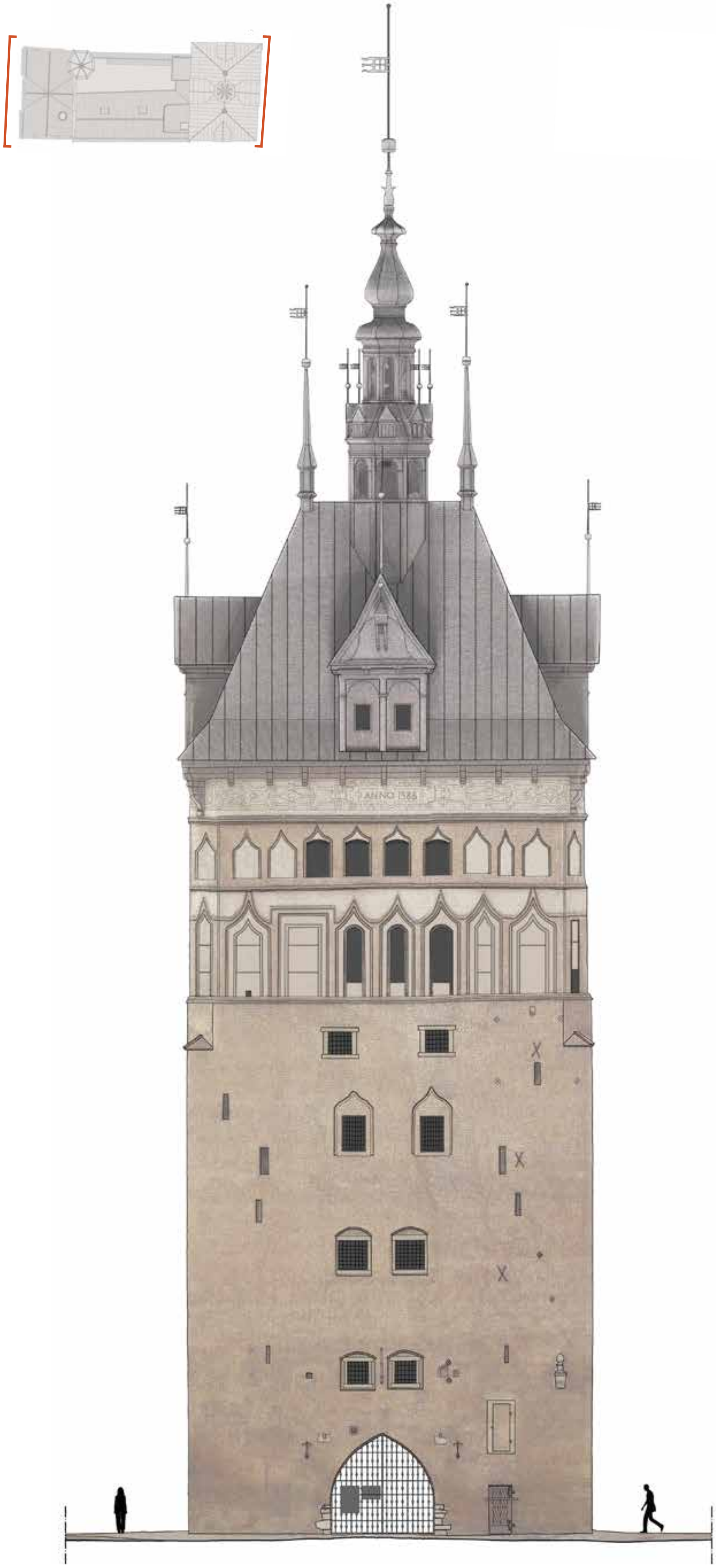
and reorganised into graphic structures that communicate meanings, hypotheses and design intentions. Drawing thus becomes the first and most effective form of critique of digital data, transforming the quantity of information into the quality of knowledge[5]. The transition from model to drawing involves a conscious process of abstraction, through which relationships, hierarchies and specificities emerge that are not immediately visible in the complexity of the point cloud or the three-dimensional model. In this sense, drawing acts as an interface between digital data and critical understanding, making otherwise dispersed information legible and contributing to the construction of shared knowledge. The interaction between digital model and drawing thus reveals a circular dimension of the knowledge process: surveying feeds the model, the model generates drawing, and drawing, in turn, guides new questions and further investigations. It is precisely in this circularity that the methodological value of the adopted approach can be recognised, as it can integrate different tools into a unified vision. In conclusion, the adoption of integrated acquisition and modelling strategies, combined with a renewed centrality of drawing as an interpretative tool, enables the complexity of contemporary architectural heritage to be addressed. In this framework, the digital twin is not merely a technological objective, but a critical device through which knowledge can be constructed, organised and transmitted, opening new perspectives for research, conservation and heritage enhancement.

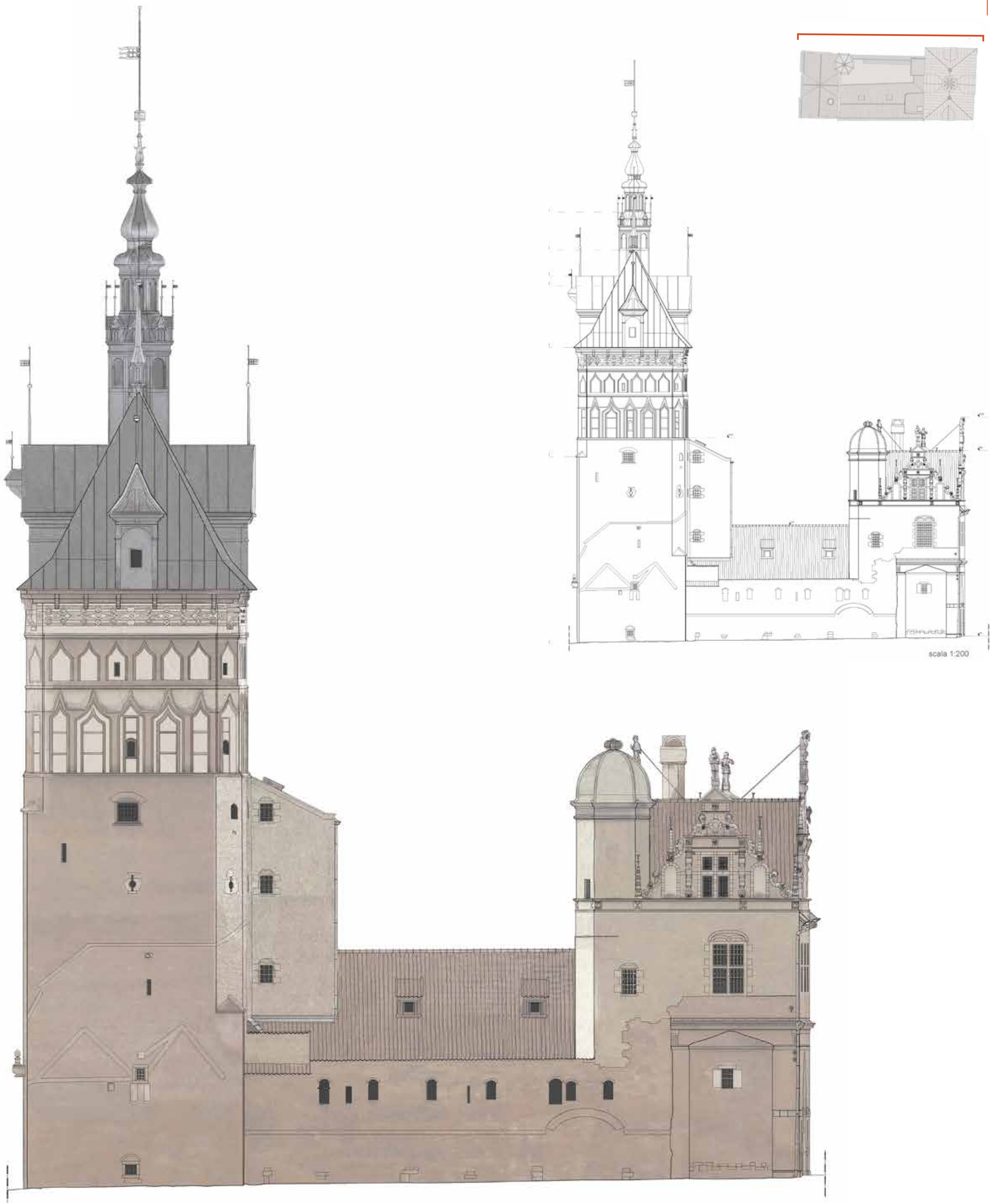
This methodological integration, critically coupled with a renewed centrality of traditional drawing as an interpretative and synthetic tool, is fundamentally necessary to effectively address the multifaceted

Side page, Fig. 09, 10
Fortified architectures in the urban fabric
Point cloud in real colour showing the integration of towers and defensive walls within the historic urban fabric.

Fig. 11
Survey of the Straw Tower
The tower within the urban system: a true-colour point cloud highlighting the integration of the tower and defensive structures into the historic urban fabric.

[5] Picchio, Parrinello (2025), *Esperienze di rilievo e documentazione digitale delle opere sanmicheliane*, *in Michele Sanmicheli architetto costruttore artista*, pp. 135-139.

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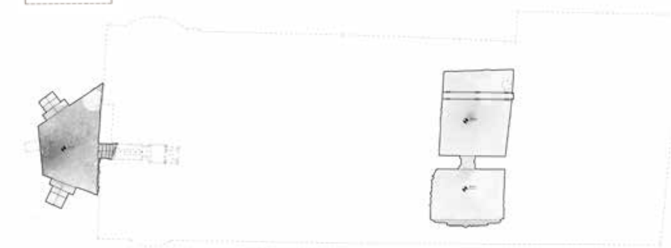
P-1,Underground Plan



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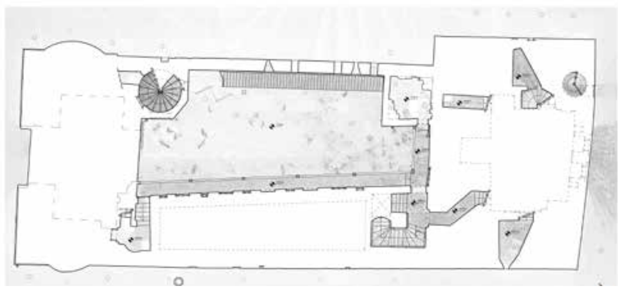

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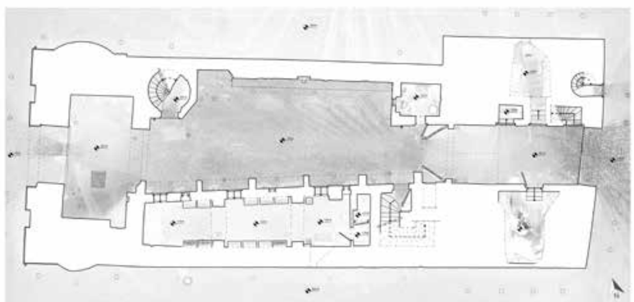
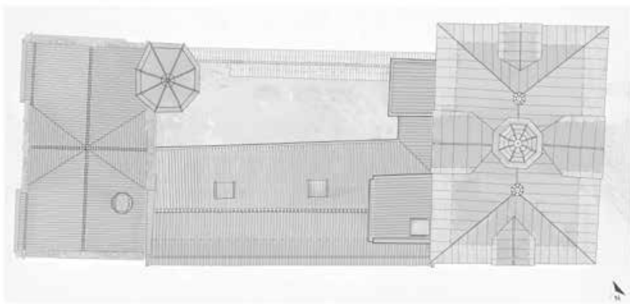
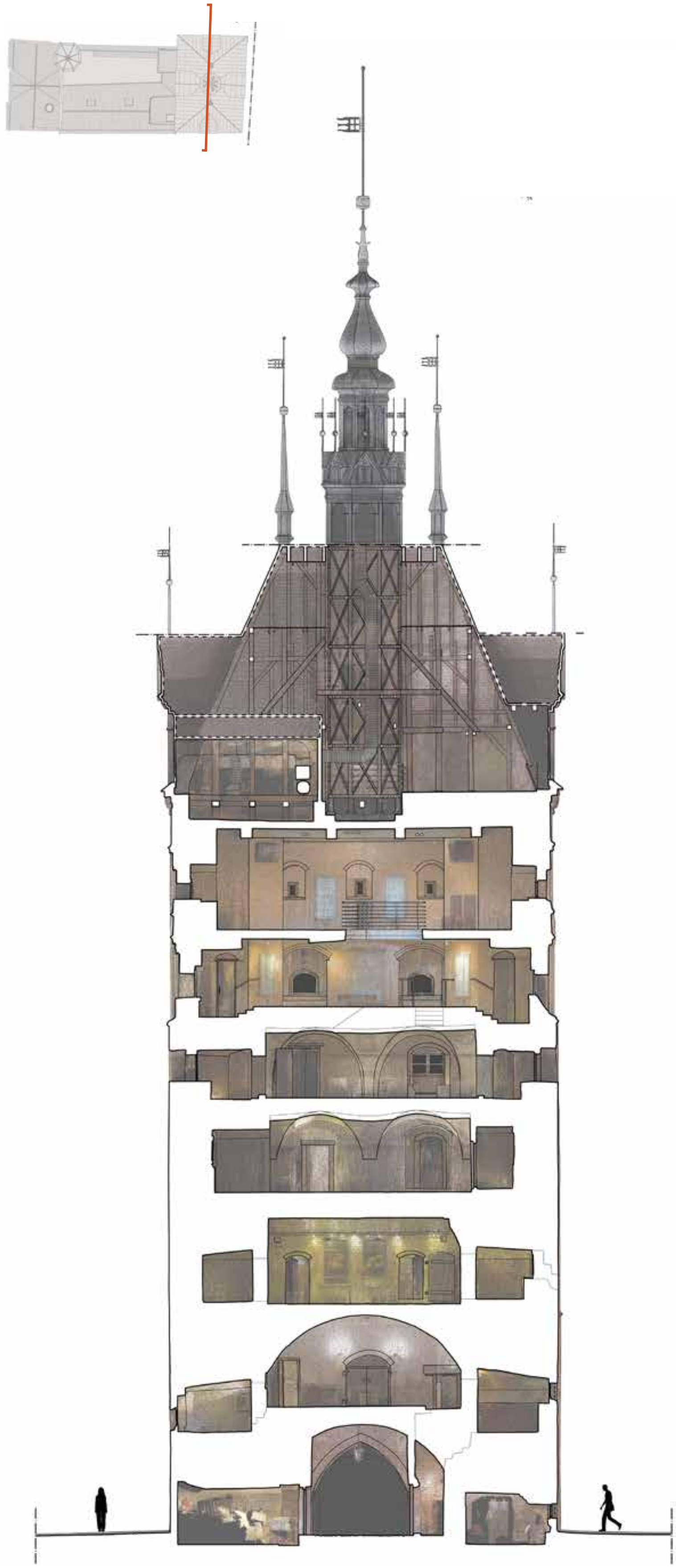
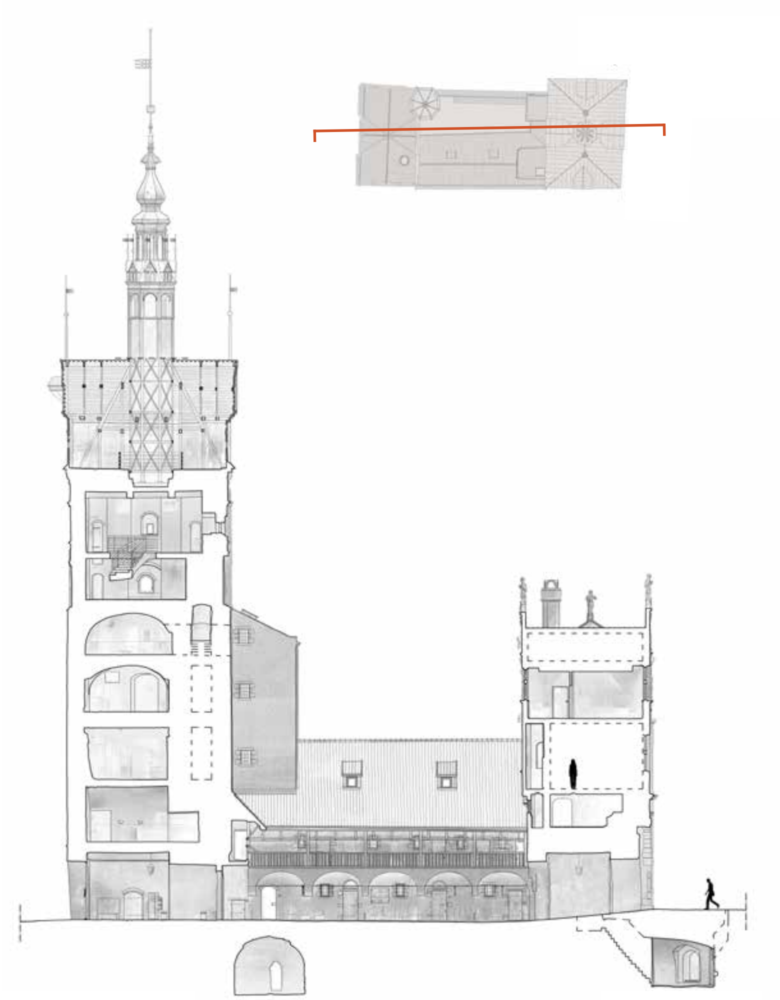
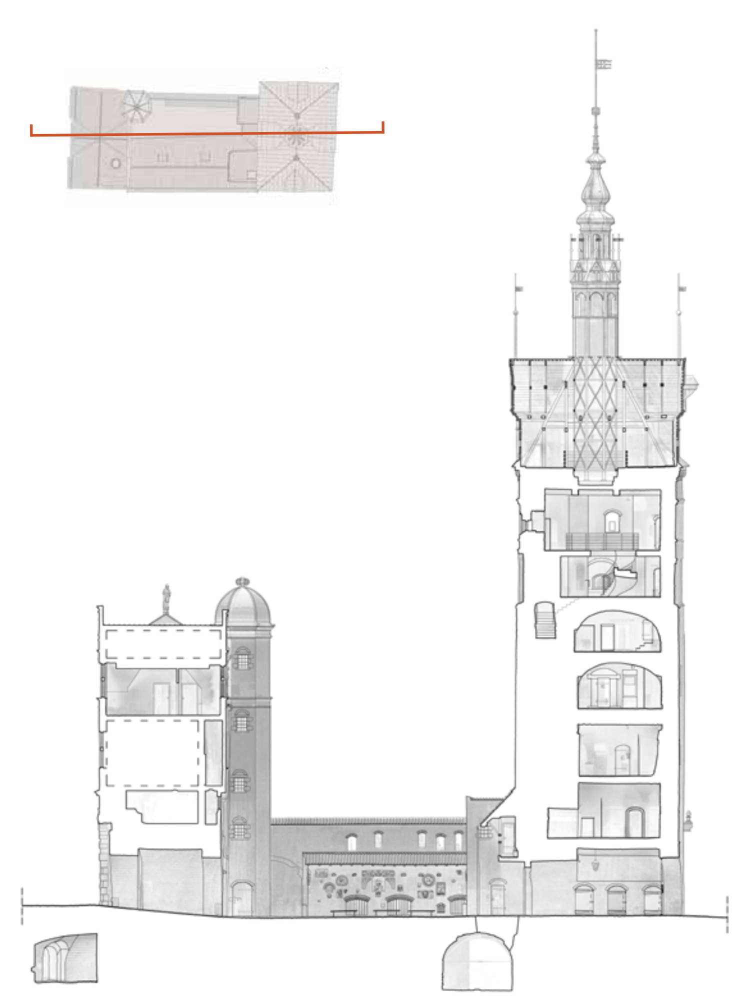


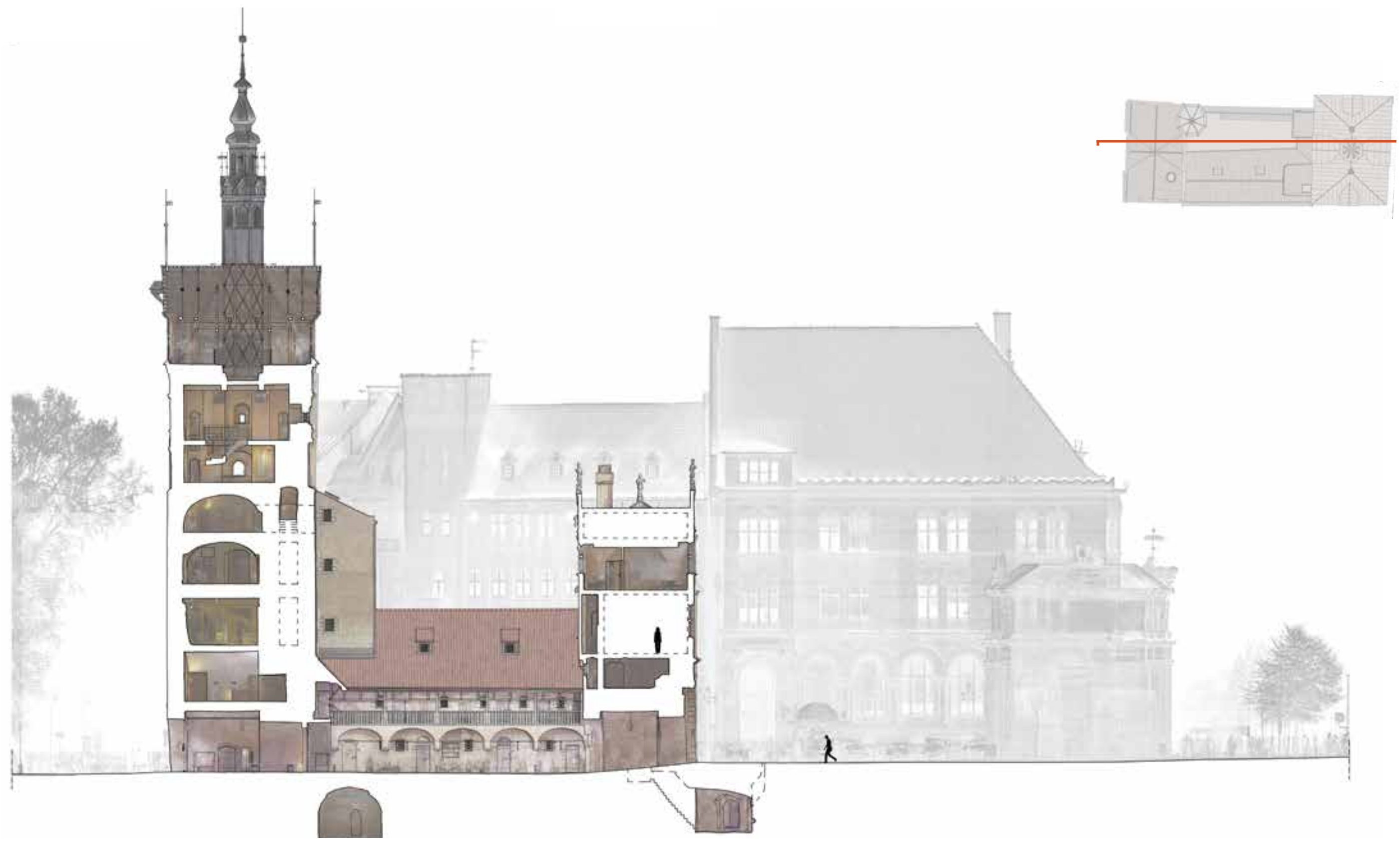
Roof Plan

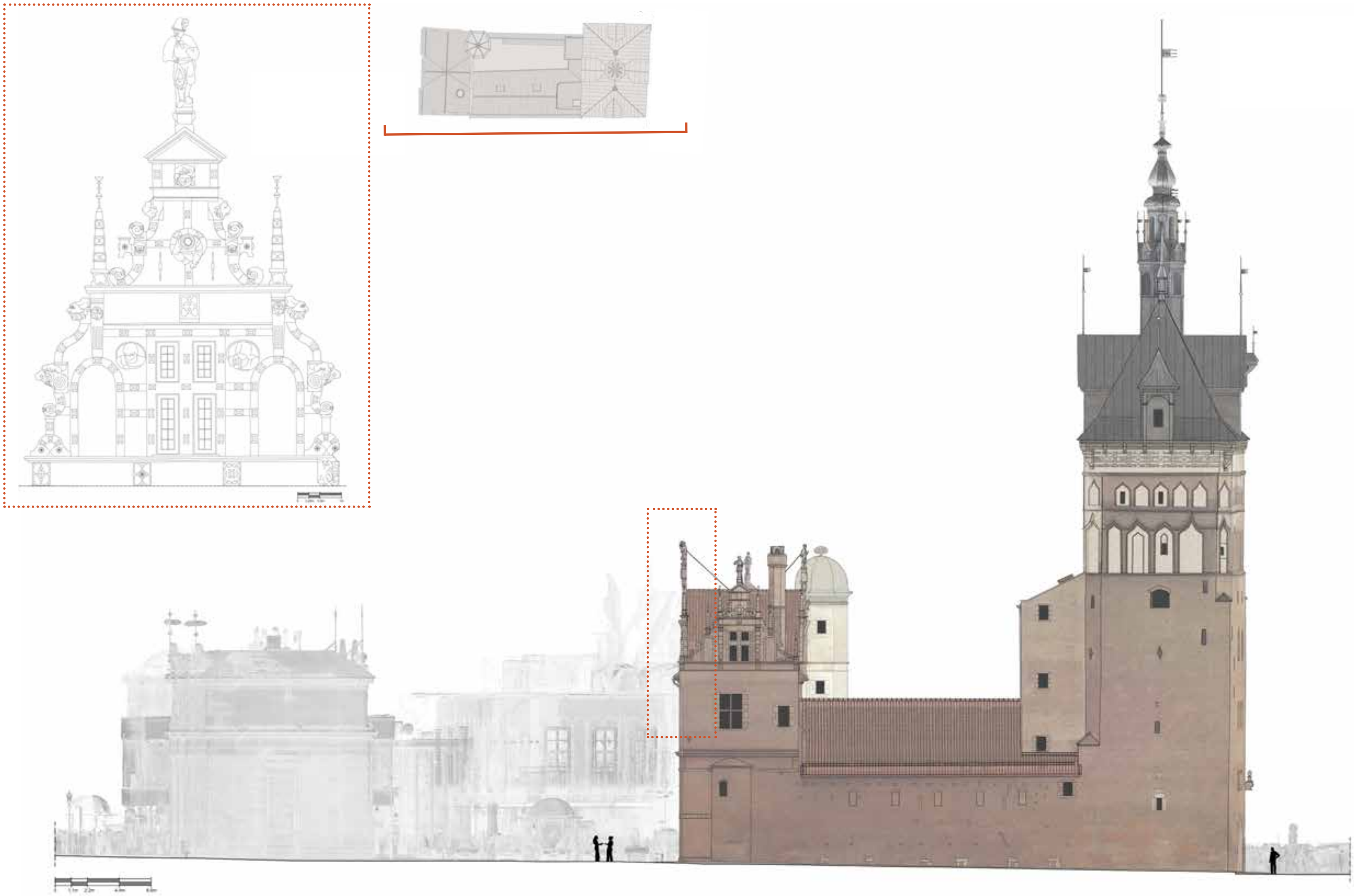


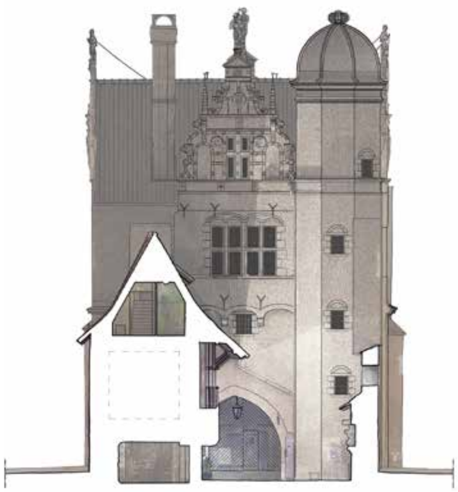




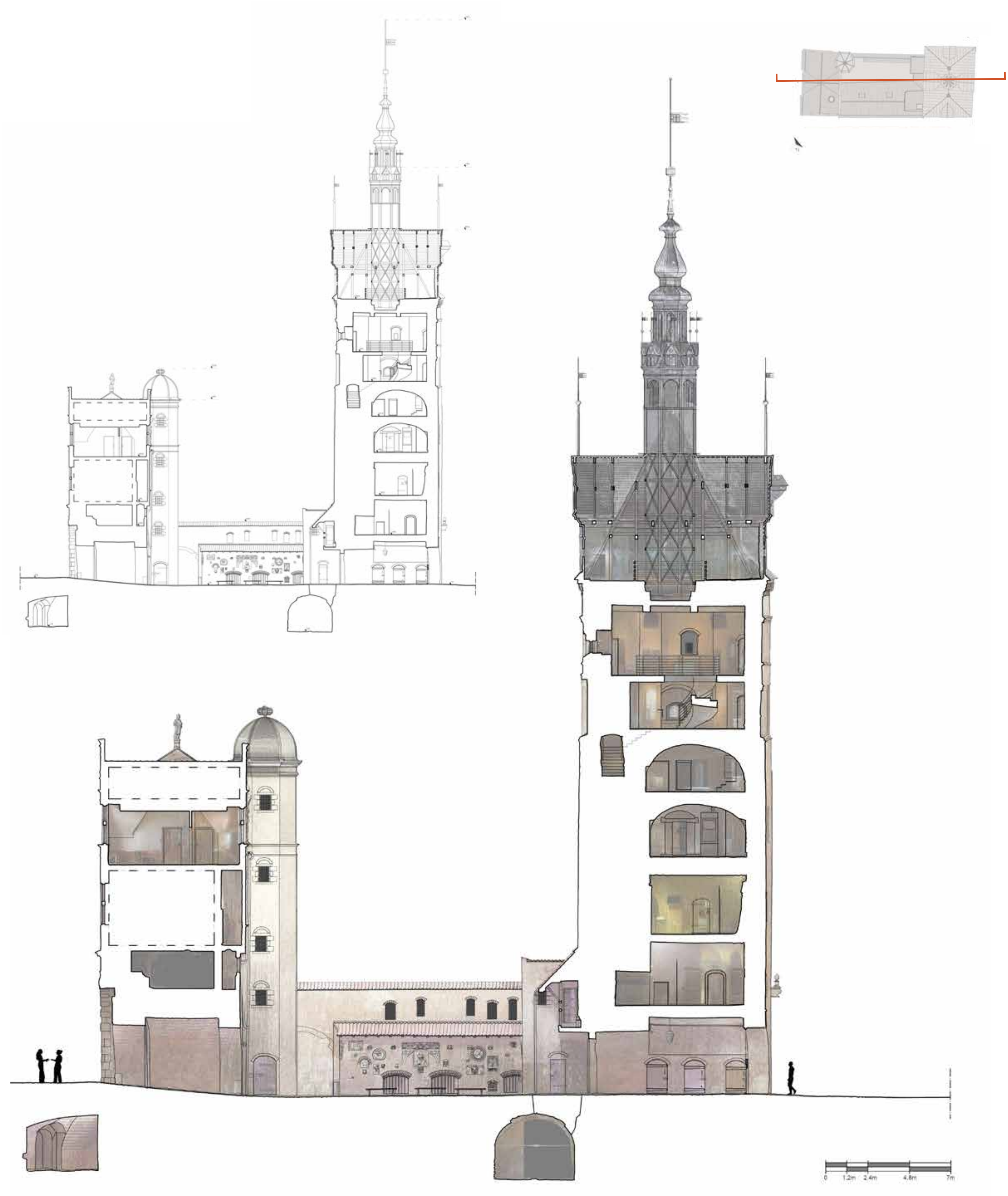









DETTAGLIO FOTOPIANO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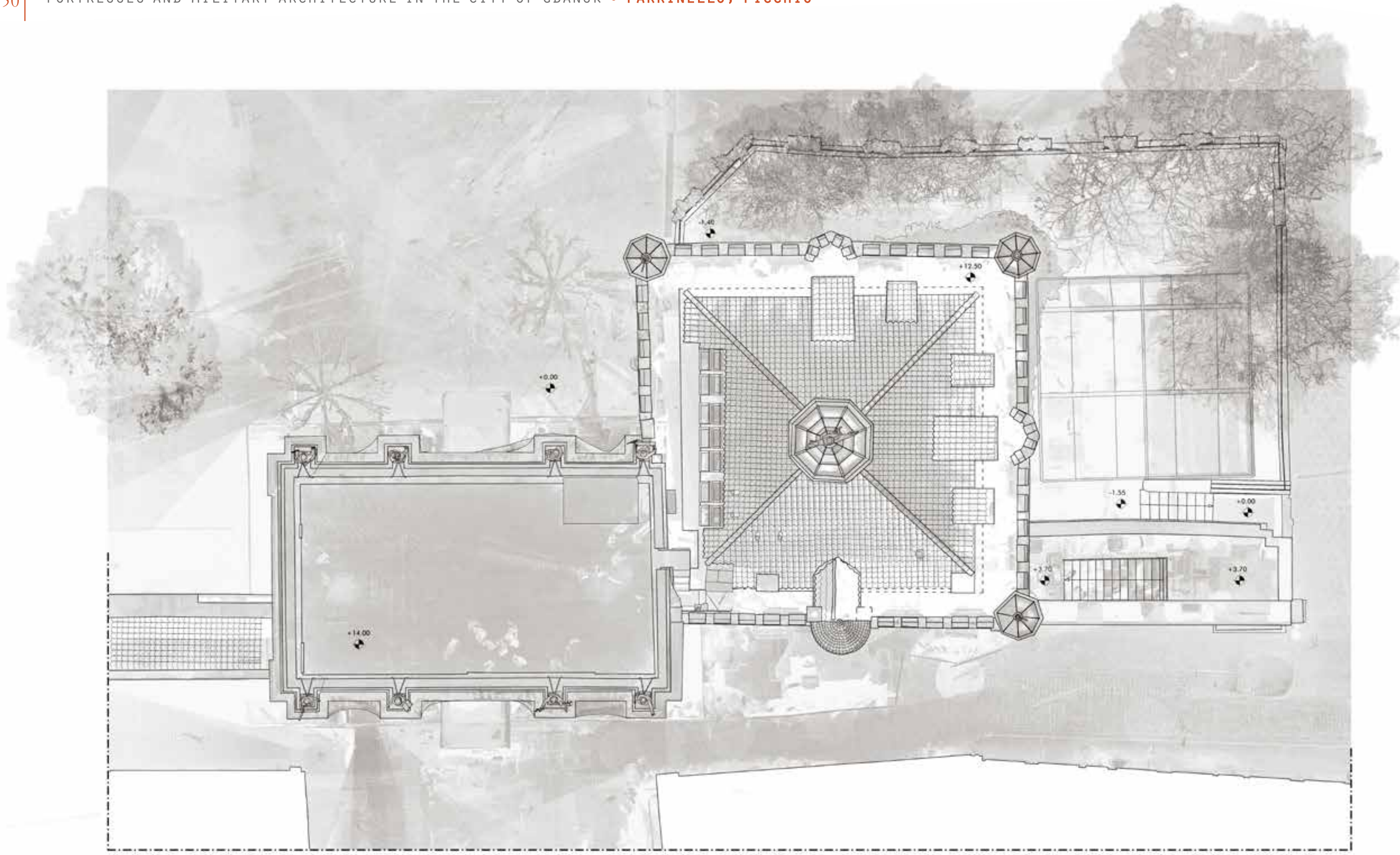

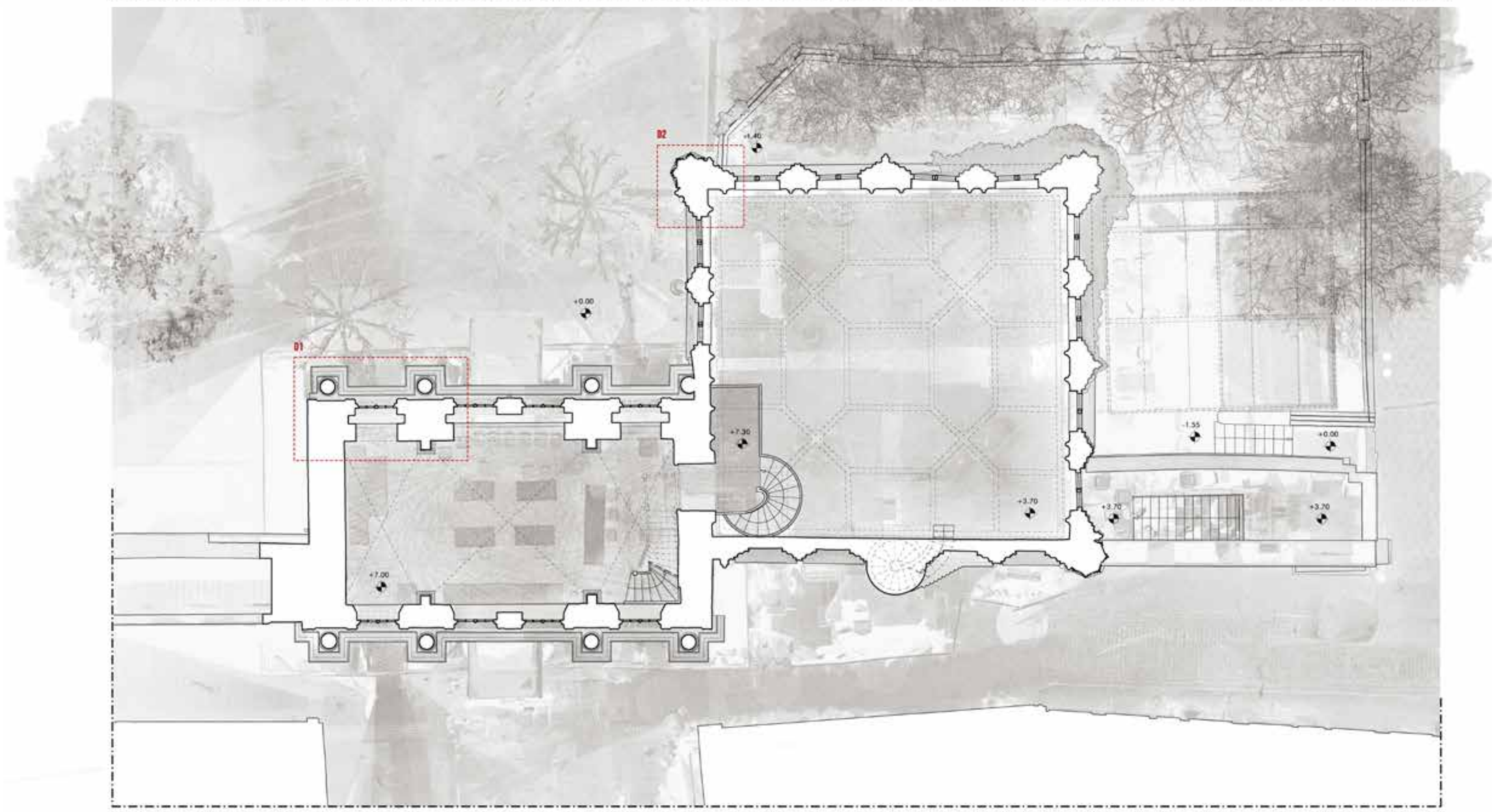
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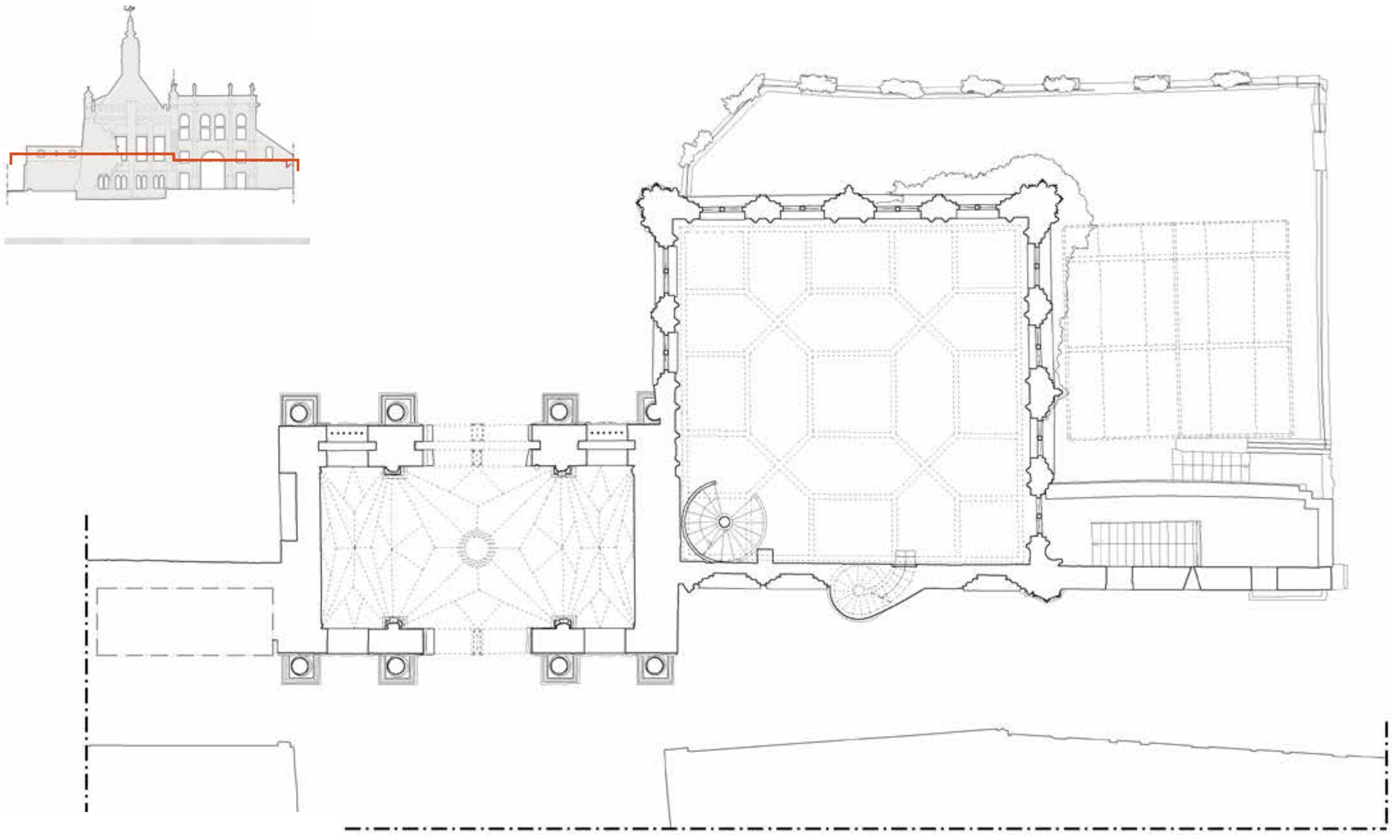

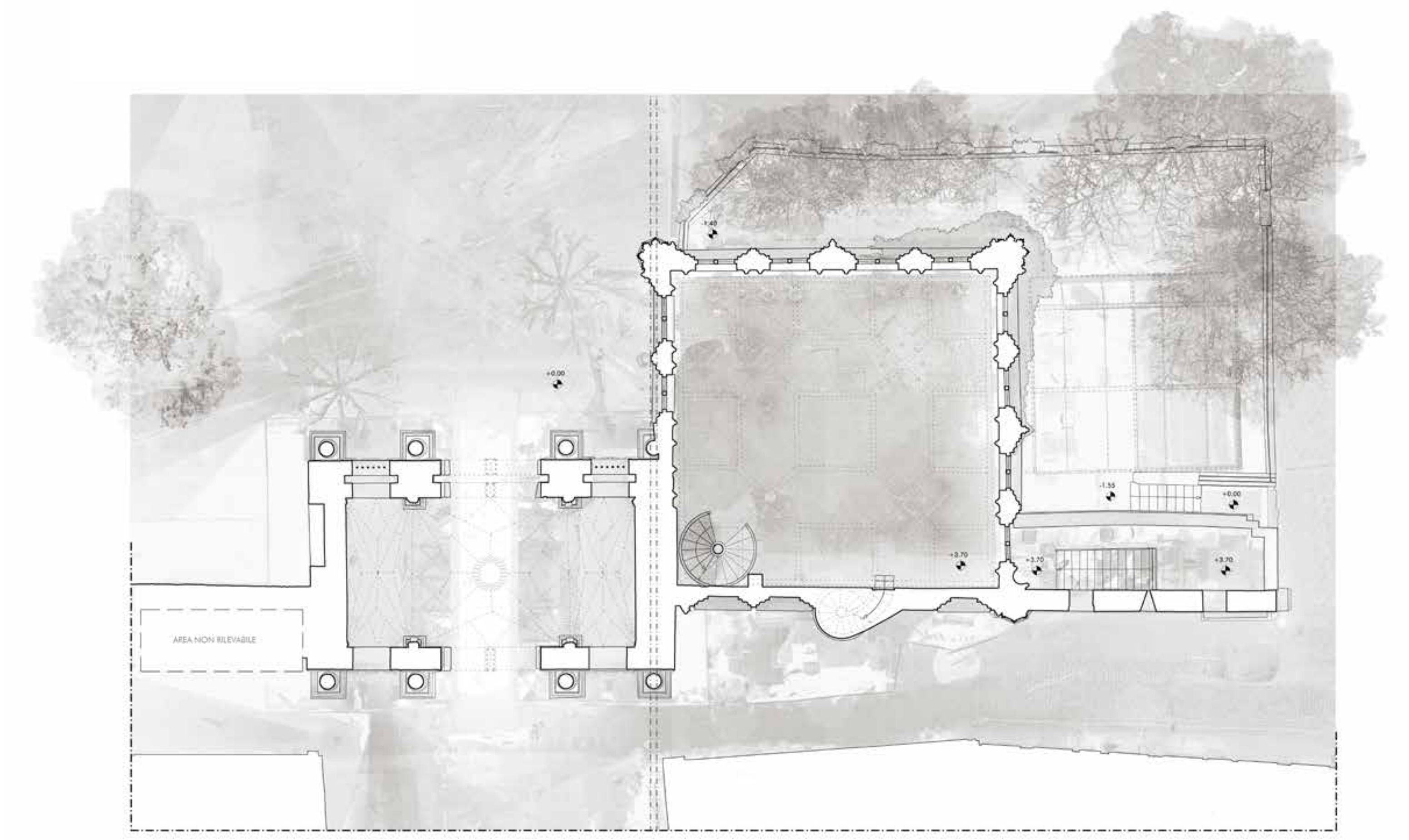
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FIL DI FERRO E FOTOPIANO
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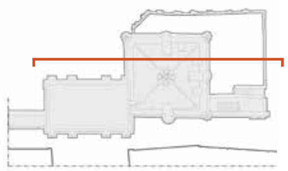

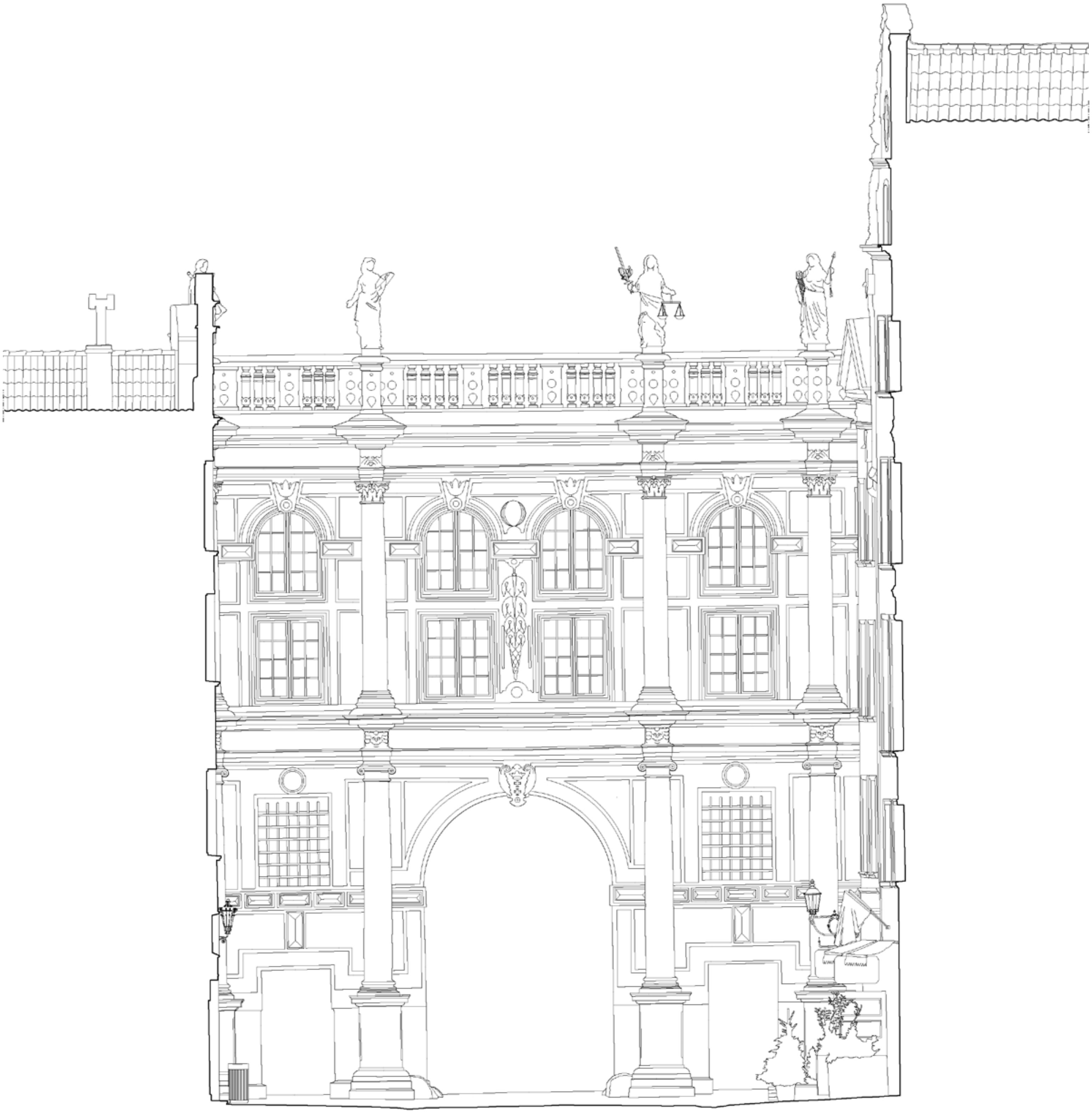

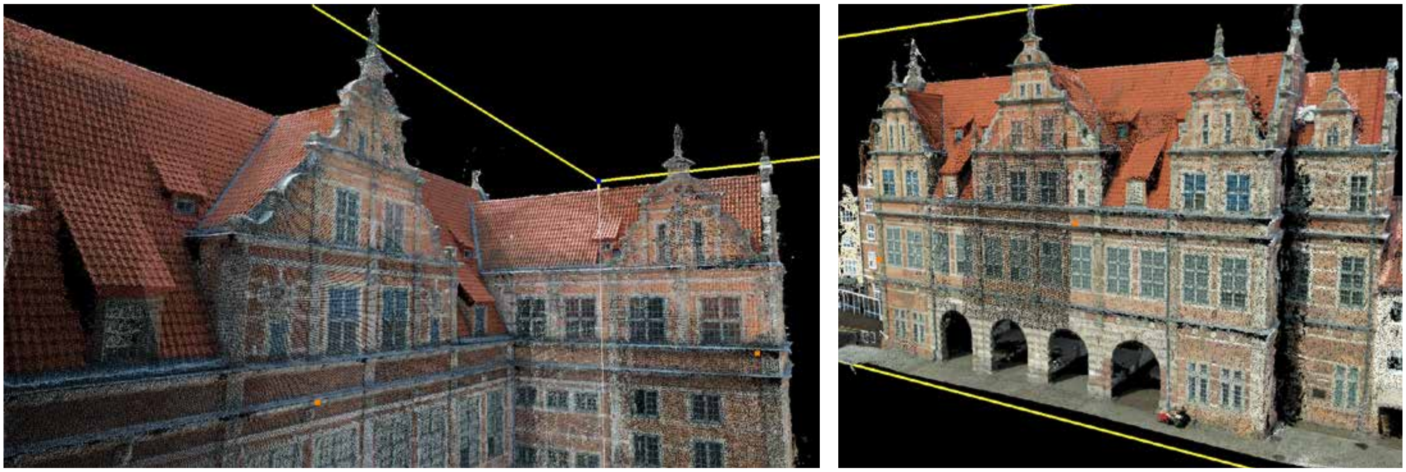

Fig. 12
UAV survey of the Green Gate
The roof covering of the Green Gate was documented through a UAV-based survey. The drone acquisition was carried out by means of low-altitude flights with overlapping nadir and oblique imagery, ensuring full coverage of the roof surfaces and architectural details. The flights were conducted by Jacek Józekowski in compliance with current regulations and safety standards.

Fig. 13
UAV survey of the Green Gate
The roof covering and upper structural elements of the Prison Tower were recorded using UAV photogrammetry. The drone survey consisted of a series of controlled flights capturing both vertical and angled images, enabling accurate documentation of the roof geometry and construction details. The flights were conducted by Jacek Józekowski, in accordance with applicable regulations.

Fig. 14
UAV survey of the High Gate
The roof and upper sections of the High Gate were surveyed using UAV technology. Image acquisition was performed through coordinated drone flights with sufficient overlap to allow detailed photogrammetric reconstruction of the roof covering and architectural features. The flights were conducted by Jacek Józekowski, following all relevant safety and operational guidelines.

complexity inherent in contemporary architectural heritage. Within this comprehensive framework, the concept of the digital twin transcends its initial perception as a mere cutting-edge technological objective. Instead, it emerges as a potent and sophisticated critical device—a dynamic, geometrically accurate, and information-rich virtual representation that serves as the primary medium for constructing, organising, and transmitting deep and structured knowledge. Knowledge is constructed by integrating data from various sources (e.g., laser scanning, photogrammetry, historical archives) into a single, cohesive model, enabling comprehensive analysis and rigorous cross-referencing. It is organised by providing a structured database (BIM/HBIM) for semantic information, material properties, decay states, and construction history, enabling systematic management and querying of heritage data. Finally, it is transmitted by offering a highly intuitive and accessible platform for stakeholders—from conservation architects and structural engineers to public audiences and policymakers—to interact with and understand the heritage asset. This approach is instrumental in opening transformative new perspectives across three key areas: research, by facilitating highly detailed geometric and material analysis, simulating environmental stressors, and enabling non-destructive structural assessments, thereby advancing the theoretical and practical understanding of heritage preservation; conservation, by providing precise, actionable intelligence for intervention planning, material selection, and monitoring the long-term performance of restoration work, moving conservation from reactive to predictive strategies; and Heritage Enhancement and Valorisation, by creating immersive and interactive experiences for the public, supporting adaptive reuse studies, and integrating the heritage asset into broader urban and economic development narratives, ensuring its continued relevance and sustainability.

References

Bigongiari M. 2025, *Beyond the module: measuring adaptation in the Laurentian palimpsest*, in *TRIBELON*, 2, pp. 66-75.

Borucka J., Picchio F. 2026, *Transforming urban experience through virtual tours: a digital storytelling of Gdańsk and its heritage*, in *npj Heritage Science*, 14(1), 129.

Picchio F., Parrinello S. 2025, *Esperienze di rilievo e documentazione digitale delle opere sanmicheliane*, in *Michele Sanmicheli architetto costruttore artista*, Campisano Editore, pp. 135-139.

Picchio F., Calia M., La Placa S., Laera R. 2025, *Narrare il patrimonio dei borghi: linguaggi grafici per la rappresentazione delle aree a rischio*, in Carlevaris L., et al. (eds.), *Èkphrasis. Descrizioni nello spazio della rappresentazione / Èkphrasis. Descriptions in the space of representation. Atti del 46° Convegno Internazionale dei Docenti delle Discipline della Rappresentazione*, FrancoAngeli, Milano, pp. 3141-3164.

Varol F., Öksüz M. 2025, *Use of advanced measurement and reality technologies in cultural heritage sites from the perspective of technology and tourism*, in *Current Issues in Tourism*, 28(4), pp. 585-603.

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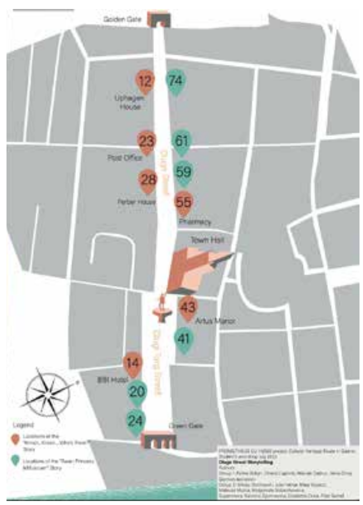
Walking the Royal Route in Gdańsk

Walking is an elementary form of experiencing the city landscape. Walking/ Passing along the most recognizable pedestrian route of the Gdańsk - the Royal Route, it is possible to immerse in the real urban activity: to know, to feel , to imagine, the past, the present and the future of the city[1]. The axis between the Foregate Complex and the Green Gate is one of the main urban features of Gdańsk. The gate buildings clearly describe and mark the end and beginning of the main axis. They stimulate the main stream of public movement leading people to this main axis of the reconstructed urban layout, encouraging them to discover the city. The Long Street together with Long Market are filled with structures that play a vital role in illuminating the city's rich past, starting from the Middle Ages. The road extends for approximately 530 meters and represents the main artery of the city center, connecting different fortified elements from west (High Gate, Prison Tower, Torture House, and Golden Gate) to east (Green Gate)[2]. The goal of this research was to create a virtual tour for that significant place of Gdańsk based on the point cloud acquired due to the survey and on 360° camera pictures[3]. The point clouds can be used for different purposes, from documentation for the preservation of the historical memory of the city, to their use to generate reality-based models, and therefore with verifiable degrees of reliability based on predefined parameters, to generate digital models both for the valorisation of the heritage and for the study and analysis for in-depth architectural (construction technologies, materials, decorative elements and urban censuses) and structural monitoring of the façades[4]. The outputs of the survey have been planned for two different purposes; the first is the acquisition of reliable metric data for the documentation of the city portion, which can be used for reality-based modelling and architectural analysis; the second is the creation of thematic virtual routes, or virtual tours, in which the information collected during the census and documentation phases is inserted[5].

Side page, Fig. 01
Long Street
The view of Long Street from the Prison Tower. In the foreground: the Golden Gate in the west part of the street.

Fig. 02
Interactive maps of Long Street
Source: Activity conducted in the Internation Summer School (July 2023)



[1] Borucka, Gatremann (2016), *Route 1- Rechtstadt (Główne Miasto) - Koenigsweg (Trakt Krówlewski)*, pp.46-63; Solnit (2001), *Wanderlust: A history of walking*.
[2] Zagajewski, Johnston(1997), *Długa Street*, pp. 288.
[3] Argyriou, Economou, Bouki (2020), *Design methodology for 360 immersive video applications: the case study of a cultural heritage virtual tour*, pp. 843-859; De Fino, Ceppi, Fatiguso (2020), *Virtual tours and informational models for improving territorial attractiveness and the smart management of architectural heritage: The 3d-imp-act project*, pp. 473-480; Borucka, Parrinello (2023), *VREA project-a digital curator for architecture and digital perspectives for heritage management and enhancement*, pp. 289-296.
[4] Parrinello, Picchio (2023), *Digital Strategies to Enhance Cultural Heritage Routes: From Integrated Survey to Digital Twins of Different European Architectural Scenarios*; Doria, Galasso, Morandotti (2022), *Heritage documentation and management processes: Castiglioni Chapel in Pavia*, p. 9; Lowenthal (2000), *Stewarding the Past in a Perplexing Present*.
[5] Kersten, Lindstaedt (2012) *Virtual architectural 3D model of the imperial cathedral (Kaiserdom) of Königslutter, Germany through terrestrial laser scanning*, pp. 201-210.

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Fig. 03
Gdansk after the WWII.
Source: Architecture Library of Gdansk Politechnika.

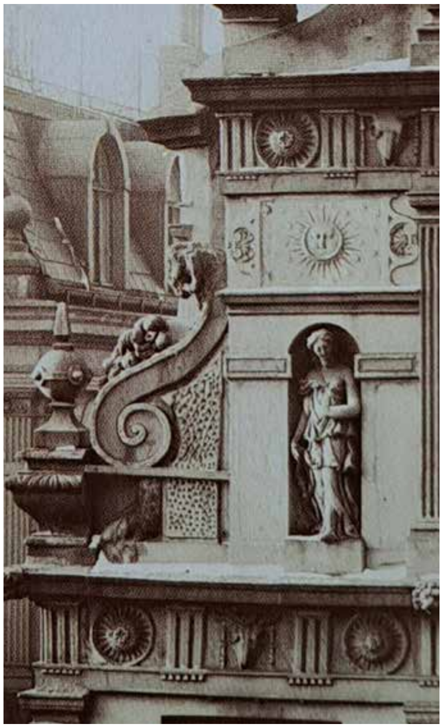
Fig. 04
A View of Market Street, 2023.

Next page, Fig. 05
Market Street
A comparison of the evolution of the historical facades in Market Square. On the right: actual state of conservation, 2023.

This core public space of the city opens many possibilities for scenarios of virtual tour allowing for discovering this place. In this chapter, a scenario called "More than urban tourism" will be presented. To execute the virtual tour, an environment acquired through survey and post-production is essential, along with a defined scenario and prepared content. The upcoming sections will detail each research stage leading to the result.

The environment for the virtual tour data acquisition and post-production

The first phase of documentation of Long Street and Long Market was carried out using TLS instrumentation for high metric and geometric reliability. The TLS survey was conducted using the Leica Geosystem RTC360 instrument, with a range of up to 130 metres and the ability to collect data at a speed of 2 million points per second, with high-quality colour scans in less than 3 minutes. One of the main features of the RTC360 is the ability to pre-register scans in near real-time in the field, using a tablet or a mobile phone directly connected to the instrument's wifi. This means that users can instantly view and verify the data acquired in the field, saving time, and ensuring accurate results as it prevents unforeseen gaps in the point cloud based on instrument positioning. In addition to the point cloud with HDR colorimetric data, a photographic acquisition campaign was carried out for both general documentation and photogrammetry using the SfM technique. The photographs were taken using standard cameras and 360° lenses - Insta360 X3 - to also capture images suitable for use in immersive virtual reality systems for spatial viewing. Focusing on the need of reality-based modelling and further architectural analysis, the outputs obtained are metrically reliable and colour-coded point clouds representing the entire extent of the street and square, including the fortified gate systems that enclose the street system.



More than urban tourism: the idea of the scenario and methods for collecting the information content

The goal of the "More than urban tourism" scenario allows one to understand the history of the place and get familiar with the most significant buildings at The Long Street and Long Market. Scenarios can be built based on general information on the whole area, included in general scenario (g.s) and on detailed information, attached to selected building or place, constituting detailed scenarios (d.s.). First general scenario considers the level of the extent of destruction during World War II (g.s.1), to point the most important remains from a historic point of view and to stress the scale of war damage. Moreover, another general scenario considers the architectural style of the original buildings at The Long Street and Long Market (g.s.2). Different functions of buildings, considering both historical and contemporary contexts, are also considered. (g.s.3).

In turn, the idea of detailed scenarios is to offer detailed information about selected buildings. First proposed detailed scenario concerns the time of the original building's construction and the most significant changes before World War II (d.s.1), second - names of architects and inhabitants (d.s.2), and third important architectural details (d.s.3). To obtain the data (content) for general and detailed scenarios the literature studies were carried out [6], archives were examined, old photos were analysed[7], so as drawings (by Norman Schulz (1854-1868), Dickmanm (1617)), paintings (Isaak van den Block - "Apotheosis of Gdańsk"(1608), Anton Möller - "Rent penny"(1601)), and literary works ("Maiden in

[6] Barylewska-Szymańska, Towarzystwo (2021), *Towarzystwo „Dom Uphagena". Zarys historii społecznej aktywności*. *Glińska tłum*, pp. 243-280; Wierzbicka (2019); Grabowski (2016), *Gdańskie Miniatury, Style architektoniczne w Gdańsku*; Hirsch (1997), *Gdańsk. Dwa oblicza miasta*; Kapuściński, Piwek (2005), *Construction work on the vaults of the Green Gate in Gdańsk*; Piwek (2004), *Budowa i przebudowy Zielonej Bramy w Gdańsk* Zarębska (1998), *Przebudowa Gdańska w jego Złotym Wieku*; https://gdansk.gedanopedia.pl/gdansk, https://muzeumgdansk.pl/oddzialy-muzeum/, https://mapy.zabytek.gov.pl/nid/

[7] https://fotopolska.eu/

Fig. 06
Long Street view and details of the reconstructed fronts after the WWII. The building on the right in closed to the Golden Gate (west part of the street).

Fig. 07
Survey activities of Long Street and Market Square conducted in February 2023.

the Window" by Deotyma (1891)). Finally, 12 buildings were selected for the further deeper analysis.

Content for different scenarios: characteristics of cases

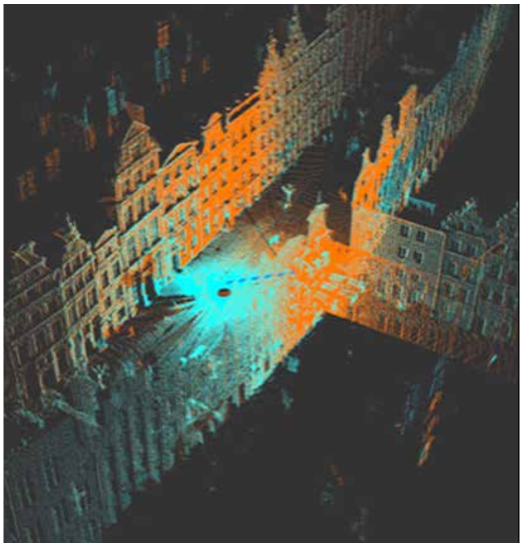
This paragraph and Table 1 point to crucial information about selected buildings[8]. Long Street Gate and Green Gate serve as pivotal elements in Gdańsk's historic landscape, extending from the Royal Route. The Long Street Gate, and Green Gate, underwent a renaissance transformation, both replacing earlier gothic gates - first in 1612–1614 and second in 1564–1568. The Main Town Hall, a gothic-renaissance edifice, has housed authorities since 1327, undergoing several rebuilds, with a significant mannerist update in 1559. The Artus Manor, also rooted in the middle ages, was rebuilt in renaissance style in 1616–1617, and served various functions, from cultural events to merchant activities and court hearings. The House of Assessors, originating in the late 15th Century, became a courthouse in 1709, with a significant transformation in 1710–1712. The Post Office, initially representing classicist concepts from 1831–1835, altered in the 1880s, was transformed by Langhorf in 1899, and in this form, it survived the war. Nowadays Long Street Gate is the headquarters of the Association of Polish Architects, Post Office still offers the same function and other discussed buildings host museums. At Long Street, aside from utility buildings, housed tenant houses, including the reconstructed Uphagen's

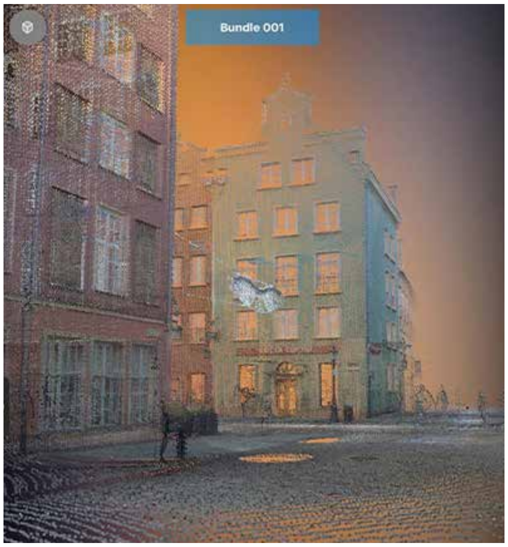
[8] Barylewska, Szymańska (2021), *Towarzystwo „Dom Uphagena". Zarys historii społecznej aktywności, in Rocznik Gdański*, pp. 243-280; Glińska (2019), *Guidebook, Gdańsk, The old town historic complex*; Grabowski (2016), *Gdańskie Miniatury, Style architektoniczne w Gdańsku*; Hirsch (1997), *Gdańsk. Dwa oblicza miasta*; Kapuściński, Piwek (2005), *Construction work on the vaults of the Green Gate in Gdańsk*; Piwek (2004), *Budowa i przebudowy Zielonej Bramy w Gdańsku*; Zarębska (1998), *Przebudowa Gdańska w jego Złotym Wieku, Oficyna Wydawnicza Politechniki Warszawskiej*; https://gdansk.gedanopedia.pl/gdansk, https://muzeumgdansk.pl/oddzialy-muzeum/, https://mapy.zabytek.gov.pl/nid/, https://fotopolska.eu/.

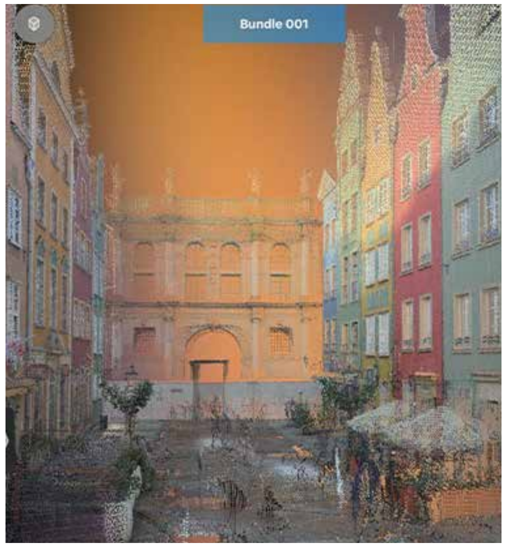
no.	English name of buildings	Address	Selected general scenarios (g.s)			Selected detail scenarios (d.s)
			g.s.1 SoD	g.s.2 Front Style	g.s.3 BF	d.s.1/d.s.2 Peolple *(inhabitants/architects - date of works)*
1	Long Street Gate (Golden Gate)	1 Long Street	P	renaissance-mannerist	BF	**Abraham van den Block** -1612–1614
2	Uphagen's House	12 Long Street	nC	classicizing baroque	U/U	**Johann Uphagen,** J. B. Dreyer - 1775
3	Post Office	23 Long Street	S	references to northern mannerism	H, U/U	**Karl August Langhorf** -1899; **Henrich Wilhelm Zernecke** - 1880s; **Julius Albrecht Licht** - 1831-1835
4	Ferber House	28 Long Street	nC	renaissance, northern mannerism	U/U	**Eberhard Ferber,** anonymous architect
5	Freder House	29 Long Street	nC	renaissance, northern mannerism	H/Hs	**Konstanty Freder,** Abraham van den Blocke - 1620
6	Lion Castle House	35 Long Street	nC	renaissance	H/Hs	**Heinrich Schwartzwald,** Hans Kramer -1569
7	Connerts' burgher house	45 Long Street	P	renaissance	H, U/Hs	**Hans Connert, Schumanns family,** anonymous architect
8	Main Town Hall	46 Long Street	P	renaissance	H, Hs/Hs	**Henryk Ungerdin** -1378-1382; **Hans Kreczmar** - 1454 -1457; **Dirk Daniels** -1559–1560; **Anton van Obberghen** -1593-1596
9	Artus Manor	43 Long Market	P	gothic-renaissance	U/U	**Abraham van den Blocke** - 1616–1617
10	The New House of Assessors	43 Long Market	nC	gothic-renaissance	U/U	**Niderhof family**
11	Steffens' burgher house (Golden burgher house)	41-42 Long Market	nC	renaissance	H,U/Hs	**Otto Steffens, Hans Speymann, Abraham van den Blocke** - 1609-1617
12	Green Gate	24 Long Market	P	renaissance, northern mannerism	U/U	**anonymous architect, Hans Kramer** 1564–1568

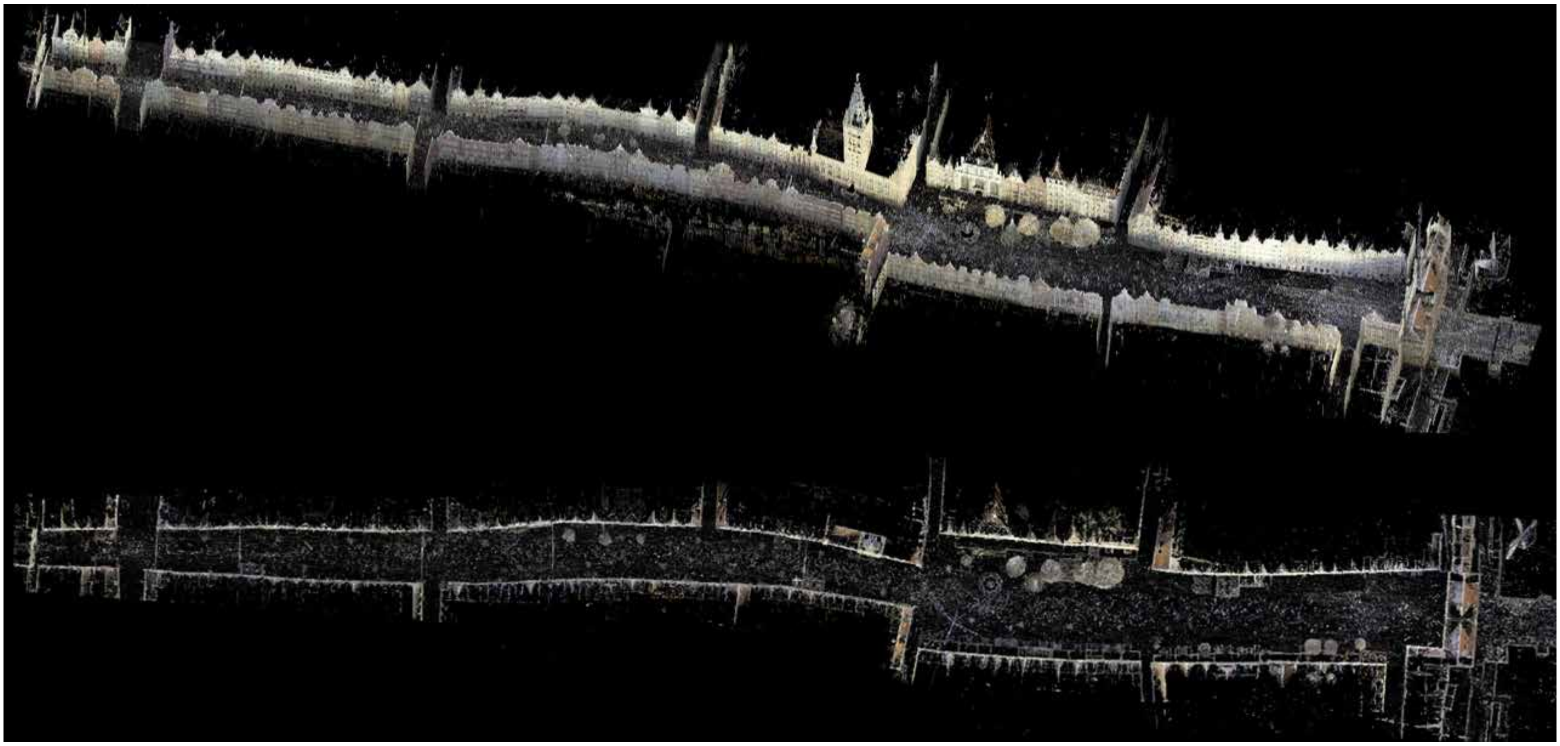
Table 1: List and characteristics of buildings selected for the scenario "More than urban tourism" including general and detailed scenarios. Legend: BF - Building's Function (in the past / today) U - utility building, H- housing, Hs - housing with services in the ground floor; SoD - Stage of Destruction in 1945: P - partly, nC - nearly completely, S - survived.

Fig. 08
360° image of Market Square
The spherical images were used as the basis for developing the interactive virtual tour.




Bundle 001


Bundle 001



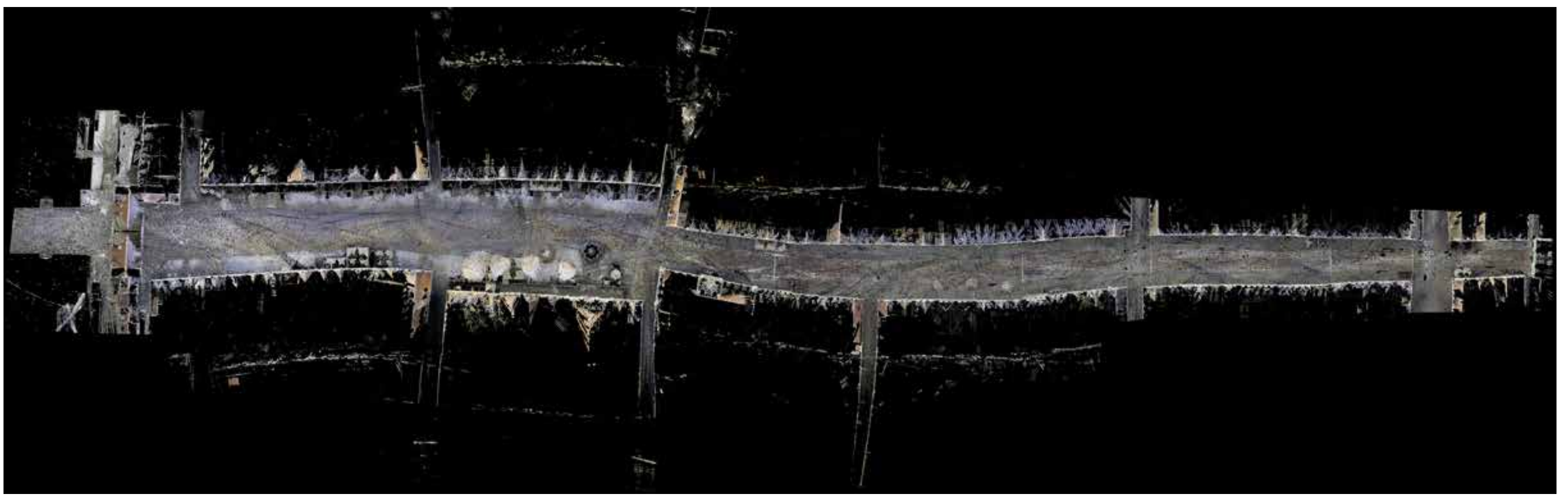


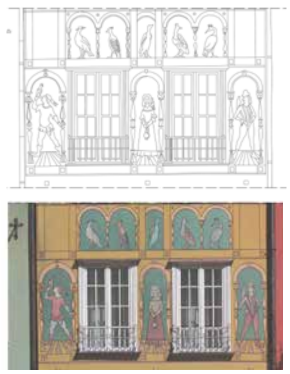
Fig. 09
Urban fronts of Long Street (south side)
On the right, the largest building is the Post Office.

Fig. 10
View of point cloud database
The long street from the Neptun fountain.

House showcasing the layout from 1775. Other notable tenant houses, Ferber House, was the manierist house from 1560. Freder House gained a renaissance image in 1620. The Lion Castle House was originally constructed in 1569 and hosted many cultural luminaries. Connert' Burgher House, was constructed in around 1560. Steffens' burgher house (so called Golden burgher house) appeared in 1609-1617, on the commission of city mayor Hans Speymann. Uphagen's House currently serves as the Museum of Bourgeois Interiors, while other tenant houses fulfil housing and service functions on the ground floor.

Section A-A'

Detail 1



Detail 2

Results - the immersive virtual walking tour

The final product of this documentation and enhancement approach is the virtual tour, that was created using 360° photographs and panoramic images extracted from the laser scanner, imported in the correct exchange format into the 3D Vista Virtual Tour software, a software platform that allows users to create interactive 3D virtual tours viewable on both mobile devices and laptops, as well as with Oculus. In the field of general scenarios (g.s.1, g.s.2, g.s.3), the filter of colour of the environment of point cloud was proposed, integrated with legible legend and "general buttons" to switch the scenario. In case g.s.4, and all detailed scenarios, unlike the three previously mentioned cases, the "points of interest" for obtaining additional information were indicated. The content was proposed in the form of: 1. description, 2. photos, sketches and paintings – historic and contemporary ones and 3. audio and videos. It could also be developed with 4. avatars of important people. The platform also offers additional features such as interactive maps and the ability to obtain analysis on the created virtual tours. The graphical approach to "points of interest" could be determined by the chosen building's features in reference to specific scenarios (s.d.1, s.d.2, s.d.3).

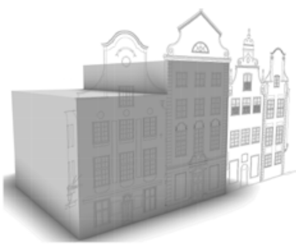


Fig. 11
The modelling phase of the virtual scenario of Long Street
The models was reality-based thanks to the use of TLS survey and vectorial drawings.
Two screenshots of the virtual tour implemented by students during the Summer School in July 2023. The two different scenario are presented in the same itneractive map.

This enables intuitive navigation and selection of desired information. Detailed scenarios could be implemented in two ways: 1. through the user's spontaneous selection of "points of interest", driven by user preference, and 2. by highlighting predetermined points along a proposed path. In the "More than urban tourism" scenario, the first method was used, so as basic signs for "points of interest". Urban tours including virtual tours can be used to promote urban heritage by telling the story about significant places around the world and engaging in social activities and educating / enriching the wide public[9]. Due to conducted research: survey, post production, literature and iconography studies, preparation of the scenario and application of final elements into 3D Vista Virtual Tour software, it was possible to realise the virtual tour for Long Street and Long Market. By using photos, videos, models, and informative content collected during the documentation phase, it is possible to create a virtual visit of the physical spaces, allowing viewers to explore the spaces from different perspectives and interact with the added informational elements. Virtual tours offer potential to enhance cultural heritage in various ways, including important aspects such as global accessibility, information sharing to enrich the experience and allow visitors to learn, interactive engagement enabling visitors to explore places independently, and digital preservation of the heritage by accurately and detailed representing places digitally to preserve cultural heritage for future generations. Virtual tour can be perceived using simple apps, but it could be also adjusted for interactive environments such as Immersive 3D Visualisation Lab at Gdańsk Tech, allowing for virtual tours in 1:1 scale[10], which is planned for further research.

References

Argyriou L., Economou D., Bouki V. 2020, *Design methodology for 360 immersive video applications: the case study of a cultural heritage virtual tour*, in Personal and Ubiquitous Computing, 24, pp. 843-859.

Barylewska-Szymańska E. 2021, *Towarzystwo „Dom Uphagena". Zarys historii społecznej aktywności*, in *Rocznik Gdański*, 81, pp. 243-280.

Borucka J., Gatremann H. 2016, *Route 1- Rechtstadt (Główne Miasto) - Koenigsweg (Trakt Królewski), in Architekturfuerer Danzig Gdańsk Sopot Gdynia*, Dom publisher, Berlin, pp. 46-63.

Borucka J., Parrinello S. 2023, *VREA project-a digital curator for architecture and digital perspectives for heritage management and enhancement*, in International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS, 48(M-2-2023), pp. 289-296.

[9] Borucka, Parrinello, Picchio (2023), *VREA project-a digital curator for architecture and digital perspectives for heritage management and enhancement*, pp. 129-134; Borucka, Wróblewska (2019), *'The Urban Walk Architecture Talk'— Bridging Socially Engaged Art, Urban Processes and Cultural Development*, pp.113-133.
[10] Lebiedź , Mazikowski (2021), *Multiuser stereoscopic projection techniques for cave-type virtual reality systems*; Życzkowska, K., Szakajło , *Architectural education and digital tools: the challenges and opportunities*, pp.535-543.

Borucka J., Parrinello S., Picchio F. 2023, *Digital data and tools in transformative education to preserve architecture and cultural heritage: case studies from Italy and Poland*, in *Global Journal of Engineering Education*, 25(2), pp. 129-134.

Borucka J., Wróblewska M. 2019, *The Urban Walk Architecture Talk - Bridging Socially Engaged Art*, in *Urban Processes and Cultural Development*, pp. 113-133.

Zagajewski A., Johnston B. 1997, *Długa Street*, in TriQuarterly, 100, pp. 288.

De Fino M., Ceppi C., Fatiguso F. 2020, *Virtual tours and informational models for improving territorial attractiveness and the smart management of architectural heritage: The 3d-imp-act project*, in *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 44, pp. 473-480.

Doria E., Galasso F., Morandotti M. 2022, *Heritage documentation and management processes: Castiglioni Chapel in Pavia*, in *Acta IMEKO*, 11(1), pp. 9.

Glińska E. 2019, *Guidebook, Gdańsk, The old town historic complex*, Studio Plan, Wrocław.

Grabowski K. 2016, *Gdańskie Miniatury, Style architektoniczne w Gdańsku, Instytut Miejskiej Kultury*, Gdańsk.

Hirsch R. 1997, *Gdańsk. Dwa oblicza miasta*, Holm, Gdańsk.

Kapuściński A., Piwek A. 2005, *Construction work on the vaults of the Green Gate in Gdańsk*.

Kersten T. P., Lindstaedt M. 2012, *Virtual architectural 3D model of the imperial cathedral (Kaiserdom) of Königslutter, Germany through terrestrial laser scanning*, in *Progress in Cultural Heritage Preservation: 4th International Conference, EuroMed 2012*, Limassol, Cyprus, October 29-November 3, 2012. Proceedings 4, Springer Berlin Heidelberg, pp. 201-210.

Lebiedź J., Mazikowski A. 2021, *Multiuser stereoscopic projection techniques for cave-type virtual reality systems*, in *IEEE Transactions on Human-Machine Systems*, 51(5), pp. 535-543.

Lowenthal D. 2000, *Stewarding the Past in a Perplexing Present*, in Avrami E. C., Mason R., De la Torre M. (eds) *Values and Heritage Conservation: Research Report*, Getty Conservation Institute, Los Angeles.

Parrinello S., Picchio F. 2023, *Digital Strategies to Enhance Cultural Heritage Routes: From Integrated Survey to Digital Twins of Different European Architectural Scenarios*, in *Drones*, 7(9), 576.

Piwek A. 2004, *Budowa i przebudowy Zielonej Bramy w Gdańsku*.

Solnit R. 2001, *Wanderlust: A history of walking*, Penguin.

Zarębska T. 1998, *Przebudowa Gdańska w jego Złotym Wieku, Oficyna Wydawnicza Politechniki Warszawskiej*, Warszawa.

Życzkowska K., Szakajło K. 2019, *Architectural education and digital tools: the challenges and opportunities*, in *World Trans. on Engng. and Technol. Educ*, 17(3), pp. 326-331.

Fig. 12
Tools used to create and to populate the virtual tour of Long Street and Market Square
The data were collected during the secodments in Gdansk and during the Summer School in July 2023.

The modern defense of the city

THE EASTERN AND SOUTHERN LINE OF GDAŃSK FORTIFICATIONS AND BASTIONS LANDSCAPE

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Side page, Fig. 01
Map showing fortifications in 1711 Gdańsk Fortification 2017.
Bird View photo by W. Stępie. source: https://www.gdanskstrefa.com/adam-koperkiewicz-gdanscy-tworcy-europejskiej-nauki/obraz1/

The new fortifications as the most important investements

The end of the 15th Century was a relatively calm period in this part of Europe. Gdańsk experienced several military conflicts but they did not cause an serious damage to the city. The situation changed at the turn of the 16th Century. A conflict was growing between Poland and Sweden, caused by a dynastic quarrel and a struggle for domination in the Baltic Sea area.

Faced with danger, the City Council decided to build modern defensive walls in the south, east and north where so far only primitive medieval bulwarks had existed. The new fortifications were one of the most important investments in the city's history. They set the city limits for hundreds of years and even today they are elements of the skeleton of Gdańsk's layout. Executing such a serious task required a lot of study. About 1600 Italian engineers from Piedmont, Captain Hieronimus Ferrero and Giovanni Battista from Vercelli prepared an expert opinion defining the assumptions for the expansion of the Gdańsk fortifications.

The new fortifications were one of the most important investments in the city's history. They defined the city's boundaries for several hundred years and are still the basic element of the spatial layout of Gdańsk's historic downtown.

Carrying out such a major task required many studies. In 1600, two engineers from Piedmont, Captain Jerome Ferrero and John Baptist of Vercelli, made preliminary designs for the southern line of fortifications. However, construction according to the concepts of the Italian engineers did not proceed, so at least provisional protection had to be made. In 1619 Wilhelm Jans Benning and Adrian Olbrants, both from Alkmaar in northern Holland, built the Stone Sluice, bringing the waters of the *Motlawa* River into the city. In 1607, a new section of the western embankment was built, running south of it and ending with the St. Gertrude Bastion. He marked a new, southwestern corner of the city fortifications.

The Stone Sluice

The construction was not carried out, though, and so at least a makeshift protection had to be provided. In 1619-1623, Willem Jansz Benning and Adrian Olbrants, both from Alkmaar in the northern Netherlands, built *Kamienna Śluza* (the Stone Sluice). The installation protected the town from floods, provided a proper water level in the mill canal yet foremost constituted an utterly effective defensive device.

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Fig. 02
Plan of the City of Danzig, 1809
Source: Pomeranian Map Archive, Polish Academy of Sciences (PAN), collection of Mr Ireneusz Krzywicki.

In an emergency, the city defenders closed the sluice to flood the areas eastward of the city. This prevented enemy armies from even approaching the town from this direction. Such flooding defended Gdańsk for the last time in 1945, which did not leave the Lower Town unaffected.

The bastions

However, the stone sluice alone was not enough. Gdańsk authorities invited two more Dutch fortification engineers, Cornelius van den Bosch and Daniel van Buren, to design the fortifications. Jan (Hans) Strakowski, who was hired as city builder, also presented his concepts. As a result of this peculiar competition in 1621. The City Council decided to go with Cornelis van den Bosch's and Peter Jansson van Werdt design. The reasons for this choice are clear. Van den Bosch and Jansson proposed a fortification that was cheaper and covered a larger area. He used the then-modern Dutch fortification system, which consisted of erecting huge, very regular bastions raised from the ground and surrounded by wide irrigated moats, while almost completely abandoning expensive stone and brick walls. Most of the bastions were relatively low. Only in sensitive places, at the gates, were the bastions piled on top of each other, forming what looked like artificial hills. The embittered Strakowski, whose more conservative concept lost out, had to settle for a commission to design the gates in the new ramparts. After the project was completed, the City Council and the Third Ordinance, grouping

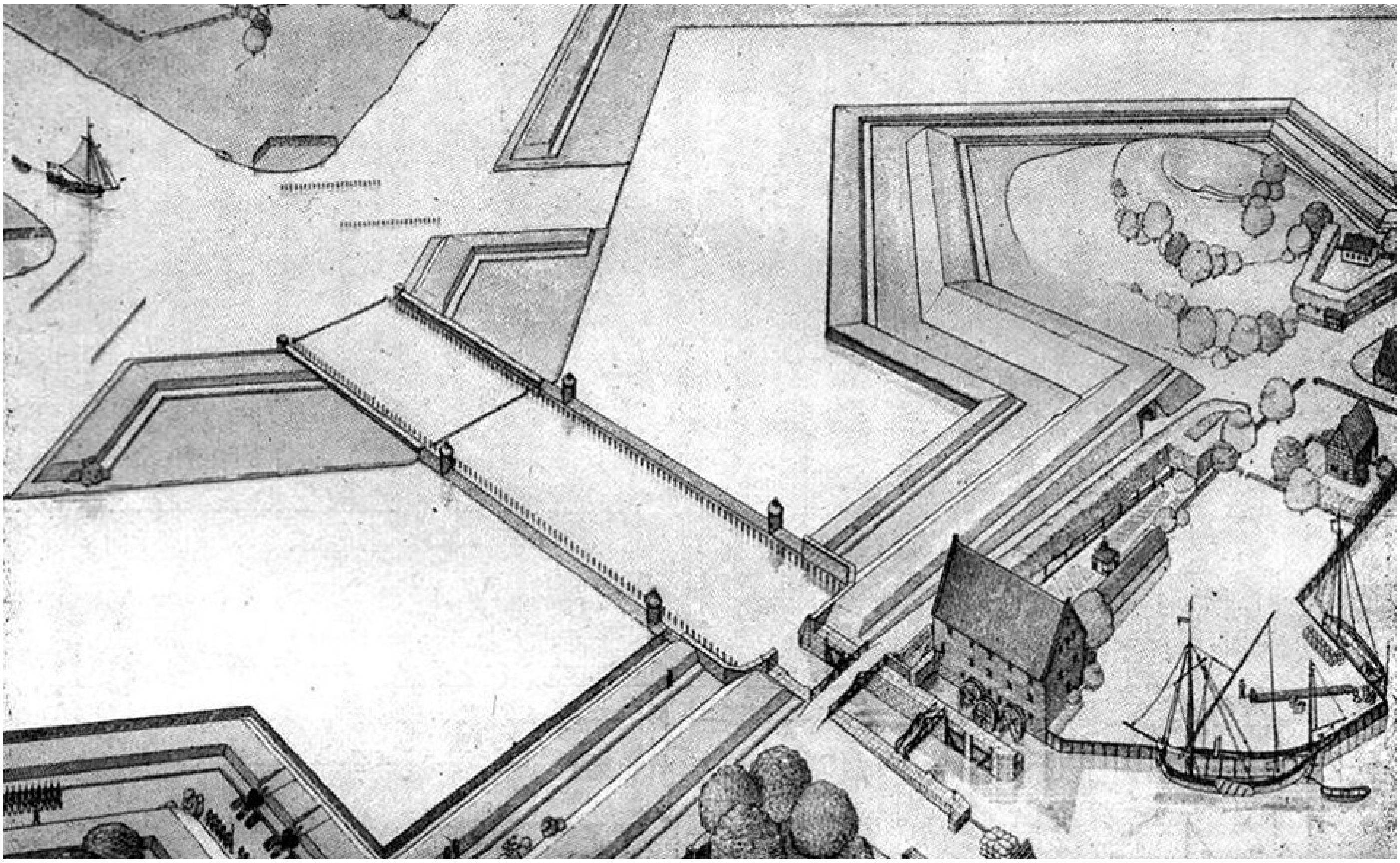

Fig. 03
The Stone Sluice, Witt's reconstruction drawing from the 1930s
Source: Kloeppel O. 1937, Das Stadtbild von Danzig in den drei Jahrhunderten seiner großen Geschichte. Die Baukunst im Deutschen Osten. Beiträge zu ihrer Gestaltungsentwicklung, Verlag A. W. Kafemann, Danzig.

representatives of the "middle class" of the time, held the usual quarrel over money. Work didn't start intensively until the second half of 1623, after the Swedish fleet appeared on the Bay of Danzig.

In 1623, the construction of the Stone Sluice was completed. Two bastions were built on both sides - Aurochs (*Auerochs Wohnung*, *Maidloch*) and Wolf. An embankment was also being built. In the same year, work was carried out in the area of Long Garden. These works initiated the construction of a new fortress circuit; it ran outside today's streets: *Grodza Kamienna*, *Reduta Wysko*k, *Reduta Dzik*, *Długa Grobla* and *Wałowa*. In 1625, construction began on the bastions of St. Jacob and further towards Long Garden, which the new circuit crossed in 1626. Probably in the years 1626-1627 the bastions of Fox (Fuchs), Lynx (Luchs) and *Motława* (Mottlau, later called the Bastion of Bucket Makers) were built. In 1627-28, the bastions of Bay Horse (*Braun Ross*), Unicorn (*Eichhorn*), Lion (*Löwe*) and Ox (Ochs) were built. At the same time as the construction of the bastions, the construction of a moat, an external rampart and an external moat was built. In 1626, the Lowland Gate (*Lege Tor*.) was built, and in 1628 the Gate of the Long Gardens (*Langgarten Tor*). In the years 1631-1632, the Rabbit Bastion (*Kaninchen*) was built. In 1633, the Garden Bastion (*Roggen*, *Herrn Garten*) was built, In the years 1633-1634 the Bear Bastion (Bär) was built and in the years 1633-1635 the Jump Bastion (*Aussprung*, *Pestilenz*). In 1635, the St. Jacob's Bastion (started in 1625) and the St. Jacob's Gate (*Jakobstor*) were completed in 1637, completing the Wilk bastion. In this way, the fortifications surrounded the entire historic urban complex of Gdańsk.

Fig. 04
The Southern fortifications of Gdańsk, 21st Century

The powerful bastions and the possibility of artificially causing a flood were so effective that none of the armies besieging Danzig ever decided to even attempt to capture Danzig from the east. The Swedes, Poles, Prussians, Russians or French always took their assaults from the direction of Wrzeszcz through the hills west of the city or from the north, from the Vistula mouth.

New fortifications and the lost of their importance

In 1852, the first railroad was brought to Gdańsk. At the time, van den Bosch's fortifications were still considered effective defensive devices. So the tracks leading to the city were equipped with a defensive railroad gate. After nearly three centuries, the Dutch bastions finally ceased to be effective defensive devices. The improvement of artillery made their existence meaningless. At the end of the 19th Century a decision was made to dismantle the fortifications. At the time, Gdańsk was far from the splendor of the "golden age" when the fortifications were built. Gdańsk was developing, but not on the same scale as other similar centers. In other major European cities that maintained their 17th Century fortifications until the 19th Century, they were most often dismantled at a rapid pace and in their place railroad stations, theaters, museums, universities, administrative edifices and parks were erected. Such magnificent architectural ensembles were built a Century ago, for example, in Vienna or in Hamburg and Szczecin, which were more similar to Gdańsk. In our country the liquidation of unnecessary bastions proceeded tardily. Some of them were dismantled only in the 1920s, during the era of the Free City of Gdańsk (*Freie Hanseatische Stadt Danzig*). The six bastions on the south side: St. Gertrude Bastion, Aurochs Bastion, Wolf Bastion, Jump Bastion, Bear Bastion and Rabbit Bastion were not dismantled because their place was not an attractive area for building.

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The new fortifications and the bastions landscape now

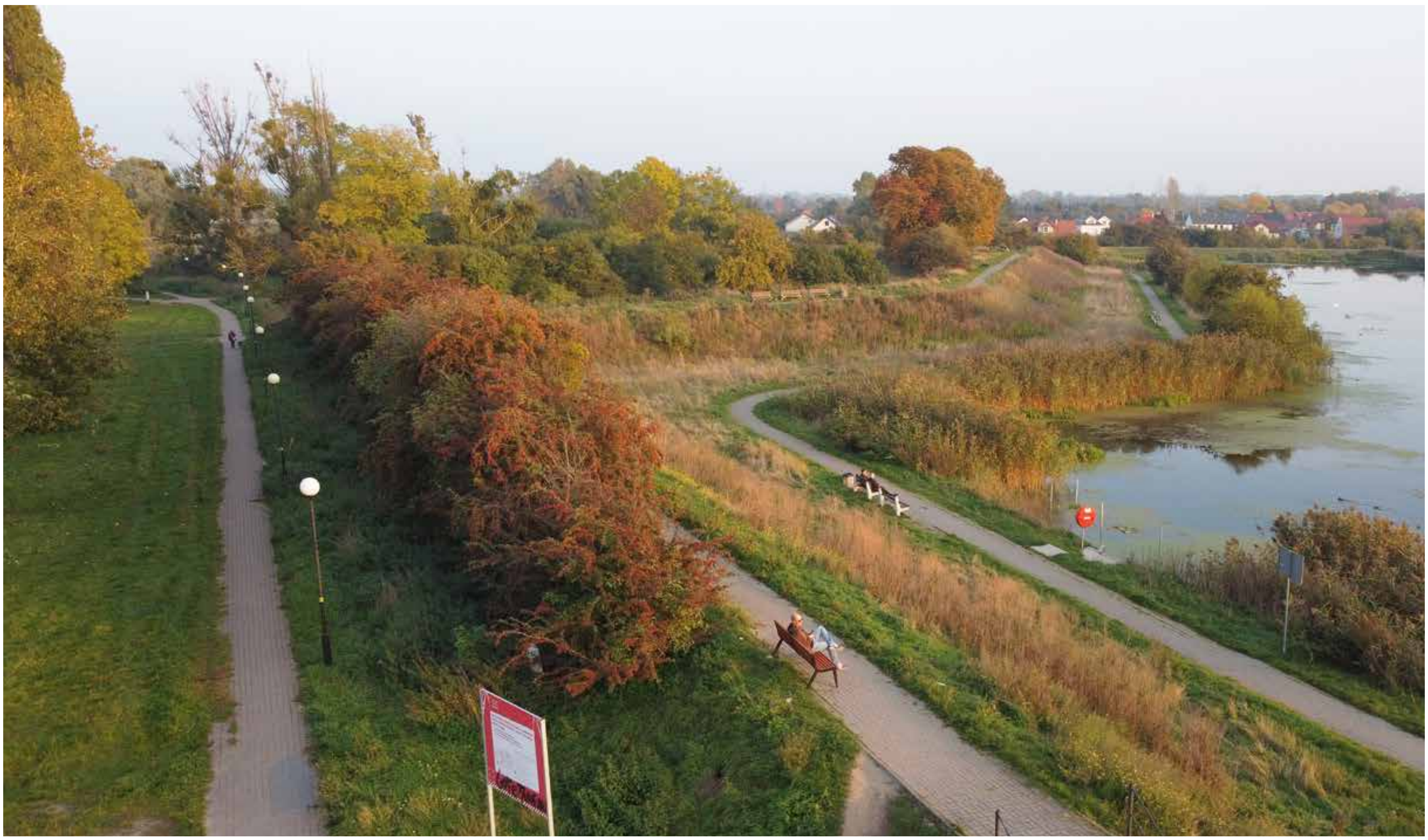
The investment backwardness of Gdańsk in the late 19th and early 20th centuries meant that Gdańsk have one of the few Dutch-type fortification complexes in Europe at the best of this type of defense equipment. The Stone Sluice has also been preserved, as well as other buildings associated with the southern string of fortifications like the mill, the Lowland Gate and the Small Armory.

Fig. 05,06,07
The Southern fortifications of Gdańsk, 21st Century
Remains of brick defensive structures and earthwork ramparts. Gate structures and surviving fragments of the fortifications.

These authentic monuments deserve attention and care. For several years, the condition of the moats and bastions has been improving as a result of ongoing work, but damage is also progressing. New construction is destroying the outer edge of the moats and the foregrounds of the fortifications. The spurs of the Stone Sluice are disappearing year by year. The railroad gate is under threat. Currently, at the beginning of the 21st Century, it is one of the most interesting examples of ancient engineering and fortification art in Europe, which should be protected and their potential used to prevent it from falling into ruin.

Today, the bastion complex is an open, green space. Similar cases can be found in many other European cities, where former fortifications have been transformed into public green and recreational areas. They often become important elements of the urban landscape, providing nature-based solutions for residents and increasing urban biodiversity[1]. In Gdańsk, the remaining southern fortifications are integrated into the Lower Town (Dolne Miasto) district, adjacent to the Main Town (*Główne Miasto*). After the Second World War, this area fell into disrepair and for many years struggled with many social and security problems. Over the last two decades, it has undergone a revitalization process, becoming a vibrant and attractive district of the city. The key element of the revitalisation was the fortifications and their transformation into a leisure and tourism complex serving both tourists and locals. Among other aspects, the bastions have become an experimental field for a number of cultural and artistic interventions, bringing back to life an attractive urban area with great potential and activating the nearby neighbourhood[2].

[1] Dos Santos (2017), *Reshaping the Urban Space in Portuguese Fortified Cities: New Green Spaces Resulting from the Rehabilitation of Urban Fortifications - From the Nineteenth Century until the End of the Estado Novo Dictatorial Regime (1974)*; Pardela et al.(2022), *How vegetation impacts preference, mystery and danger in fortifications and parks in urban areas.*
[2] Lorens (2001), *New Master Plan for the Young City in Gdańsk*; Tölle (2008), *Gdańsk*; Wołodźko (2017), *Recipe for success: how to revitalise Dolne Miasto (Lower Town) in Gdansk*; Barański, Chełstowska (2013), *Social partnership and local identity in the revitalization process of Dolne Miasto and Orunia in Gdańsk.*



References

Bukal G. 2006, *Fortyfikacje Gdańska 1454–1793*, in G. Bukal (ed) *Fortyfikacje Gdańska, Nadbałtyckie Centrum Kultury*, Gdańsk.

Bukal G. 2012, *Fortyfikacje Gdańska i ujścia Wisły 1454–1793*, Sopot.

Kloeppel O. 1937, *Das Stadtbild von Danzig in den drei Jahrhunderten seiner großen Geschichte. Die Baukunst im Deutschen Osten. Beiträge zu ihrer Gestaltungsentwicklung*, Verlag A. W. Kafemann, Danzig.

Kościelak S. 2019, *Gdańsk a Italia – u genezy kontaktów na przełomie epok – średniowiecznej i nowożytnej (Gdańsk and Italy - at the genesis of contacts at the turn of the eras - medieval and modern)* in Kaleciński M. (ed) Włochy w Gdańsku (Italy in Gdańsk), vol I, ed, Gdańsk 2019, pp. 155-175.

Stankiewicz J., Biskup K. 1998, *Fortyfikacje miejskie Gdańska od XVI do XIX wieku*, in Kostarczyk A. (ed) *Gdańsk pomnik historii*, vol 1,. *Regionalny Ośrodek Studiów i Ochrony Środowiska Kulturowego w Gdańsku*, Gdańsk, pp. 82-114.

Szczepański J. 2008, *The Lower Town and Its Bathhouse*, in Leszkowicz P. (ed) *Laznia - the Bathhouse. Architecture, Art and History*, CSW Łaźnia, Gdańsk.

Dos Santos J.M.R. 2017, *Reshaping the Urban Space in Portuguese Fortified Cities: New Green Spaces Resulting from the Rehabilitation of Urban Fortifications - From the Nineteenth Century until the End of the Estado Novo Dictatorial Regime (1974)*, in *J. Urban Hist.* 43, pp. 53-69.

Pardela Ł., Lis A., Zalewska K., Iwankowski P. 2022, *How vegetation impacts preference, mystery and danger in fortifications and parks in urban areas*, Landsc. Urban Plan. 228, pp. 0-2.

Lorens P. 2001, *New Master Plan for the Young City in Gdańsk*, in Lorens, P. (ed.), *Large Scale Urban Developments. Wydawnictwo Politechniki Gdańskiej*, Gdańsk.

Tölle A. 2008, *Gdańsk*, in *Cities*, 25, 1 pp. 07-119.

Wołodźko D. 2017, *Recipe for success: how to revitalise Dolne Miasto (Lower Town) in Gdansk* (in Polish: Przepis na sukces, czyli jak zrewitalizowano Dolne Miasto w Gdańsku.) MAZOWSZE Studia Regionalne, 20, pp.105-110.

https://bibliotekanauki.pl/articles/461392 / (accessed 1.3.24).

Barański M., Chełstowska M. 2013. *Social partnership and local identity in the revitalization process of Dolne Miasto and Orunia in Gdańsk* (in Polish: Partnerstwo społeczne i tożsamość lokalna w procesie rewitalizacji Dolnego Miasta i Orunii w Gdańsku.) Problemy Rozwoju Miast, 2, pp. 71-82. https://bibliotekanauki.pl/articles/447222 (accessed 1.3.24).

Hirsch R. 2010. *Gdańsk fortifications as a tourist attraction (*in Polish: *Fortyfikacje Gdańska jako atrakcja turystyczna).* in Przybylski, J. (ed.), Tourism and Sightseeing with the Sea in the Background: Studies and Materials from the History of Sightseeing in Gdańsk Pomerania (In Polish: Turystyka I Krajoznawstwo Z Morzem W Tle: Studia I Materiały Z Dziejów Krajoznawstwa Na Pomorzu Gdańskim). Pomorskie Publishing House at RPK PTTK in Gdańsk, Gdańsk, pp. 103-110.

Szczepański J. 2008, *The Lower Town and Its Bathhouse*, in Leszkowicz P. (ed) *Laznia - the Bathhouse. Architecture, Art and History*, CSW Łaźnia, Gdańsk.

Gdańsk Development Office 2017, *Basic directions of functional and spatial changes in the municipal revitalization program of the city of Gdansk: Dolne Miasto / Plac Wałowy / Stare Przedmieście area* (in Polish: *Podstawowe kierunki zmian funkcjonalno-przestrzennych gminnego programu rewi*. Gdańsk.)

Side page Fig. 08,09
The Southern fortifications of Gdańsk, 21st Century
Aerial and ground views of the former bastioned system, now integrated into the urban landscape.

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Side page, Fig. 01
Ravelin in Front of the Stone Sluice
Aerial view of the ravelin located in front of the Stone Sluice, an isolated fortification element surrounded by the river and the moat, and accessible only by water.

The cultural significance of the Gdańsk Bastions is rooted in its rich history, distinctive architecture, and natural features, forming a heritage of significant importance. The connection to the city of Gdańsk is evident through key urban entities like the river course, moat, embankments and architectural elements. However, neglect in recent history has led to decay and abandonment, compromising the structural stability[1]. Addressing this, specific documentation actions are essential to fill the gap in understanding the monument's cultural significance[2]. As mentioned in 2.3, the creation of a 3D database is crucial not just for representation but also for preserving a comprehensive archive of architectural elements and contextual landscape. The use of terrestrial and aerial survey methods optimizes data collection, with terrestrial laser scanning capturing details and mobile scanning covering large areas quickly. UAVs contribute to imaging, especially in inaccessible areas, though with accuracy limitations. Integrating data from various sources is vital for a comprehensive representation, requiring careful consideration of data coherence and potential discrepancies.

In light of these considerations, it is crucial to establish a digital documentation methodology that incorporates various tools[3]. The choice of tools should be based on criteria such as the required level of detail for object representation, the relationship between instrumental acquisition time and the surveyed area, and the existing risk and access conditions[4]. The categorization of survey instruments in the study of the Gdańsk Bastions was carried out through the analysis of geometries related to the natural and architectural elements that characterize the fortified system. It was imperative to ensure the readability of these elements within the metadata of the overall point cloud[5] and to ensure an appropriate level of documentation for the object under consideration, while also considering the type of output required for the subsequent stages of study and analysis[6].

[1] Szczepański (2010), *Sightseeing in Gdańsk: the southern line of Gdańsk fortifications (Zwiedzanie Gdańska: południowy ciąg fortyfikacji Gdańska.*
[2] Letellier et al. (2015), *Recording, documentation and information management for the conservation of heritage places.*
[3] Masciotta et al. (2021), *A digital-based integrated methodology for the preventive conservation of cultural heritage: the experience of HeritageCare project.*
[4] Bertocci, Parrinello (2015), *Digital survey and documentation of the archaeological and architectural sites, UNESCO World Heritage List.*
[5] Thomson (2016), *From point cloud to building information model: Capturing and processing survey data towards automation for high quality 3D models to aid a BIM process.*
[6] Parrinello et al. (2017), *The drawn landscape in 3D databases: the management of complexity and representation in the historical city.*

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Fig. 02
Typological Elements of the Fortified Landscape
Images of the southern bastions highlighting the main architectural and natural features of the fortified system, such as bastions, moats, embankments, and counterscarp structures.

Strategic approaches to surveying Bastions landscape

Within the context of the Gdańsk southern Bastions survey, several characteristics emerged (Fig.1) that required a rigorous methodological approach and careful planning. This landscape system is characterized by a combination of complex and risky accesses and the extent of the area introduces potentially influential variation on the accuracy of the survey, underlining the importance of establishing an effective metric control system. The river and moat system pose an additional challenge, especially in terms of connections and linkages, as well as the embankments and the elevation morphology of the earthworks that represent an additional critical point, being characterized by difficult access and areas of dense vegetation. The variation in heights and visibility within the fortified system raises questions about the accurate detection of the different levels of eathworks. In addition, the presence of architectural and engineering elements distributed throughout the system requires detailed documentation: the need to capture more in-depth metric information about such elements highlights the importance of a survey methodology that can accurately capture morphometric information to perform analysis of the state of degradation and structure stability.

Considering these issues, the need to optimize field work, performing fast survey operations while maintaining a high quality dataset, required planning and organizing documentation activities based on the types of the system to be surveyed and the most suitable instrumentation for the object[7]. It was then decided to divide the survey actions into five main documentation activities, carried out by the researchers involved in the project.

The first activity concerned the documentation of fortified earthworks through the use of TLS instrumentation. The use of a Leica RTC360 made it possible to structure a metrically reliable basis upon which to set up the following documentation activities. Taking into account the extent of the areas in focus[8]

[7] Apollonio et al. (2010), *Una pipeline per l'acquisizione di dati in 3D.*
[8] The bastions Gertrude, Aurochs, Wolf, and curtain links, as well as the counterguard systems.

and the lack of visible masonry structures[9] as well as visual obstructions, the laser parameters were set to optimize the scanning timing[10]. This allowed for a rather large number of scans[11] going to cover a particularly large area while still maintaining a quality appropriate to the object. By planning the scans through eidotypes, the locations were set up in such a way[12] as to reduce the possibility of error.

The second activity focused on documenting the surrounding environments and inter-area relationships through the use of wide-coverage MLS instrumentation. KAARTA Stencil 2 was used in order to cover a large urban area and the one of the west bastions[13] as it presents a range of about 80 meters, about 400,000 points per second, allowing to cover it in a limited timeframe[14]. The chosen instrument was appropriate not only because of the extent of the area (which was covered with a total of 7 scans in 2 hours time), but especially because of the vegetation (compared to the ramparts to the west, there are more trees and bushes in the east) as it represents one of the most suitable SLAM instruments in plant mapping[15].

The third activity focused on analyzing the architectural and engineering elements spread around the area using a combination of short-range photogrammetry (conducted with a Canon EOS 2000D), short-range MLS acquisitions (Leica BLK2GO), and TLS instrumentation.

Fig. 03
Natural Landscape and Architectural Features of the Stone Sluice Area
The image shows the integration between the natural system of the southern bastions—embankments, moat, and vegetation—and the architectural elements related to the Stone Sluice, visible in the upper part of the scene.

Fig. 04
Ravelin with Bartizan
View of the ravelin structure featuring a masonry bartizan used for sentry duty, located in front of the Stone Sluice and enclosed by the surrounding moat system.

[9] Because of the vegetation it is possible to observe the masonry walls only from the river and the moat.
[10] In order to optimize the settings, the laser was set up decreasing the density of the points and increasing the coverage distance.
[11] For all the areas a total of 324 scans were performed.
[12] On the bastions, downward spiral paths were made maintaining the field of view between the different terrain levels; for the curtain links and counterguards, on the other hand, a triangular scanning grid was opted for, trying to control the error by densifying the number of scans in the connections areas (the outer area of the Gertrude bastion, the Lowland gate link, and the bridge over the Wyskok bastion).
[13] We're referring to the urban area next to Stone sluice, as well as Wyskok, Bear and Krolik Bastions and their counterscarp on the opposite side of the moat.
[14] It should be emphasized that the field of view of the instrumental shooting angle is limited. It imposes an angular shooting limit (360° horizontal FOV 30°(from +15° to -15°) vertical FOV) with metric reliability (Accuracy ±30mm ±10mm post-processed).
[15] Dell'Amico 2023, *The walled city of Verona. Integrated survey systems for the enhancement and promotion of Verona's city walls.*

Fig. 05
View from the *Żubr* Bastion toward the Stone Sluice and Ravelin
Photograph taken from the ŕubr Bastion showing the sluice system and the ravelin in the foreground, with the Wilk Bastion visible in the background.

Fig. 06
Aerial View of the Lowland Gate (*Brama Nizinna*)
Drone photograph capturing the architectural structure of the Lowland Gate, an important access point within the fortified system of Gdańsk.

Each architectural element in the area exhibited its unique morphological features, diverse preservation states, as well as distinct access points and risks for the operator/instrument. For this reason, for each element, only the most appropriate instrument was chosen. The Lowland Gate was surveyed only through TLS instrumentation, going to increase the number of scans, as well as the density of scan points. Similarly, the remains of the railroad present alongside the Aurochs Bastion, but the state of degradation of the structures highlighted the need for a detailed survey through close-range photogrammetry. The Stone Sluice, due to the morphological complexity of the building, was surveyed through the different instrumentations, also considering the degree of risk to the operator and the instrument. Rooftop and hard-to-access areas were documented using UAV devices (DJI Phantom 4 RTK and DJI Mavic Mini 2). The fourth activity then involved the use of drones for the overall survey of the area[16]. In particular, some isolated parts[17], or those with dense vegetation[18] that precluded the operator's movement, as well as areas that were difficult to access due to the presence of the river[19]. Considering the specific performance of the device and its minimum flight altitude, due to the presence of obstacles such as trees, overhead cables and potential interference with flight due to birdlife, the planned flight altitude was 30 meters above the ground. The area of study was divided into 6 sub-areas, with a minimum overlap of 10% between each pair.

The width of each area was also conditioned by the battery life of the UAV. With the goal of accomplishing the entire survey in a small time frame[20] every portion was captured using the energy of a single battery ensuring to complete each survey in a single session[21]. Since the survey data, heterogeneous in terms of format and acquisition mode, had to be integrated to constitute a single database, a major problem

[16] Focusing on the Gertrude, Aurochs, and Wolf bastions.
[17] We're referring to the ravelin in front of the Stone Sluice, not accessible by land but only by water from the river.
[18] In particular, the counterguard area in front of the ravelin, where the second level of moat is still present.
[19] As already mentioned, for example, the masonry fronts of the bastions.
[20] A total of 1 day, including technical battery charging time
[21] With a dataset of nearly 230 images each.

Fig. 07
TLS Point Cloud of the Eastern Fortification Sector
Terrestrial laser scanning data covering the eastern portion of the fortified system, including the Wilk Bastion and part of the Wyskok Bastion, connected through acquisitions along the moat enabling documentation of the counterscarp beyond the ditch.

Fig. 08
GNSS Rover Survey Operations
Field use of a GNSS rover for the acquisition of georeferenced control points, essential for aligning and integrating datasets from different survey methods.

concerned the definition and assignment of a common reference system (the coordination of internal/individual systems and measurement ones)[22].

The solution to this problem was to use georeferenced control points (GCPs) during all the survey activities. These points, consisting of both morphological points and black-and-white targets, were surveyed with the different instruments, ensuring an overlap of the different surveyed areas and allowing the development of a basis for connecting datasets from different sources. In total, a number of 24 points were also surveyed with a GNSS rover (Fig. 6), allowing georeferencing of the entire database, moving from a local to a global reference system.

Datasets registration and Model elaboration

The high complexity of the number of acquired elements and the different quality of the data collected during the survey of the rampart area brought about the need to define a methodological process for managing a complex database[23]. Taking into account the operational protocol followed during the survey, it was deemed appropriate to divide the dataset according to the object and technology used, following the survey activities carried out in the field in the data elaboration process. In this way it was possible to develop five main autonomous databases:

- earthworks and fortification levels of the ramparts to the west (TLS);
- surrounding environment and fortified system to the east (MLS);
- architectural/engineering elements (TLS/MLS and close-range photogrammetry);
- fortified system to the west (close-range photogrammetry);
- georeferenced points (GNSS);

For TLS and MLS registration of individual datasets, visual matching systems based on cloud-to-cloud

[22] Dell'Amico (2021), *Mobile laser scanner mapping system's for the efficiency of the survey and representation process*; Parrinello, Picchio 2017, *Databases and complexity. Remote use of the data in the virtual space of reliable 3D models*.
[23] Markiewicz (2012), *Aspects of photogrammetric data integration for generation 3D models of the selected objects located in the urban space*.

a.

b.

c.

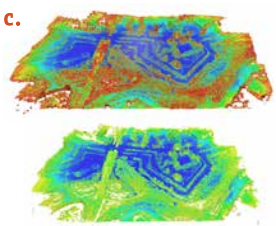
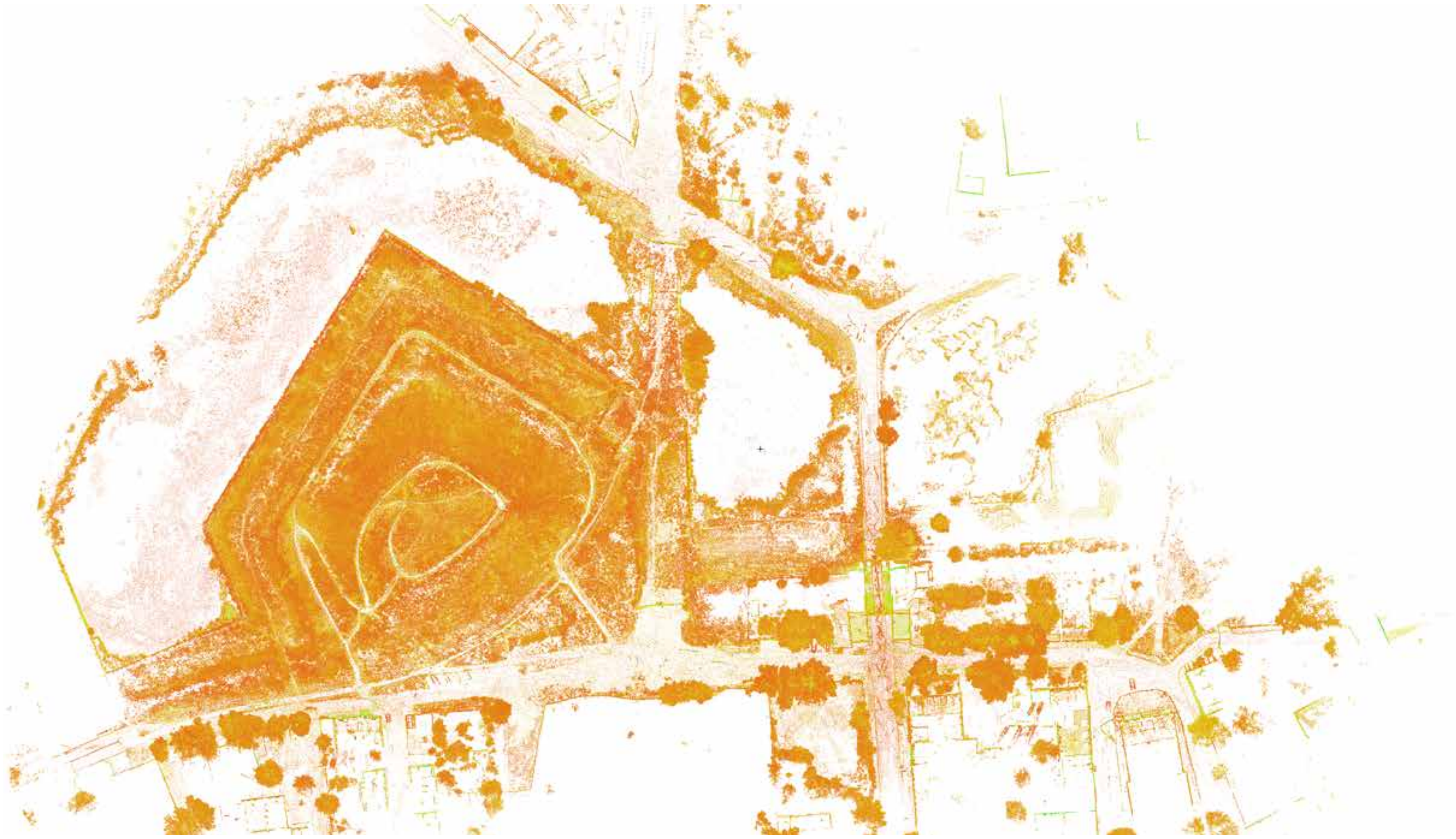


Fig. 09
Photogrammetric Workflow for UAV Data Processing
Top: stages of drone-based photogrammetric processing, including image alignment, point cloud generation and cleaning, mesh creation, and texturing.



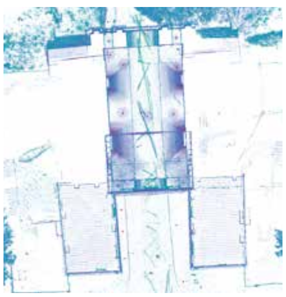


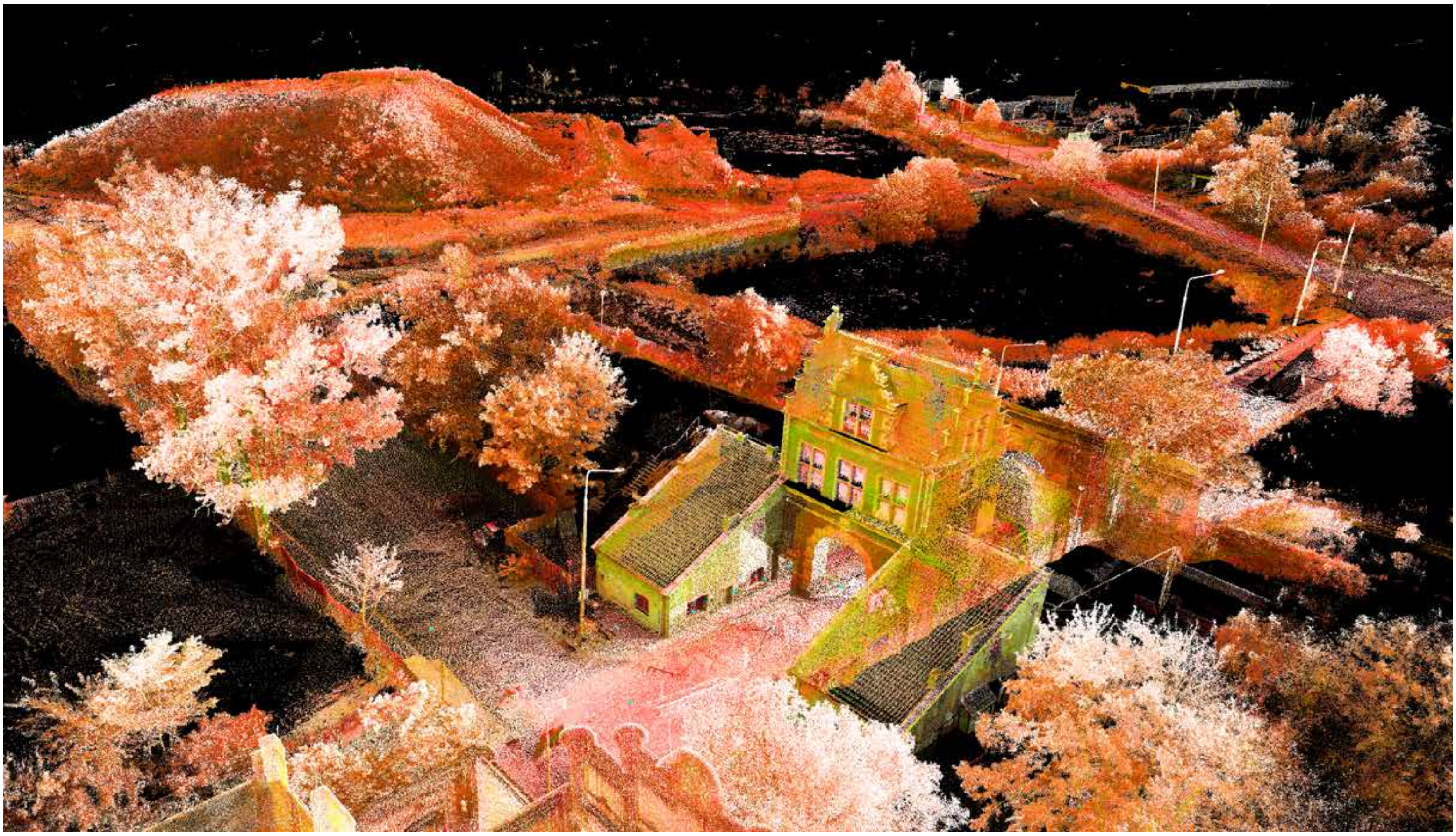
Fig. 10
TLS Point Cloud of the *Żubr* Bastion and Adjacent Structures
Terrestrial laser scanning data of the *Żubr* Bastion, with the Stone Sluice visible on the left and the Lowland Gate on the right, illustrating the spatial relationship between these key elements of the fortified system.

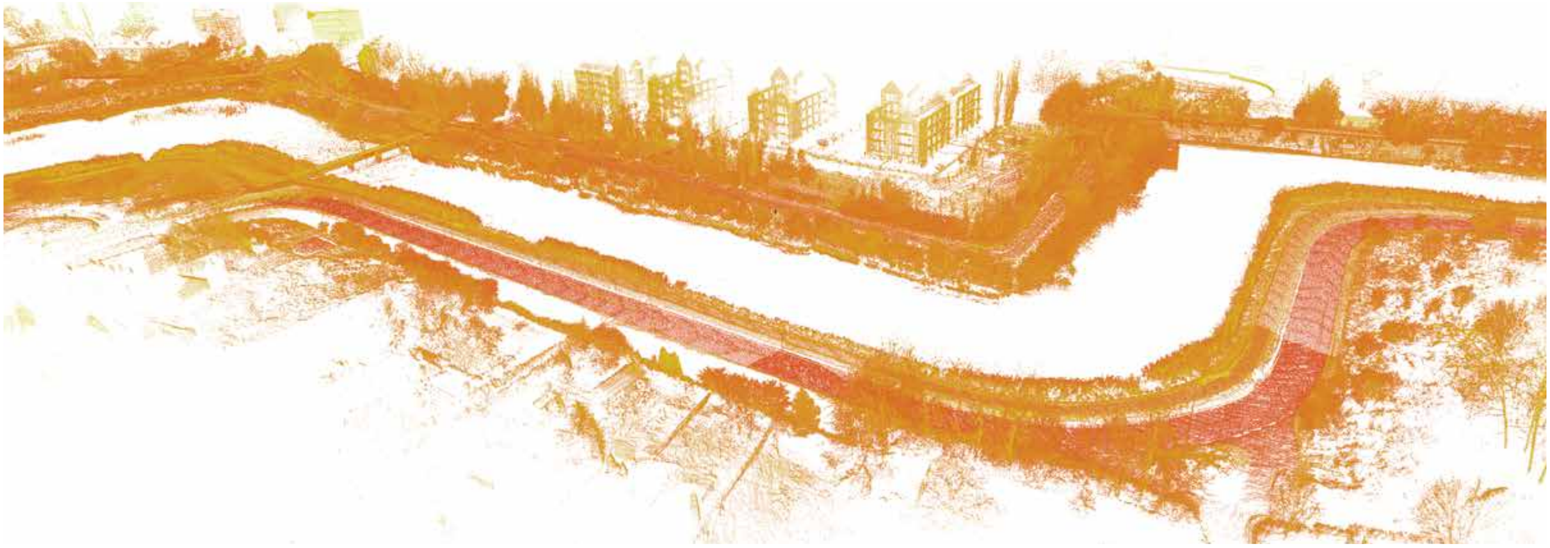
Fig. 11
TLS Point Cloud Detail of the Lowland Gate
Close-up view of the point cloud showing the interior of the Lowland Gate, with visible scan positions that illustrate the density and coverage of the terrestrial laser acquisition.Gate and MLS cloud of Stone Sluice. Bottom: MLS acquisition of the eastern bastions.

algorithms were applied using Leica Cyclone Core software. In order to control the error of each component, closed polygons paths were provided during the acquisition phase; then overlapping areas were distributed along the perimeter and calibrated to ensure metric strongholds to verify the merging between the areas. Specifically, for the recording of TLS scans related to the earthworks to the east, the scans were divided according to each bastion[24], processing 3 independent datasets[25].

For processing the datasets from camera and drone each set of data related to the chosen object was processed individually with photogrammetry software (Agisoft Metashape). In each area, the point cloud model was generated at the highest resolution obtainable. Only for the western fortified system, given the large number of photographs (1488) photogrammetric processing was divided into portions. Then, based on the targets prepared at the acquisition phase and morphological points, the different groups were aligned together. The possibility offered by the software to optimize the point cloud through a semiautomatic process of discretization by point confidence allowed for more reliable mesh models, optimizing not only the processing time but also the weight (in terms of GB) of the models.

24 Also including the surrounding defensive structures as the counterguards and the moat.
25 The decomposition into recording subgroups allows for a layered database that enables analysis of the relationship between individual areas or in-depth study of portions of the boundary related to a single element.





Data integration: evaluation method and results

The different databases, divided by object and instrumentation, constitute autonomous non-integrated elements, so they have the issues and limitations related to the instrumentation used. For a suitable reading of the object and an optimization of the technologies used, the integration of these databases followed a division according to 3 clusters. These clusters made it possible to organize the data according to a structure that would allow a greater control of the error, trying to optimize the general view offered by the drone survey to the metric reliability of the terrestrial laser scanner .

Considering particularly what were the intended outputs of the project, the structure of the database was organized as follows:

- fortified system to the west (TLS, aerial photogrammetry and GNSS);
- fortified system to the east (MLS);
- point elements (TLS/MLS and photogrammetry).

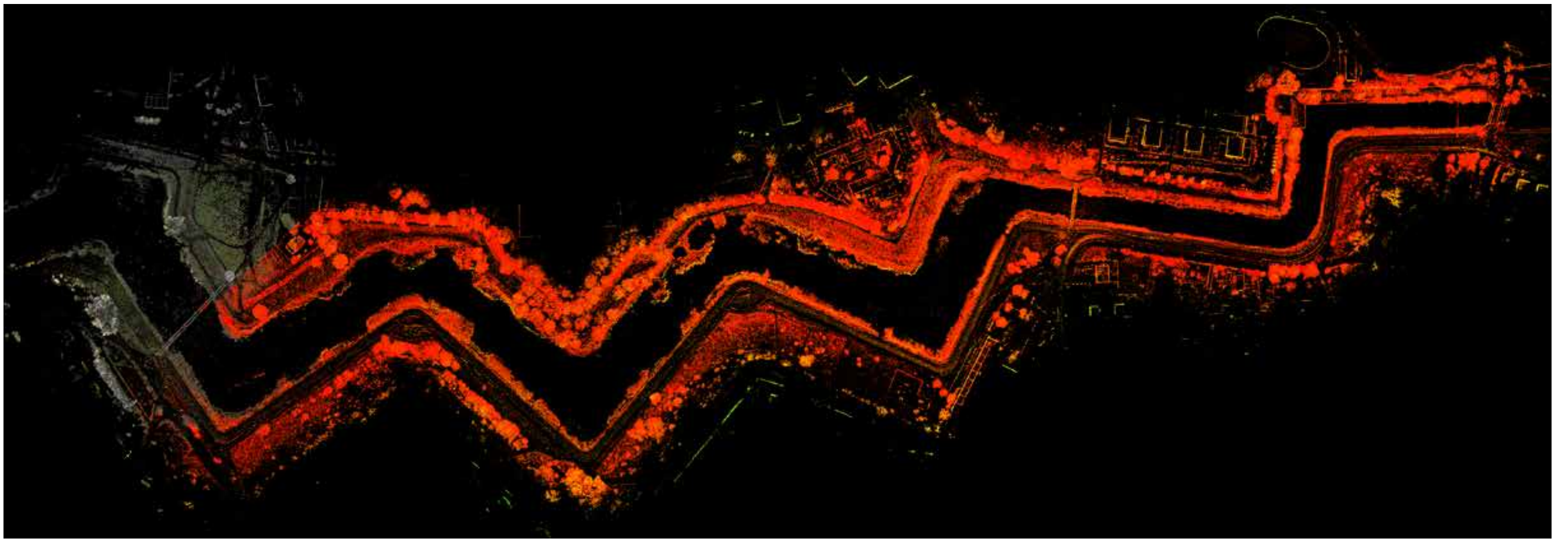
Specifically, for the western fortified system, the integration was done by trying to minimize the error due to the use of different instruments over a relatively large area. The scanworlds related to the individual bastions, once aligned and error checked, were referenced based on the coordinates of the points surveyed by GNSS rover. This process allowed the entire database to be georeferenced, since subsequent clusters were aligned using the first one as a base. Also the photogrammetric models, once the georeferenced coordinates were obtained from the point cloud, were shifted to a global reference system, allowing for an easier handling of the next steps, such as insertion into information systems such as BIM or GIS.

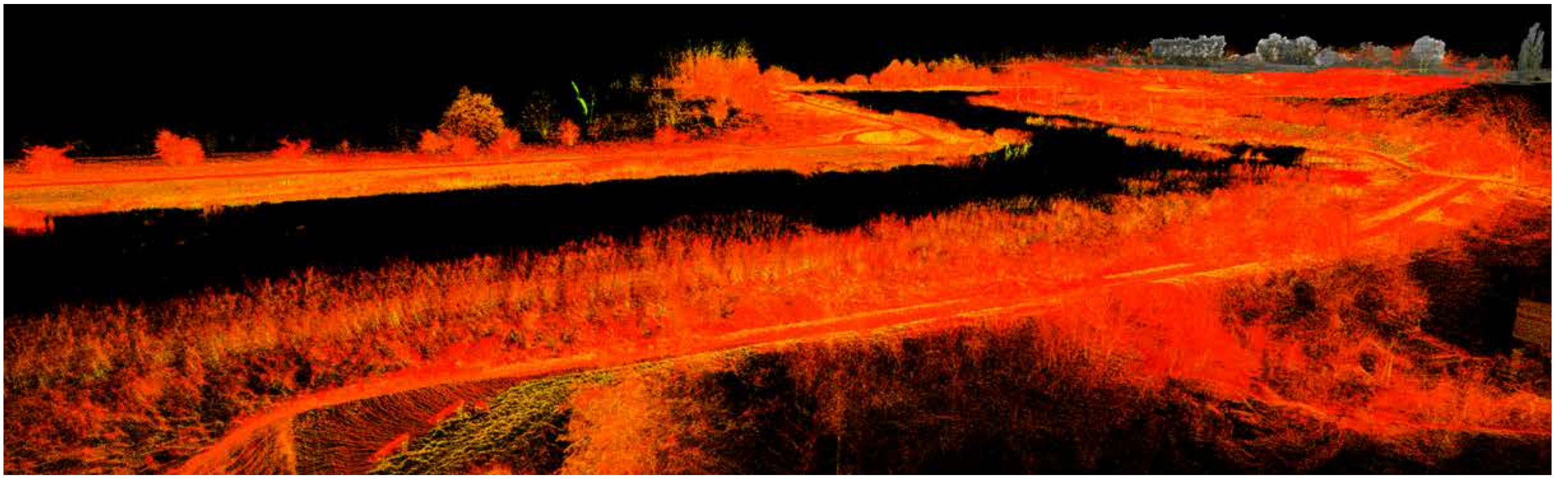
during the survey of the rampart area brought about the need to define a methodological process for managing a complex database[26].

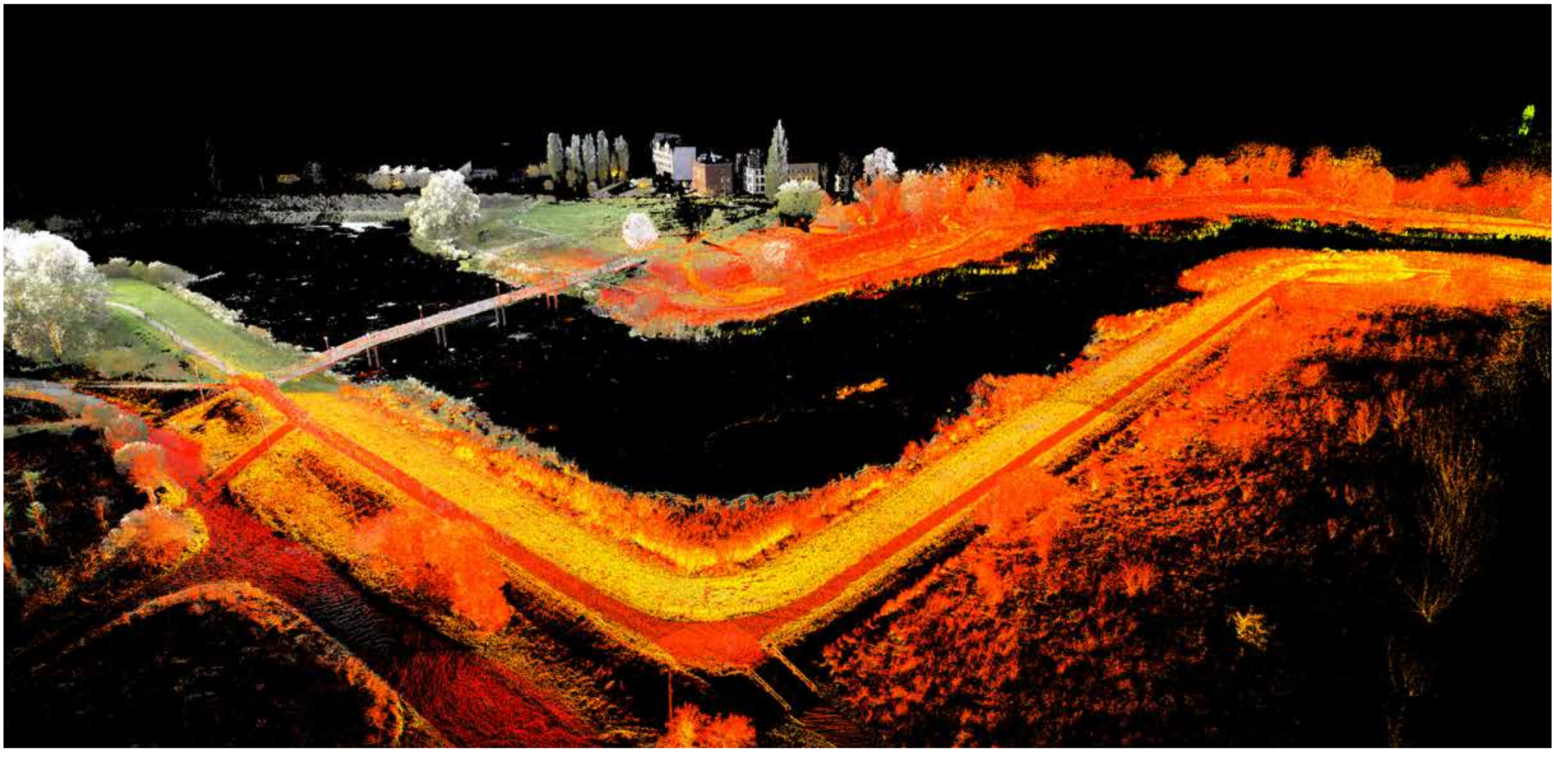
Side page, Fig. 12
TLS and MLS Point Clouds of Bastions and Counterscarp Structures
Top: integration between TLS and MLS point clouds documenting bastions and counterscarp areas. Bottom: planimetric TLS view of the Gertrude Bastion, situated west of the Lowland Gate.

Fig. 13
Point clouds processed by laser scanner acquisition, and UAV acquisition

[26] Markiewicz (2012), *Aspects of photogrammetric data integration for generation 3D models of the selected objects located in the urban space.*







References

Apollonio F., Gaiani M., Remondino F. 2010, *Una pipeline per l'acquisizione di dati in 3D*, in Benedetti B., Gaiani M., Remondino F. (eds.), *Modelli digitali 3D in archeologia: il caso di Pompei*, Edizioni della Normale, Pisa, pp. 39-63.

Bertocci S., Parrinello S. 2015, *Digital survey and documentation of the archaeological and architectural sites, UNESCO World Heritage List*, Edifir, Firenze.

Dell'Amico A. 2023, *The walled city of Verona. Integrated survey systems for the enhancement and promotion of Verona's city walls*, in *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 48, pp. 481-489.

Dell'Amico A. 2021, *Mobile laser scanner mapping system's for the efficiency of the survey and representation process*, in *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLVI-M-1-2021, Proceedings of the 28th CIPA Symposium "Great Learning & Digital Emotion", Beijing, pp. 199-205.

Letellier R., Eppich R. (eds.) 2015, *Recording, documentation and information management for the conservation of heritage places*, Routledge.

Markiewicz J. 2012, *Aspects of photogrammetric data integration for generation 3D models of the selected objects located in the urban space*, in *Archives of Photogrammetry, Cartography and Remote Sensing*, 24, pp. 199-209.

Masciotta M. G., Morais M. J., Ramos L. F., Oliveira D. V., Sanchez-Aparicio L. J., González-Aguilera D. 2021, *A digital-based integrated methodology for the preventive conservation of cultural heritage: the experience of HeritageCare project*, in *International Journal of Architectural Heritage*, 15(6), pp. 844-863.

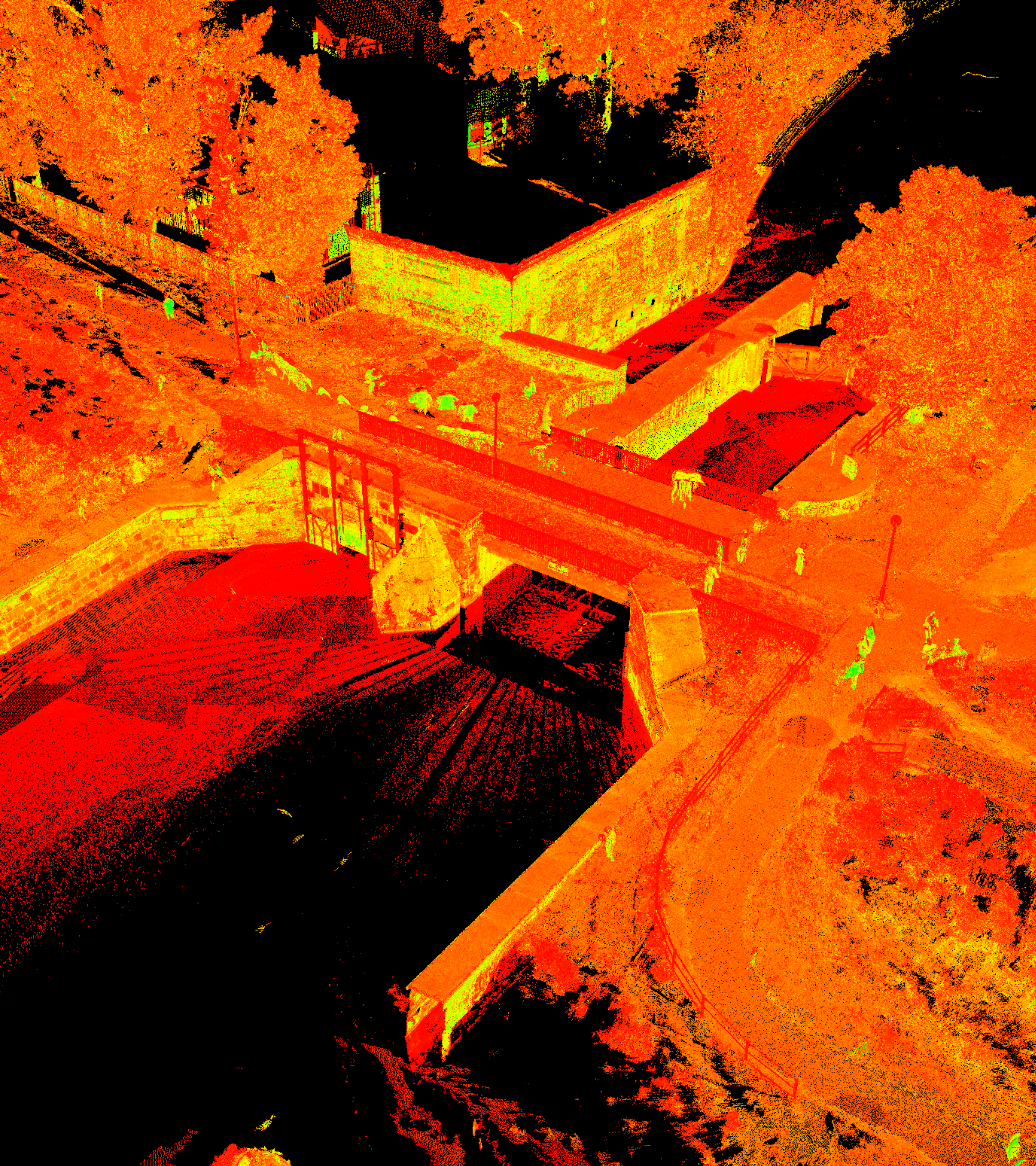
Parrinello S., Picchio F., Becherini P., De Marco R. 2017, *The drawn landscape in 3D databases: the management of complexity and representation in the historical city*, in *Atiner's Conference Paper Series*, pp. 299-322.

Parrinello S., Picchio F. 2017, *Databases and complexity. Remote use of the data in the virtual space of reliable 3D models*, in *Architecture and Engineering*, 2(2), pp. 27-36.

Szczepański J. 2010, *Sightseeing in Gdańsk: the southern line of Gdańsk fortifications (Zwiedzanie Gdańska: południowy ciąg fortyfikacji Gdańska)*.

Thomson C. P. H. 2016, *From point cloud to building information model: Capturing and processing survey data towards automation for high quality 3D models to aid a BIM process*, Doctoral dissertation, UCL (University College London).

Figs. 14-16
Integration of TLS and MLS Data from Western and Eastern Bastions
Merged point clouds combining TLS acquisitions of the western bastions with MLS data from the eastern sector, enabling unified spatial representation of the entire fortified system.



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Side page, Fig. 01
TLS point cloud instrumentation for detailed documentation of the basin and mill

Introduction and historical background

With the rise in popularity of siege firearms during the Renaissance, the necessity for fortification upgrades in the City of Gdańsk became evident. In 1571, the initial efforts to enhance the medieval fortifications of Main Town, Old Town, and Old Suburbs from the western side began, employing the trace italienne – an Italian style of bastion fortifications. Fearing a potential conflict with Sweden, Gdańsk extended its fortifications to the eastern front, completing the project in 1635 by implementing the Dutch system of fortifications. This extensive initiative also encompassed the construction of a sluice at the Motława River entrance, serving to regulate water levels in the port and moats, with the strategic capability to flood the eastern and southern sides of the city.

The sluice, crucial during floods in Żuławy, protected the town and prevented upstream flooding during backwater periods. Constructed between 1622 and 1623, the granite Stone Sluice was designed by Dutch engineers and overseen by Jan Strakowski, the town's architect at the time. Initially enclosed by two water gates and a drawbridge for sail passage, the structure underwent significant modifications in 1649-1650. During this period, 100-meter-long granite bulkheads with four round turrets were added, spanning the moat and forming a channel leading to the sluice. Adjacent to the sluice, a watermill was erected to support the medieval Great Mill in the city center in the flour grinding. Between 1892 and 1893, it underwent a final reconstruction, replacing the drawbridge with a fixed bridge. Damaged during the Red Army's siege in 1945, the mill's remains were reinforced and safeguarded against further destruction. The sluice itself stands as a remarkable waterwork engineering monument, integral to Gdańsk's Renaissance fortifications, and recognized as a Polish historical monument[1].

From digital survey to integrated database

The historic and architectural features of Stone Sluice attract attention, leading to the need for detailed documentation of the area. During the first acquisition campaigns (October 2022), the

[1] Bukal (2012), *Fortyfikacje Gdańska i ujścia Wisły 1454-1793. Studium z dziejów nowożytnej architektury militarnej (Fortifications of Gdańsk and the Vistula estuary 1454-1793. Study in the history of modern military architecture)*, pp.122; Hoburg (1852), *Die Steinschleuse in Danzig: nach den darüber im Archiv der Stadt Danzig vorhandenen Originalpapieren; ein Beitrag zur Kenntniß der Bauwerke dieser Stadt (The stone sluice in Gdańsk: according to the original papers in the archives of the city of Gdańsk; a contribution to the knowledge of the buildings of this city*; Szczepański (1995), *Stone Sluice Mill in Gdańsk, in Preservation of the Industrial Heritage - Gdańsk Outlook II: International Seminar, October 4-7, 1995, Gdynia - Gdańsk, Poland; Final Report*, pp. 69-75.

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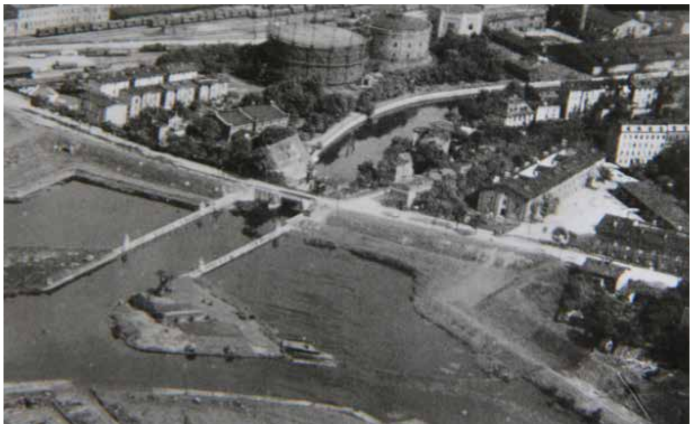
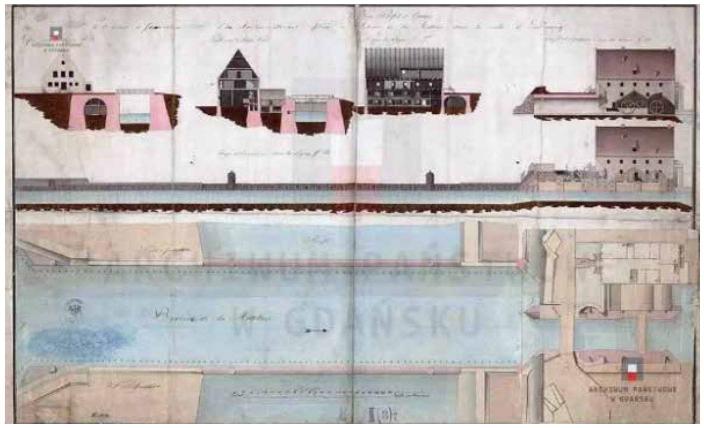




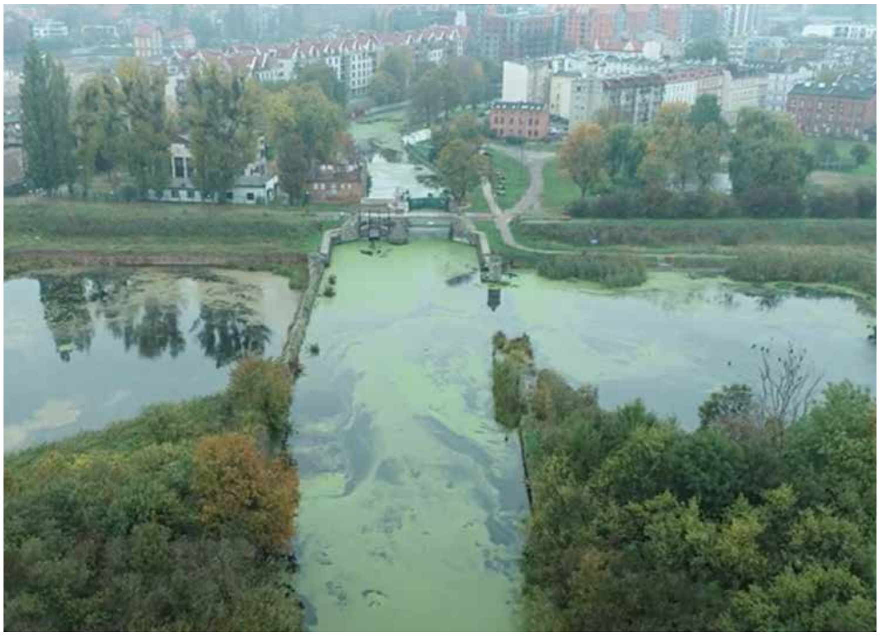
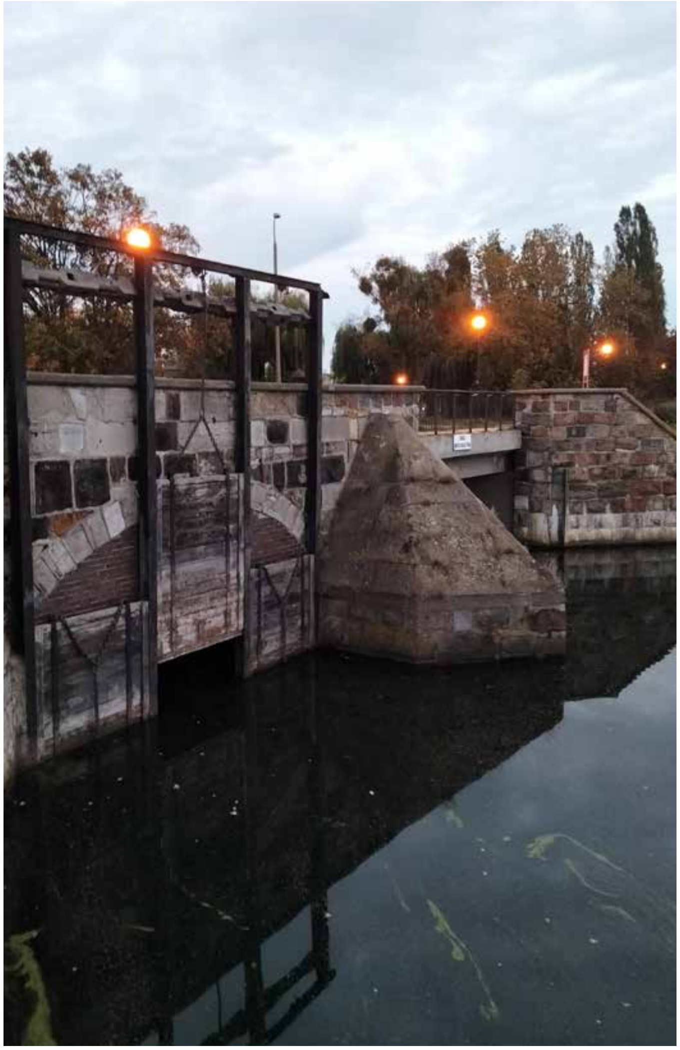


Fig. 02
Historical aerial photograph showing the stone sluice and watermill dated around 1930's. Right - architectural inventory from the 19th Century

Next page, Fig. 03
The Stone Sluice basin, The photographs show the current condition of the basin, in two views oriented towards the urban centre
The study drawing, made from life, depicts the condition of the structure adjacent to the basin, showing some of its details.

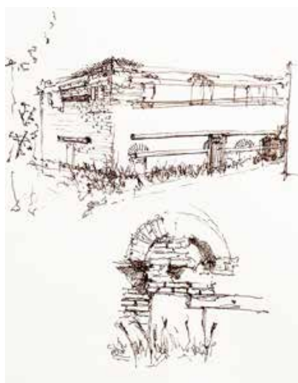
basin had been documented, together with the entire bastions system, within an extensive survey, performed with expeditious methodologies and UAV and mobile laser instruments.

To enable the development of a detailed architectural model of the Stone Sluice area, a different data acquisition method had to be employed. Accordingly, an integrated point survey strategy was designed to gather precise information on the state of the masonry, existing openings, and potential access points. The resulting dataset was intended to serve as a foundation for future restoration planning.
The fieldwork, planned and carried out in July 2023, involved photogrammetric techniques (ground and at aerial) and terrestrial laser scanner equipment. An initial site inspection resulted in the realisation of a site plan, and scan positions were planned using a LeicaRTC360 scanner. The laser scanner recorded the lateral walls of the basin, the bridge, and the perimeter of the mill. A total of 77 scans were recorded, with medium density settings and a camera activated during

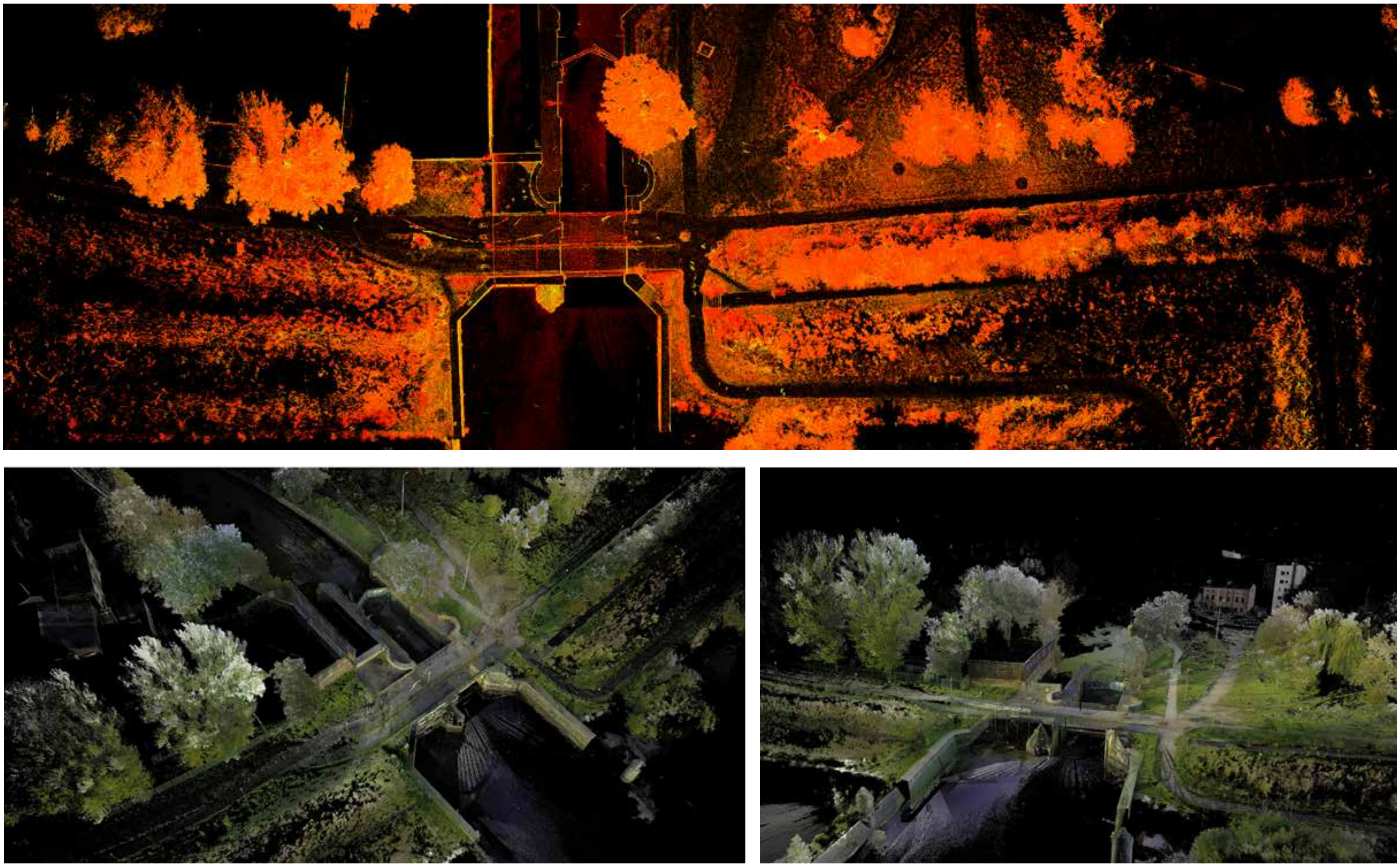


scanning. The data was processed in the field using the Leica Cyclone FIELD 360 app, installed on a mobile device. This enabled immediate visualisation of the point cloud data, which was then processed and verified in the laboratory with Leica Cyclone software (average total error: 1.2 cm). The external walls of the mill were also recorded using ground-based photogrammetry with a Canon EOS 2000d camera set manually. The resulting photogrammetric data allowed for a detailed analysis of the masonry structure's degradation and the generation of a texture for the digital model with high colour correspondence with the real building[2] .

To document the interior of the mill and the stone towers, which are located approximately 30 meters from the bridge and inaccessible by land, an aerial photogrammetric survey was conducted. This used a DJI drone Phantom 4 RTK in mapping mode (GSD, Ground Sampling Distance ca. 2 cm/pix). The dataset acquired (from 333 photos) was then scaled based on the point cloud gen-



[2] Picchio (2020), *Acquisition protocols for UAV photogrammetric data. Comparison in methodological SfM procedures from architectural till urban scale*, pp. 70-79.



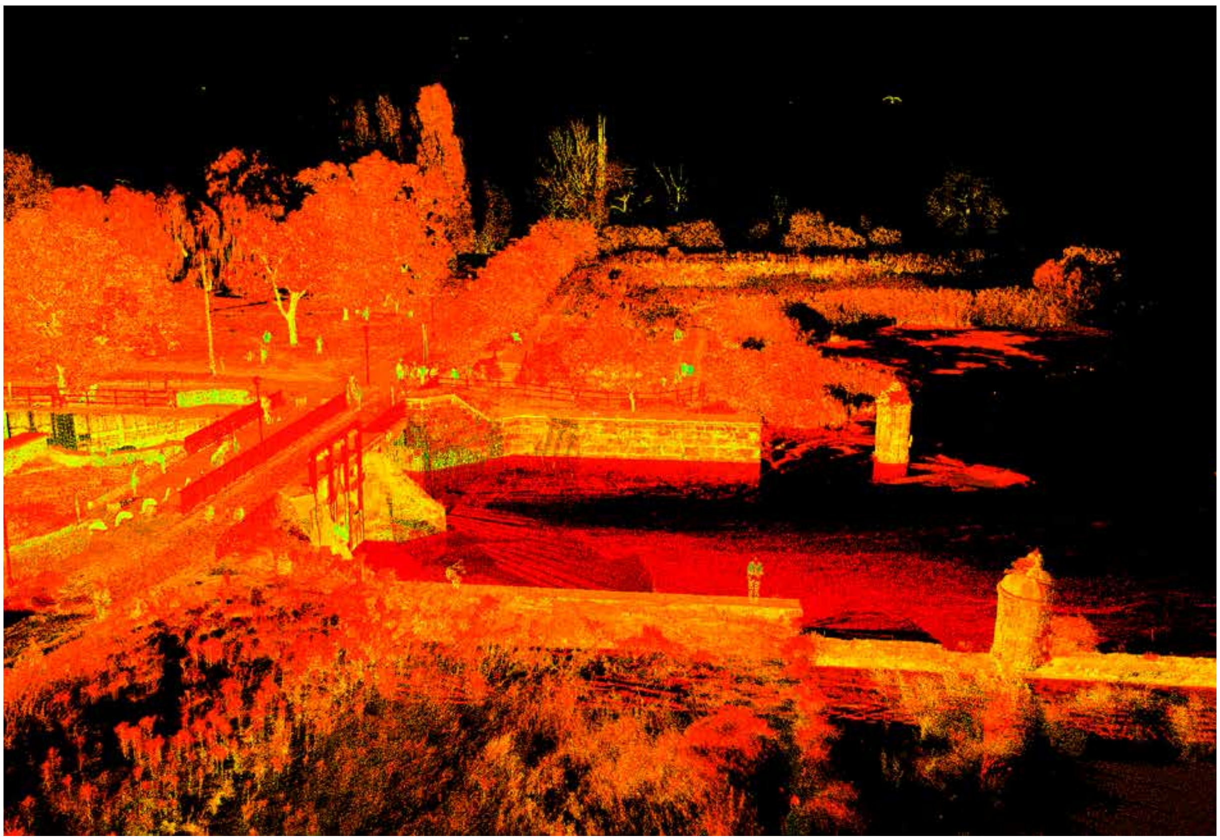
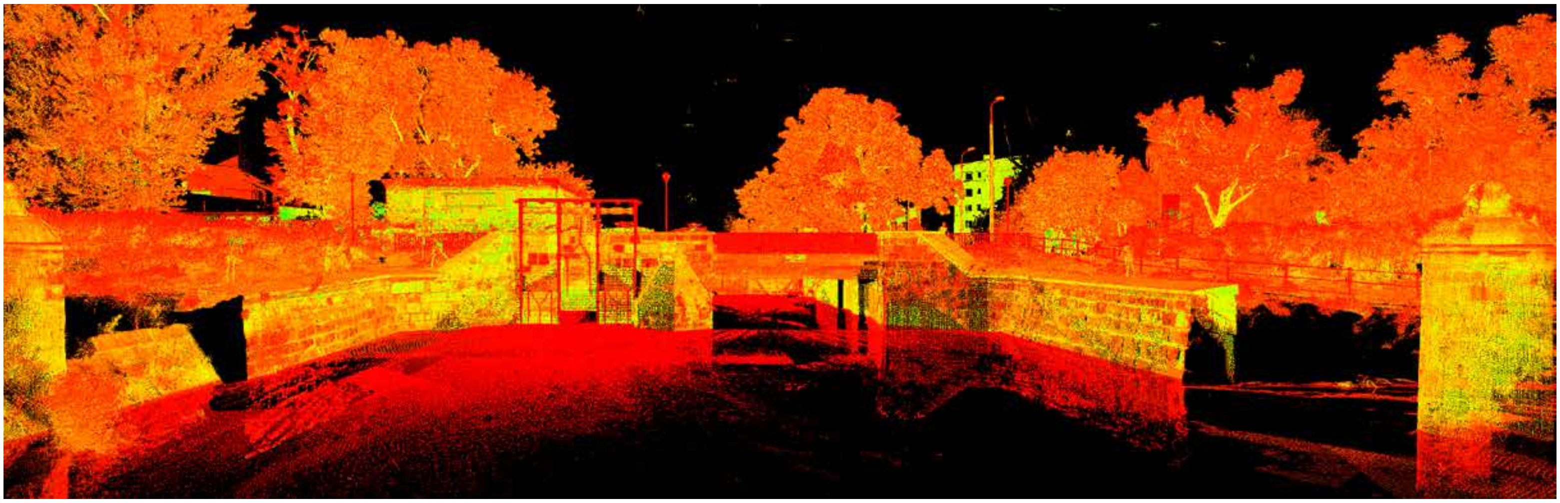
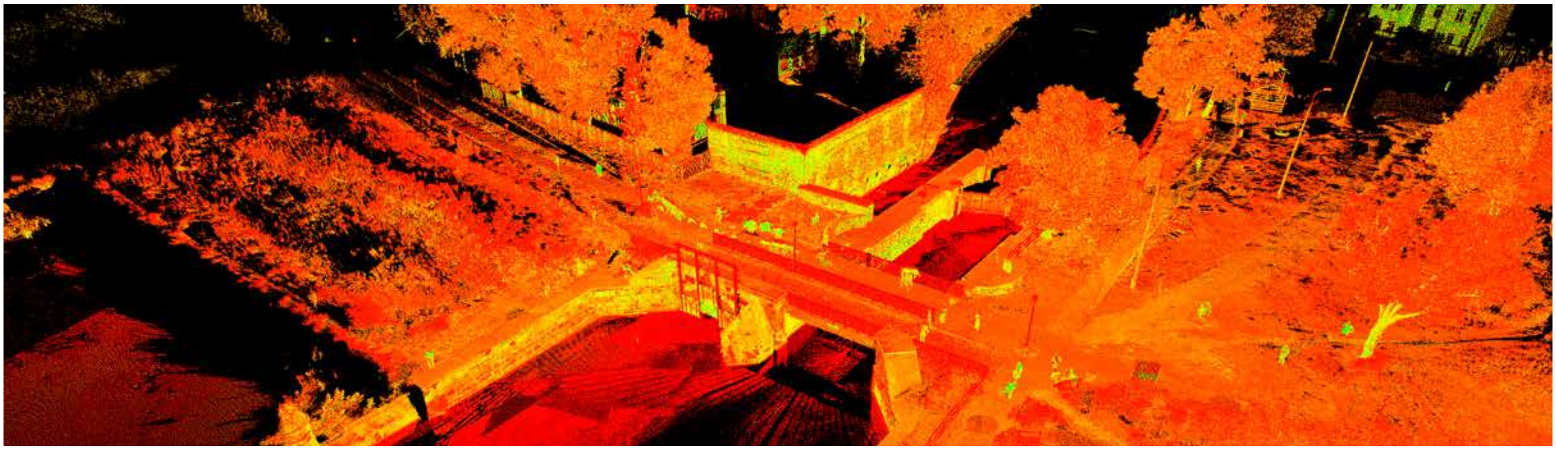
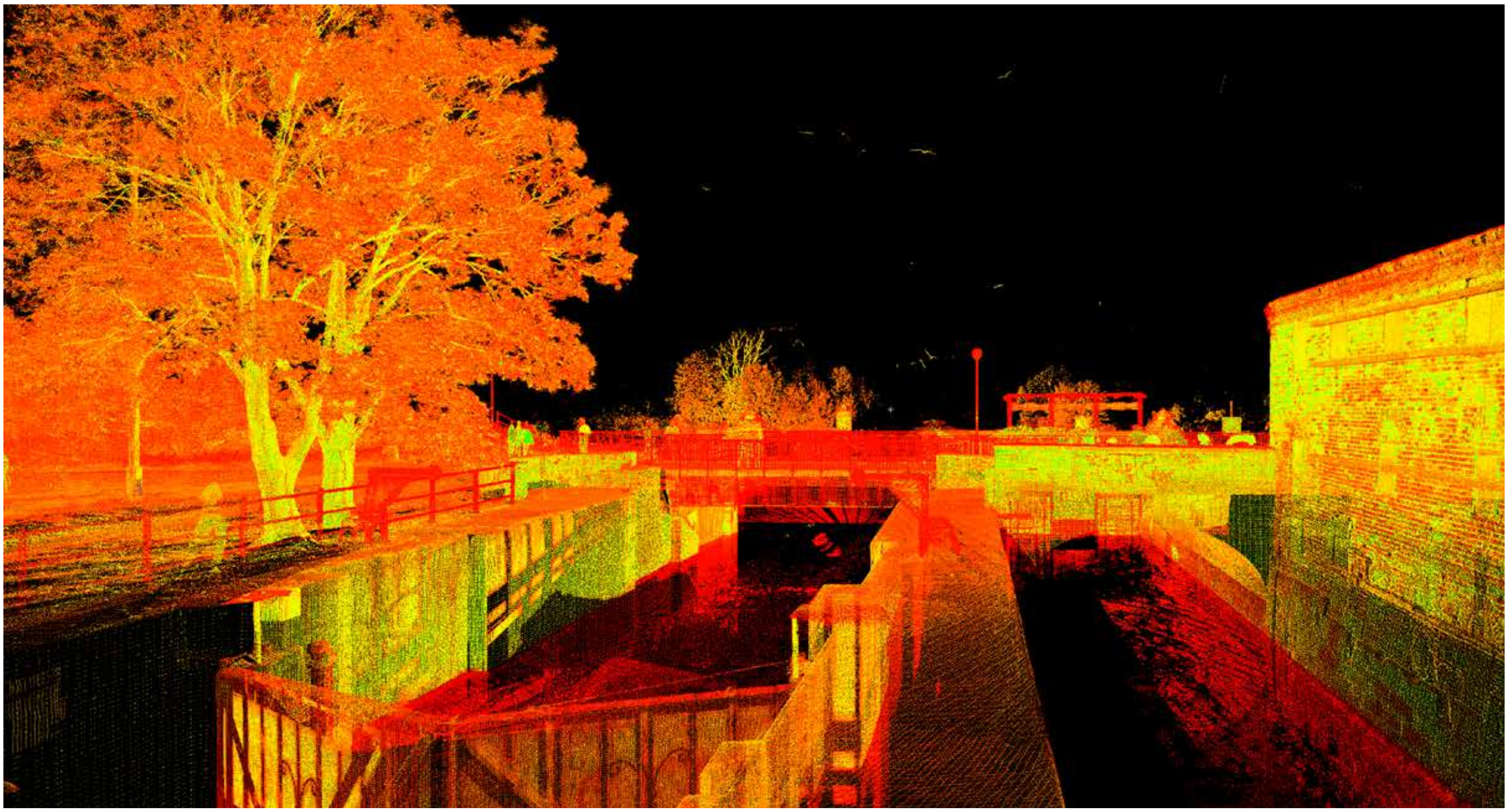


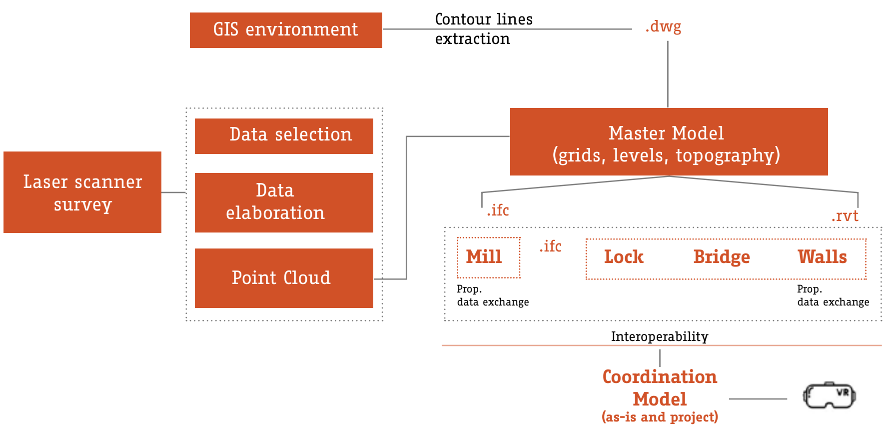
Fig. 04
Stone Sluce digital database. The panoramic and top-down views, realised on Leica Cyclone software, show the basin system, with the gates closed to prevent transit

Next page, Fig. 05
MLS technology for data acquisition. Images from the database obtained by acquisition with Leica's Blk2GO mobile laser instrument









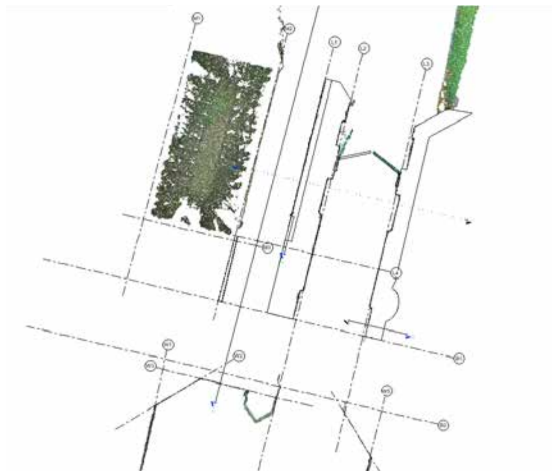
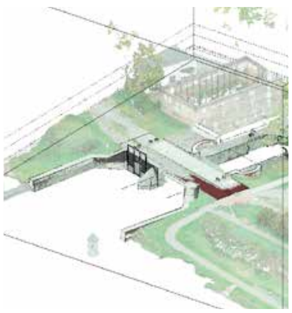


Fig. 06
Scan-2-BIM workflow. From data acquisition with laser scanner technology to the creation of federated BIM models. Master model with grids, levels and topography on the right

Fig. 07
Coordination view with the federated models of existing elements



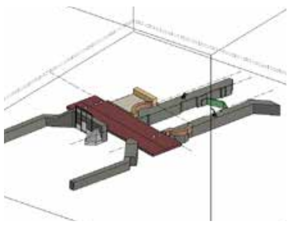


Fig. 08
Scan-2-BIM workflow

Fig. 09
Master file with grids and levels

erated by the laser scanner, enabling subsequent integration[3]. The resulting database was divided into layers for each dataset, making it easy to use, manage, and read the restored digital spaces, simplifying subsequent studies through disassembly and modeling of individual components.

BIM modeling

Using a scan2BIM methodology[4], researchers switched from point cloud to BIM modelling using Autodesk Revit and Archicad software. The use of two different BIM authoring software allowed them to experiment the problems of interoperability and information exchange between two different software in the case of federated models.

In the first part of the workflow the point cloud described above was imported into the Autodesk ReCap software in .e57 format and then it was converted into .rcs format. This step is necessary for the point cloud in order to be linkable within the Revit software while the Archicad software is able to import the .e57 format directly.

Starting from this input data, it was possible to proceed with the 3D modelling of the building by defining a system of grids and levels in a master file within Autodesk Revit. This coordination file was used as a reference for the subsequent modelling phase on the two software with a different import procedure. On the Revit side, in fact, it was sufficient to link the master file within the project and recreate the necessary levels using the "copy/check" command, while for interoperability with the Archicad software, the IFC format was used, where the grids, defined in Revit, were exported as IfcGrid class and the levels were defined as IfcBuildingStorey. Within the same master file, a file in .dwg format was also linked containing the contour lines for the area of interest extrapolated from a GIS system and reworked using Autodesk AutoCad software. The import of these lines allowed the automatic creation of an editable topography using control points, particularly for the area crossed by the river. Then, through the use of a shared coordinate system, the entire work was split into

[3] Chiabrando et al. (2016),*TLS models generation assisted by UAV survey*, pp. 413-420.
[4] Biagini (2022), *From Geospatial Data to HBIM of Romanic Churches in Sardinia: Modelling, Check and Validation*, pp. 368-378.

Fig. 08
Single federated models: the existing lock on the left (Autodesk Revit) and the watermill's project on the right (Archicad). Grids and levels were copied from the master file

four areas - the mill (Archicad), the lock (Revit), the bridge (Revit) and the external walls (Revit) - in order to work on different workstation without the need to use central and local models. The modelling process, based on the current status of the asset, involved, in a first phase, the restitution of the main geometries (walls, floors,...) and then the restitution of the individual architectural elements or BOMs (doors, windows,...).

For the latter elements, defined as loadable families by the Revit software, the modelling was based on measurements taken within the ReCap software because the Revit family editor does not allow the direct import of point clouds as is the case for the main workspace. The level of detail set was set as a concept design project, so greater importance was given to the representation of the main volumes than to the geometric accuracy of the individual elements with respect to the data obtained from the point cloud; the same principle was followed on the alphanumeric information, omitting the insertion of particular parameters for future implementations of the model. Once the restitution of the different parts was completed, these were linked together, in .rvt or .ifc format, within a sheet model in Autodesk Revit for the graphic restitution of the entire complex.

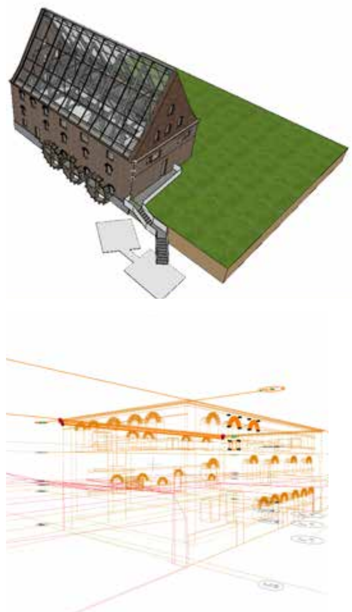


Fig. 09
Final BIM model of the watermill's project (Archicad)

Outputs - census cards, restoration concepts/concepts design, VR

Subsequently, based on entry-stage concept drawings, a redesign hypothesis was modeled for the watermill area only, with the rest of the stone sluice concept treated as a background. The concept was developed by a workshop group of students under the guidance of tutors. The concepts developed during the project activities emphasize the conservatory approach and adhere to the principle of maximum respect for authentic substance.A new, modern addition was introduced, designed to remain clearly distinguishable and easily reversible in future interventions. A deliberately simple design was chosen for the exhibition space, one that complements the historic character of the building while preserving its open interior layout. In the discussion, a decision was made to opt for a steel construction, serving as bracing for all the remaining authentic walls, for the purpose of this example. The architectural concept, developed in the BIM environment, aimed to demonstrate

Fig. 10
Restoration concept design
Visualisations of exterior and interior of adapted watermill showing the conceptual design.

Fig. 11
Projects rendering
Reuse project proposal designed on the base of H-BIM model.

Fig. 12
Immersive sighting
Tests and evaluation of projects by the research team.

the potential adaptation of the existing structure to a new function, focusing on illustrating the methodology rather than extensively elaborating on the adaptation concept. To facilitate potential immersive visualization, the Oculus Quest 2 VR goggles were employed, connected to the computer workstation via the Oculus Link cable. The architectural concept was emulated using the Enscape visualization plugin in the Revit software, enabling an immersive Virtual Reality experience. The idea was to evaluate the potential project using virtual reality and test the design solutions in an immersive setting without leaving the project software, in this case, Revit. The research group was able to assess different immersive concepts, providing a comprehensive understanding of the potential pros and cons associated with each design.

The integrated survey and application of the scan2BIM methodology can prove exceptionally beneficial in the context of designing, redesigning, or adapting pre-existing structures. This approach opens up the potential to leverage the full capabilities of high-precision inventory, achieved through laser scanning and/or photogrammetry, coupled with BIM usage. BIM introduces numerous possibilities through 3D modeling and the integration of diverse data into the conceptual design project. This methodology is particularly valuable when working with heritage objects, fully capitalizing on its potential for intricate architectural structures. The visualization of the project in virtual reality provides an intriguing method for the design process, offering an immersive evaluation of the developed design.

Fig. 13
Project coordination view with models and point cloud

References

Chiabrando F., Di Pietra V., Lingua A., Maschio P., Noardo F., Sammartano G., Spanò A. 2016, *TLS models generation assisted by UAV survey*, in *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 41, pp. 413-420.

Picchio F. 2020, *Acquisition protocols for UAV photogrammetric data. Comparison in methodological SfM procedures from architectural till urban scale*, in *D-SITE. Drones-Systems of Information on culTural hEritage for a spatial and social investigation*, Pavia University Press, pp. 70-79.

Biagini C., Bongini A., Verdiani G. 2022, *From Geospatial Data to HBIM of Romanic Churches in Sardinia: Modelling, Check and Validation*, in *Architectural Graphics. EGA 2022*, Springer Series in Design and Innovation, vol. 22, Springer, Cham, pp. 368-378.

Bukal G. 2012, F*ortyfikacje Gdańska i ujścia Wisły 1454-1793. Studium z dziejów nowożytnej architektury militarnej (Fortifications of Gdańsk and the Vistula estuary 1454-1793. Study in the history of modern military architecture)*, Grzegorz Bukal, Sopot, pp. 122.

Hoburg K. 1852, *Die Steinschleuse in Danzig: nach den darüber im Archiv der Stadt Danzig vorhandenen Originalpapieren; ein Beitrag zur Kenntniß der Bauwerke dieser Stadt (The stone sluice in Gdańsk: according to the original papers in the archives of the city of Gdańsk; a contribution to the knowledge of the buildings of this city)*, C. J. Dalkowski, Königsberg.

Szczepański J. 1995, *Stone Sluice Mill in Gdańsk, in Preservation of the Industrial Heritage - Gdańsk Outlook II: International Seminar*, October 4-7, 1995, Gdynia - Gdańsk, Poland; Final Report, pp. 69-75.

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Side page, Fig. 01
Geographic Information System for the management of the Bastions

The defortification of Gdańsk was occurring from the end of the 17th Century due to various processes related to the modern transformations of the city. One of the obvious reasons was losing the military significance of the fortifications, and another - the pressure of urbanisation and the need for spatial development of the city's new districts[1] . By the beginning of the 20th Century, the western, northern and eastern strips of Gdańsk fortifications were dismantled and new neighbourhoods were constructed there. The southern bastion fortifications, however, remained intact and are still determining the historical landscape of this part of the city. The reason behind this was simply that this was not an attractive area for development[2]. Nowadays, the bastion complex remains an open, green area. Similar cases can be found in many other European cities, where the former fortifications were transformed into public green and recreational areas, often becoming important elements of the urban landscape, providing nature-based solutions for the inhabitants and enhancing urban biodiversity[3]. In the case of Gdańsk the remaining southern fortifications are connected with the Lower Town district, adjacent to the Main City. Following WWII, the area fell into a state of disrepair and for many years it was known for its many social and safety problems. During the past two decades it has been undergoing the process of revitalisation and one of its key elements was the refurbishment of the fortifications and its transformation into a recreational and touristic complex so that it can serve both visitors and the inhabitants. In recent years we can observe a growing interest in the fortifications complex. Numerous fieldworks have been carried out to restore the condition of the bastions and moats. On the other hand, they are still exposed to further damage, also due to new investments in the area[4]. Therefore, the important aspect of preserving this unique complex is its closer spatial integration with the Lower City district and making it attractive and usable not only for tourists, but especially for the local inhabitants[5].

[1] Omilanowska (2010), *Defortyfikacja Gdańska na tle przekształceń miast niemieckich w XIX wieku*, pp. 293-334.
[2] Samól et al. (2023), *Where the Second World War in Europe Broke Out: The Landscape History of Westerplatte*; Szczepański, 2010.
[3] Dos Santos (2017), *Reshaping the Urban Space in Portuguese Fortified Cities: New Green Spaces Resulting from the Rehabilitation of Urban Fortifications - From the Nineteenth Century until the End of the Estado Novo Dictatorial Regime (1974)*, pp. 53-69.
[4] Szczepański (2010), *Sightseeing in Gdańsk: the southern line of Gdańsk fortifications [in Polish: Zwiedzanie Gdańska: południowy ciąg fortyfikacji Gdańska].*
[5] Gdańsk Development Office, 2017.

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Figs. 02, 03
Gdańsk Fortification System: Past and Present.
Comparison between the full extent of the Gdańsk fortifications in 1813 (left) and the currently preserved southern strip (right, highlighted in dark blue). Source: Author's elaboration based on the 1813 historic map and 2023 spatial data from the Head Office of Geodesy and Cartography.

This, however, comes with many challenges related to the management of the overlapping historical and environmental features. This issue was addressed during an interdisciplinary, international workshop held during the realisation of the Prometheus project. The results of an extensive digital survey of the area and other available spatial and historical resources were subjected to careful analysis, followed by a detailed analysis of the urban and landscape context.

State of the art

The digital preservation of Heritage is crucial for safeguarding its value in the face of physical damage, to ensure its relevance remains intact even if the tangible structure is compromised or lost. Cultural Heritage Institutes globally have prioritised digitisation efforts to ensure the online access and protection of digital data[6]. The same applies to the management of environmental resources and challenges, the dynamics of which require constant monitoring and modelling. The digital representation of the natural conditions and processes in the built environment should therefore be properly governed and conserved[7]. Since 1972, with the Convention concerning the Protection of the World Cultural and Natural Heritage, guidelines have been established for the conservation of world heritage. Since 1987, the European Community has promoted programs for the enhancement of Heritage, with particular attention to the connection between territory, architecture, and communities[8]. The United Nations' Agenda 2030, among its many objectives,

[6] Nishanbaev et al. (2021), *A Web GIS-Based Integration of 3D Digital Models with Linked Open Data for Cultural Heritage Exploration*.
[7] Kloppenburg et al. (2022), *Scrutinizing Environmental Governance in a Digital Age: New Ways of Seeing, Participating, and Intervening*, pp. 232-241.
[8] Dell'Amico (2022), *Memoria e modello digitale. La costruzione di un sistema informativo per la salvaguardia del patrimonio architettonico diffuso dell'Upper Kama*; Trematerra (2022), *Il Patrimonio mondiale religioso inaccessibile. Conservazione e fruizione ampliata*, pp.452-457.

aims to “strengthen efforts to protect and safeguard the world’s cultural and natural heritage,” also emphasising digitisation (UN, 2015). Similarly, the implementation of technology driven digital models, and in particular digital twins, is very high on the agenda, facilitating the integration of the 3D models and data of urban ecosystems and making it feasible to simulate potential impact and sustainability of decision-making[9]. The combination of the cultural heritage and environmental aspects makes it possible to comprehensively manage and preserve the valuable assets of the built environment and the suitable tool for this purpose is the Geographical Information System (GIS), including 3D GIS, heritage GIS and GIS online. Since the late 1980s, the market has seen the emergence of several commercial GIS solutions for georeferencing data, utilised by diverse entities like cartographic agencies, local administrations, commercial companies, the military, and telecommunications. GIS is an integral part of Information Systems, responsible for storing, managing, and processing digital data[10] . Georeferenced databases enable data utilisation for tourism, education, and research. Recent developments include web repositories, webGIS platforms, and cloud-based archives, contributing to the long-term preservation, visualisation, and analysis of 3D Heritage and urban environment models. Current research focuses on developing repeatable and expandable methodologies for the online preservation of Cultural Heritage and urban landscape data, leveraging free and open-source technologies[11]. Recent advancements in 3D modelling techniques, facilitated by laser scanning and SfM photogrammetry, play a significant role in historical and natural heritage conservation. These 3D models are utilised for visualising and preserving artefacts, with applications in GIS databases and augmented/virtual reality. Web repositories, WebGIS platforms, and cloud-based storage are emerging for long-term storage and analysis of Heritage 3D models[12]. Specifically the WebGIS, introduced in 1993 by the Xerox Corporation, allows users to retrieve and interact with online geospatial information. Initially based on features such as zoom and layer selection, the WebGIS has evolved with the Semantic Web, adding geovisualization, data querying, and information collection[13]. OpenStreetMap illustrates users’ voluntary participation in collecting geospatial data. The WebGIS also facilitates the dissemination of information through user interaction with the data, enabling downloading or sharing[14]. Another example can be the set of tools developed by Esri Inc. within the ArcGIS Online platform, which include not only the platforms for mapping, storing data and spatial analysis,

[9] Ferré-Bigorra et al. (2022), *The Adoption of Urban Digital Twins*; Lei et al. (2023),.*Challenges of Urban Digital Twins: A Systematic Review and a Delphi Expert Survey*.
[10] Migliaccio (2007), *Sistemi Informativi Territoriali e Cartografia*.
[11] Nishanbaev (2020), A *web repository for geo-located 3D digital cultural heritage models. Digital Applications in Archaeology and Cultural Heritage*, pp.1-9.
[12] Guidi et al. (2015), *Massive 3D digitization of museum contents*; Campanaro et al. (2016), *3D GIS for cultural heritage restoration: A ‘white box’ workflow. In Journal of Cultural Heritage*.
[13] Fu, Sun (2011), *GIS in the Web Era*.
[14] Rowland et al. (2020), *Towards Self-Service GIS—Combining the Best of the Semantic Web and Web GIS*.

Fig. 04
Social, Cultural, and Landscape Features of the Lower Town and Fortification Complex
Overview of the urban and environmental characteristics defining the relationship between the Lower Town district and the southern Gdańsk fortifications.

but also ready-to-use tools, accessible also to non-expert users, for building a variety of interactive resources, which include digital narratives, supplemented with geospatial resources and models, or immersive web apps (2023). In particular, the last set of tools was used in the presented case study with the aim of demonstrating the current possibilities for digital management of the cultural and environmental urban landscape.

Study site, materials and methods

A significant step in the ongoing efforts to understand, preserve and promote the historical significance of the Gdańsk Bastions was conducted by students from Gdańsk University of Technology and the University of Pavia during a five-day workshop held in Gdańsk in July 2023. The workshop aimed to improve understanding of the complex's landscape and to develop a concept for the conservation and enrichment of the area, as well as dissemination to the public through the creation of an online platform for visualising thematic routes, analysis and future development. The study focused in particular on three bastions - Gertrude, Aurochs and Wolf - rather than on the entire fortified complex, and involved students in a multi-phase approach to analysis to develop a pathway between past, present and future. To delve into the past, students were provided with the available cartography, from which they could trace the historical evolution of the fortified system. Georeferencing the historical maps allows a visual representation of the landscape conformation of the complex in different periods, providing an essential historical context for understanding the evolution and role of the fortified system in the development of the city. Moreover, it makes it possible to juxtapose the historical elements with the current spatial layout and the environmental features and facilitate the management of existing urban systems and green spaces, considering

Fig. 05
Workflow of the Interdisciplinary Workshop
Diagram outlining the preservation and management process of the Lower Town Fortification Complex, from GIS database creation to interactive web applications and master planning activities.

the preservation of cultural and landscape heritage[15]. In the analysis of the current state, the focus lies on the integration of 3D data from digital surveying, as illustrated in Section 3.3, and the use of available 3D maps and tools. The digital transformation of spatial data into 3D formats, together with standardised data models, confers considerable advantages in digital space, making the decision-making process clearer, more comprehensible and more exemplary[16]. In particular, a tiled model[17] was created from the photographic set obtained by drones - through the processing of the point cloud and subsequent georeferencing. This model, characterised by a light file in terms of gigabytes and the ability to display high quality textures, was designed for easy use on online platforms[18].

The processing software[19] allows the model to be exported in the .slpk (Esri Scene Layer Package) format, facilitating optimal uploading to ArcGIS. In parallel, the georeferenced space was enriched with 2D and 3D data available online, such as digital terrain models (DTM) and building information[20]. Looking to the future, the workshop imagines design solutions that go beyond mere conservation, aiming at the enhancement of this heritage. Students were therefore given the

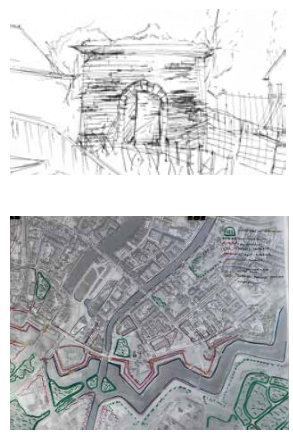


Fig. 06
Student Maps and Drawings from the Workshop.
Selection of analytical sketches and maps developed by students during the workshop to support and illustrate key aspects of their investigation on the fortification system and its context.

[15] Badach et al. (2022), *Developing the Urban Blue-Green Infrastructure as a Tool for Urban Air Quality Management.*
[16] Schrotter et al. (2020), *The digital twin of the city of Zurich for urban planning.*
[17] A tiled model in photogrammetry refers to a 3D model that has been divided into smaller, manageable sections or tiles. Each tile represents a portion of the overall model and is processed independently during the photogrammetry workflow.
[18] Tiled models are well-suited for online platforms, enabling progressive loading for smooth navigation and interaction. Additionally, the optimised file sizes per tile enhance distribution, sharing, and internet-based accessibility, making tiled models particularly beneficial for applications like mapping, urban planning, cultural heritage preservation, and virtual tourism.
[19] Agisoft Metashape was used for the elaboration of all photogrammetric data.
[20] The following open geospatial datasets were used: Database of Topographical Objects the Head, 3D buildings models in CityGML format, raster Digital terrain models, aerial lidar point clouds and imagery (source: the Head Office of Geodesy and Cartography data, published in: geoportal.gov.pl). All the data was georeferenced and was imported into ArcGIS Pro to create the integrated spatial models, which were then published to ArcGIS Online.

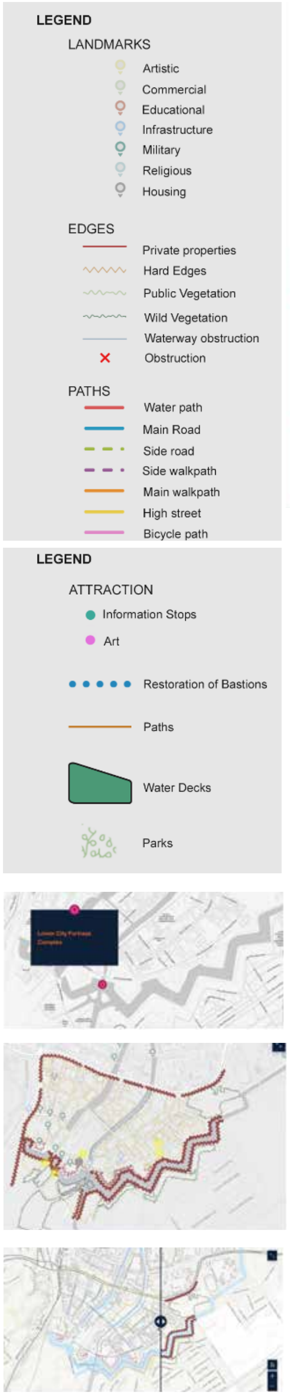


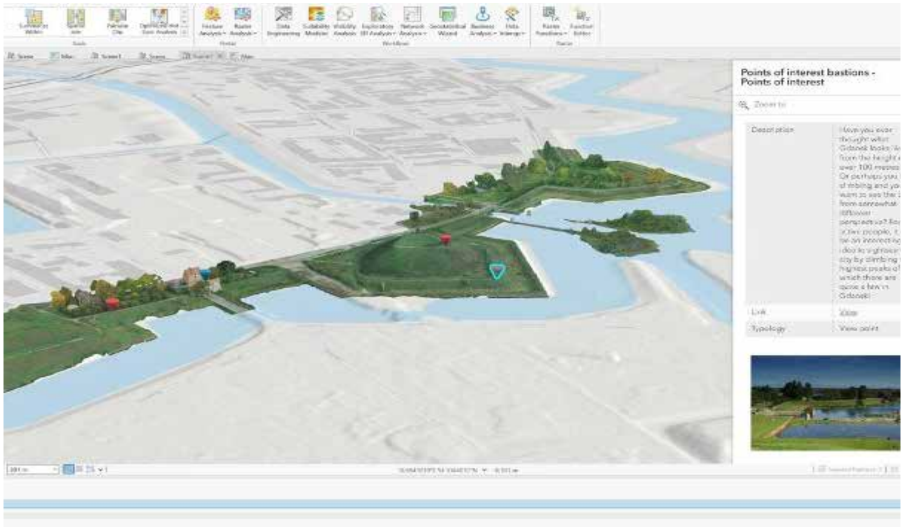
Fig. 07
Illustrative Diagrams and Project Concepts
Sketches and conceptual diagrams representing the logical processes behind the design and communication strategies for the requalification of the bastions.

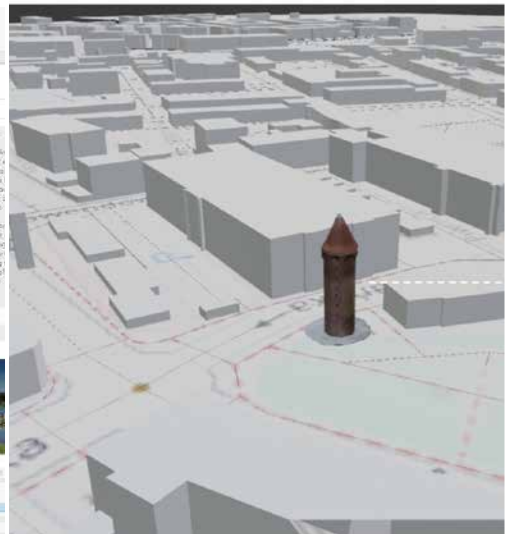
task of graphically representing projects and ideas for potential interventions and adaptive reuse strategies. The emphasis is not only on the preservation of historical significance, but also on the transformation of the ramparts into a valuable urban space that can be enjoyed and appreciated by citizens. The integration of these three temporal dimensions - past, present, and future - within an information system was a pivotal aspect of the workshop. This interconnected approach ensures a holistic understanding of the bastions' complex. The envisaged web app, showcasing the works produced by individual working groups, becomes a dynamic platform for disseminating knowledge and fostering public engagement. Pursuing these ambitions, over the course of the 5-day workshop, the students made use of the resources provided to actively contribute to the research. They developed an application on ArcGIS Online to synthesise and disseminate their insights from the group activities. The process was divided into four main phases, which included the study of the available bibliography and cartography, the survey of the area, the analysis of urban forms following Lynch's method, and finally, the creation of a master plan and concept for the reuse of the area.

The first phase of the project involved an investigation into the historical aspect of the ramparts, encompassed bibliographical research to identify pertinent cartographies and images. The purpose was to make history accessible to non-experts and to stimulate interest.

Secondly, an on-site survey was conducted in order to discern the strengths and weaknesses of the site. It is noteworthy that in spite of the diverse cultural backgrounds of the participating students, they all acknowledged the significant potential of the complex. This led to the identification of various aspects of analysis, including landmarks, greenery, points of view, and meeting points.
Applying Kevin Lynch's urban analysis method[21], the urban context was semantically divided into

[21] As delineated in his most famous work "*The Image of the City*" (1960):
paths refer to channels or routes along which people move. They can be streets, sidewalks, footpaths, or other linear elements that guide pedestrian or vehicular movement. Paths often play a crucial role in urban navigation and create connections between different parts of the city; nodes are focal points or strategic locations within a city. They are typically areas of intense activity or points of intersection between different paths or districts. Nodes can be plazas, squares, parks, major intersections, or significant





Paths, Edges, Nodes, and Landmarks. The process was also developed using ArcGIS software, in which individual Features were attributed to each element and classified into distinct Layers. This analysis led to developmental prospects for commercial, social, cultural, and naturalistic purposes.

The outcome of this planning phase was a conceptual master plan for the area. The masterplan comprised the restoration of bastion edges, the organisation of greenery within the various bastions, construction of bridges, and establishment of new circular paths and walkways to enhance the link with the water element, also with the realisation of natural pools. The plan also featured the installation of new information panels, benches, and small architectural monuments, to facilitate user engagement with the heritage and value of the complex. As a result of these efforts, three potential future functions for the bastion were identified: a museum, a restaurant, or an art gallery, which could also be of use to the students at the nearby art school. The presented study sought a comprehensive analysis of the urban context of the Gdańsk Lower Town Fortification Complex, with the objective of creating an online platform for visualisation and comprehension of the site. Adopting a multi-phase approach involving literature research, field surveys, urban analysis, and conceptual master planning, the potential future functions of the bastions were explored. Then the results were brought to wider audiences by means of GIS-based online tools. The ArGIS StoryMap platform, developed by Esri, proved to be the most appropriate tool for presenting all the results. It makes it possible to create websites providing an immersive and engaging experience by seamlessly integrating various media forms, such as photos, videos, carousels, 2D maps and 3D ArcGIS scenes. In order to further explore the potential of this tool, a survey was also designed to gather feedback, fostering a connection between the researchers and the end-users within the study area.

Figs. 08. 09, 10
StoryMap Platform and User Survey Link
Main concept for the development of the digital platform, featuring access to the ArcGIS StoryMap and an embedded survey to gather user feedback and promote engagement.

landmarks. They serve as gathering places and often act as centres of economic, social, or cultural activity; edges are boundaries or linear elements that separate different areas or define the limits of a district or neighbourhood. They can be physical features like rivers, canals, or railroad tracks, or they can be man-made, such as walls, fences, or major roads. Edges provide a sense of enclosure and define the spatial extent of urban areas; landmarks, or topoi, are prominent and easily identifiable features within the urban environment. They can be buildings, monuments, sculptures, unique natural formations, or other visually distinctive elements. Landmarks serve as reference points and help people orient themselves within the city. They often have symbolic or historical value and can be used for wayfinding and navigation.

The workshop, therefore, acted as a catalyst for bridging academia, technology, and community involvement. By leveraging cutting-edge tools and methodologies, the students contributed to the ongoing dialogue about the preservation and revitalisation of cultural heritage. The resulting web app serves as a digital gateway, allowing users to virtually explore the bastions' multifaceted story and envision the potential transformations that could shape the future urban landscape of Gdańsk. The outcomes of the workshop, however, should be also discussed in a wider context of cultural and landscape heritage preservation as it actively explored various tools for collective database building and participatory planning. It was shown that the GIS environment is indeed suitable to integrate various current geospatial data (open urban data, models, results of digital surveys etc.) with historical sources. Most recently, the online and interactive tools bring even more possibilities to promote cultural and landscape heritage, increase the understanding of how they can be integrated with urban structures and support the process of urban planning. The management of such sites, which are a part or urbanised areas, is challenging, also due to the increasingly complex nature of urban governance and the need to integrate historical, environmental and social aspects. New digital tools and models can facilitate such management process and they make it possible to include various stakeholders into this process, especially due to the incorporation of online interactive tools based on geospatial resources (maps, models, spatial surveys etc.). This helps them to understand the complexity of such sites and express their needs regarding their use with respect to heritage and landscape assets. This was shown in the presented case study. Moreover, these new online digital tools offer the possibilities for rapid mapping and surveying that can be done on-site and in real-time, alongside the more detailed and complex digital survey methods such as laser scanning and photogrammetry, which makes it possible to better understand the urban structure and composition of the studied site and propose solutions for its future use.

References

Badach J., Szczepański J., Bonenberg W., Gębicki J., Nyka L. 2022, *Developing the Urban Blue-Green Infrastructure as a Tool for Urban Air Quality Management*, in *Sustainability*, (Switzerland), 14(15).

Campanaro D. M., Landeschi G., Dell'Unto N., Leander Touati A. 2016, *3D GIS for cultural heritage restoration: A 'white box' workflow, in Journal of Cultural Heritage*, 18, pp. 321-332.

Dell'Amico A. 2022, *Memoria e modello digitale. La costruzione di un sistema informativo per la salvaguardia del patrimonio architettonico diffuso dell'Upper Kama*, in *Restauro Archeologico*, 1, pp. 32-53.

Dos Santos J. M. R. 2017, *Reshaping the Urban Space in Portuguese Fortified Cities: New Green Spaces Resulting from the Rehabilitation of Urban Fortifications - From the Nineteenth Century until the End of the Estado Novo Dictatorial Regime (1974)*, in *Journal of Urban History*, 43, pp. 53-69.

Esri Inc. 2023, *ArcGIS Online - Web GIS Mapping Software*. https://www.esri.com/en-us/arcgis/products/arcgis-online/overview.

Ferré-Bigorra J., Casals M., Gangolells M. 2022, *The Adoption of Urban Digital Twins, in Cities*, 131.

Fu P., Sun J. 2011, GIS in the Web Era, in Fu P., Sun J. (eds.), *Web GIS: Principles and applications*, Esri Press, pp. 1-24.

Guidi G., Gonizzi Barsanti S., Micoli L. L., Russo M. 2015, *Massive 3D digitization of museum contents, in Built Heritage: Monitoring Conservation Management*, pp. 335-346.

Head Office of Geodesy and Cartography 2023, Geoportal. Geoportal (WWW Document). URL https://geoportal.gov.pl/ (accessed 1.4.23).

Kloppenburg S., Gupta A., Kruk S. R. L., Makris S., Bergsvik R., Korenhof P., Solman H., Toonen H. M. 2022, *Scrutinizing Environmental Governance in a Digital Age: New Ways of Seeing, Participating, and Intervening*, in *One Earth*, 5(3), pp. 232-241.

Lei B., Janssen P., Stoter J., Biljecki F. 2023, *Challenges of Urban Digital Twins: A Systematic Review and a Delphi Expert Survey*, in *Automation in Construction*, 147, 104716.

Migliaccio F. 2007, *Sistemi Informativi Territoriali e Cartografia*, Maggioli Editore.

Nishanbaev I. 2020, *A web repository for geo-located 3D digital cultural heritage models, in Digital Applications in Archaeology and Cultural Heritage*, 16, pp. 1-9.

Nishanbaev I., Champion E., McMeekin D. A. 2021, *A Web GIS-Based Integration of 3D Digital Models with Linked Open Data for Cultural Heritage Exploration*, in *International Journal of Geo-Information*, 10, 684.

Omilanowska M. 2010, *Defortyfikacja Gdańska na tle przekształceń miast niemieckich w XIX wieku*, in Biuletyn Historii Sztuki, 72, pp. 293-334.

Rowland A., Folmer E., Beek W. 2020, *Towards Self-Service GIS—Combining the Best of the Semantic Web and Web GIS*, in *ISPRS International Journal of Geo-Information*, 9(12).

Samól W., Kowalski S., Woźniakowski A., Samól P. 2023, *Where the Second World War in Europe Broke Out: The Landscape History of Westerplatte, Gdańsk/Danzig*, in *Land*, 12.

Schrotter G., Hürzeler C. 2020, *The digital twin of the city of Zurich for urban planning*, in *PFG – Journal of Photogrammetry, Remote Sensing and Geoinformation Science*, 88(1), pp. 99-112.

Szczepański, J., 2010. *Sightseeing in Gdańsk: the southern line of Gdańsk fortifications [in Polish: Zwiedzanie Gdańska: południowy ciąg fortyfikacji Gdańska]* [WWW Document]. iBedeker.pl. URL https://ibedeker.pl/spacery/atrakcje-gdanska-poludniowy-ciag-fortyfikacji-gdanska/ (accessed 1.5.23).

Trematerra A., 2022, *Il Patrimonio mondiale religioso inaccessibile. Conservazione e fruizione ampliata*, *Restauro Archeologico*, 1, 452-457.

United Nations UN, 2015. Retrieved from https://unric.org/it/agenda-2030/

External fortifications of 17th and 18th centuries

PLAN
der
STADT und SITUATION
von
DANTZIG
23. Flux Bast:
24. St. Jacobs Bast
25. Heil Leichnams Bast:
26. St. Elisabeths Bast:
27. Das Rathhauss
28. Der Pferde Marckt
29. Die Pfarr Kirche
30. St. Johanns Kirche
31. Grau Mönchen Kirche
32. St. Catharinen Kirche
33. St. Peters Kirche
34. St. Bartholomäi Kirche
35. St. Jacobs Kirche
36. Die Nonnen Kirche
37. Schwartze Mönchen Kirch
38. Weisse Mönchen Kirche
39. St. Elisabeths Kirche
40. Das Spende Hauss
41. Das Zucht Hauss
42. Das Post Hauss
43. Das Zeug Hauss
44. Die grosse Mühl
45. Die Langgartsche Kirche
46. Olivische Thor
47. Das Neugartsche Thor
48. Das Petershagische Thor
49. Die Schuss Bude
50. Jesuiter Kirche
51. Die Kohwalsche Brücke
52. Die Barmhertziger Brüder
53. Gross grund Berg
54. Horn Berg
55. Lange Berg
56. Kleine grund Schantz
57. Wundersberg
58. Rabenberg
59. Rosinen Berg
60. Heide Berg
61. Galgen Berg
62. Die Kleine Moll
63. Die grosse Moll
64. Der Weinberg
65. Der Leimberg
Rheinländische Ruthen
Ruthen
Zigankendorf
Hagelsberg
Bischofsberg
Holtz Raum
DAS
BÜRGER
WALL

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Side page, Fig. 01
Map showing Gdańsk fortifications in 1711

Gdańsk today stands as a remarkable example of one of the most extensive fortification works in present-day Poland and was among the largest in Europe until the 19th Century. The unique characteristic of the Gdańsk fortress lies in the simultaneous occurrence of lowland, mountain, and coastal fortifications, a result of its strategically vital location. The construction of Gdańsk's fortifications aimed to adapt to evolving needs driven by political developments within the city and trends in European fortification art. The Gdańsk fortress, in its most extended form, comprised several large fortification complexes that evolved over several hundred years across different parts of the city. To provide a brief overview, these can be divided into three distinct groups of fortifications: the main perimeter surrounding the Main Town, the Old Town, the Old Suburb, Granary Island, and the Lower Town after 1622; hill fortifications primarily situated on the hills of Biskupia Górka and Grodzisko; and the so-called coastal fortifications of Ostrów Island and the Vistula River course, along with the fortifications of Wisłoujście.

Historical contex

The mediaeval brick fortifications, erected in the latter half of the 14th and early 15th centuries, were characteristic of Teutonic Prussian cities. In Gdańsk, the brick wall enclosed only the Main Town, while the remaining settlements were predominantly protected by traditional semi-permanent fortifications made of wood and earth ramparts. In 1454, when an uprising against the Teutonic Knights broke out, the reign of the Teutonic Knights in Gdańskcame to an end after 145 years and 3 months. The city council decided to dismantle the existing Teutonic castle, removing the cross out suzerain stronghold that maintained control over thecross out "over the Gdańsk". In the following years, the city council decided to extend the existing mediaeval city defences to cover the Old Town and Old Suburbs. This late mediaeval fortification faced a threat due to the popularisation of firearms and new siege techniques, leading to the recognition that the existing fortifications were obsolete. The great change in thinking occurred in the years 1570-1577 when the so-called western front of the Main Town was completed, with the Lowland Gate crowning this endeavour. This type of fortification was far more resistant to artillery bombardment and represented a significant advancement, thanks to the strategic use of bastions that enabled intersecting fields of defensive fire. During this period, there was also a focus on extending the brick bulwark in Wisłoujście, the primary stronghold of the Vistula estuary. At the turn of the 17th century, Gdańsk featured a mix of medieval and Renaissance fortifications, though

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its defensive perimeter remained incomplete. To achieve full enclosure, the city adopted the proposal of Dutch siege engineer Peter Janssen of Veert, based on the principles of the so-called Old Dutch school, following a competitive selection process. He proposed continuing the already existing Italian type of Renaissance fortification but with the more cost-effective Dutch type of bastion fortifications. This plan resulted in the construction of a fortified perimeter extending approximately 1,280 meters from Gdańsk's Main Town Hall. The complete fortification of the city's defensive complex was finalized around 1637.

Fortification of the hills

In the initial planning phase, it was recognized that the two hills on the western side of Gdańsk had long been seen as vulnerable points, dating back to the early medieval period. Once seized and equipped with cannons, these elevations exposed the city to siege fire. As a result, reinforcing the defense of these hills became a key priority during the Renaissance modernization of the fortification system.

The invasion of Royal Prussia by the Swedes forced Gdańsk to build external fortifications. The hill fortifications were planned on two hills: Biskupia Górka and Gradowa Góra. Construction took place from 1628 to 1630 and reached completion in 1634. The so-called crown work, consisting of three bastions, was incorporated into the outline and constructed on Biskupia Górka. Probably in 1635, the earthen redoubt was added to serve as the final point of resistance. On the other hill, the Horn Work, consisting of two half-bastions, was erected. To cover the curtain wall between the bastions, the ravelin was added. In the middle of the 17th Century, the two separate fortification works were joined together with a new line of defences spanning through the valley between the hills, but still serving as two independent forts. Between 1706 and 1710, the fortifications on Biskupia Górka were completely rebuilt. The outer works were extended with ravelins, counter-bastions, and a covered road.

In 1793, during the second Partition of Poland, Gdańsk came fully under Prussian rule. This presented an opportunity to modernise the series of fortifications according to newer principles. The Prussian authorities deemed only the fortifications at the mouth of the Vistula useful: Wisłoujście fortress, Westerplatte, and New Port, due to advancements in artillery. With the outbreak of the Napoleonic Wars, in 1807, in anticipation of a French siege, a makeshift fortification in the form of an earthen lunette was hastily built on Jesuit Hill, which had been captured by Napoleonic troops at the beginning of the siege in March 1807.

Following the conquest of Gdańsk by Napoleon's army in 1807, it was decided to establish Gdańsk as a free city-state for the first time, under French influence. French engineers took charge of reconstructing and expanding the fortifications, particularly those on Gradowa Gora, transforming their initial hornwork shape into a much more modern form. Additionally, the French added a final resistance redoubt, named after the great French siege engineer, Sebastian Vauban.

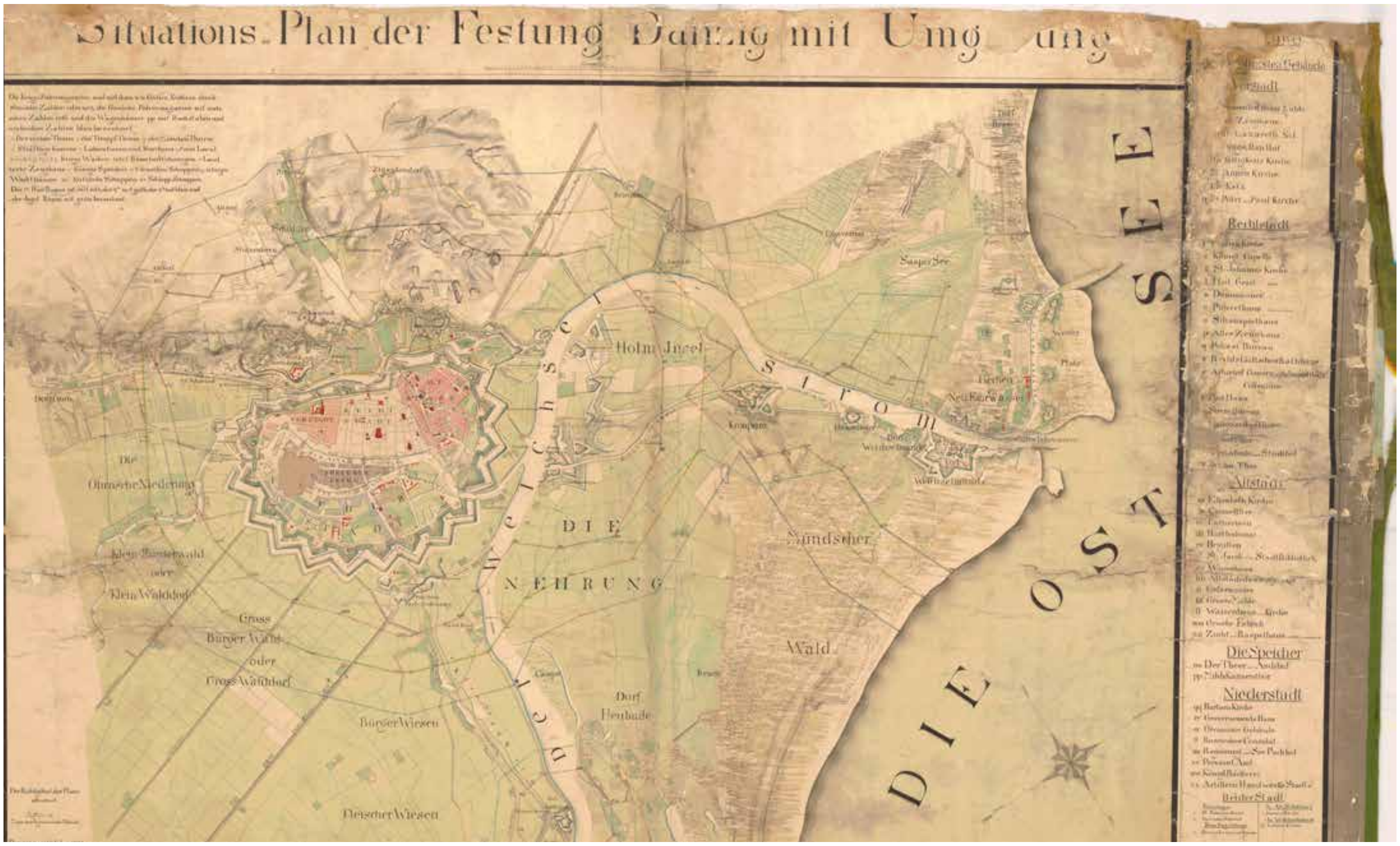

Fig. 02
Map showing Gdańsk fortifications in 1835

After the recapture of Gdańsk by the anti-French coalition in 1814, the city returned once again under Prussian rule. The new government resolved to strengthen the vulnerable Jesuit Hill and reconstructed the redoubt into a typical New Prussian fortification in the form of a flattened pentagon. Subsequently, it underwent further enhancements with warfare technology corresponding to the 19th Century, such as caponiers and shooting galleries, along with a detached gunpowder magazine and an ammunition laboratory. The following year marked a period of significant military investment, leading to the enhancement of the existing fortification system situated on Bishops Hill. The final defence redoubt was reconstructed, incorporating military residential functions and taking the form of fortified barracks. These investments also resulted in the construction of a separate structure dedicated to the military post commander. Additionally, the adjacent hill underwent extensive investment, leading to further reconstruction of French changes, such as the implementation of caponiers covering the dry moats in front of the hill's fortifications.

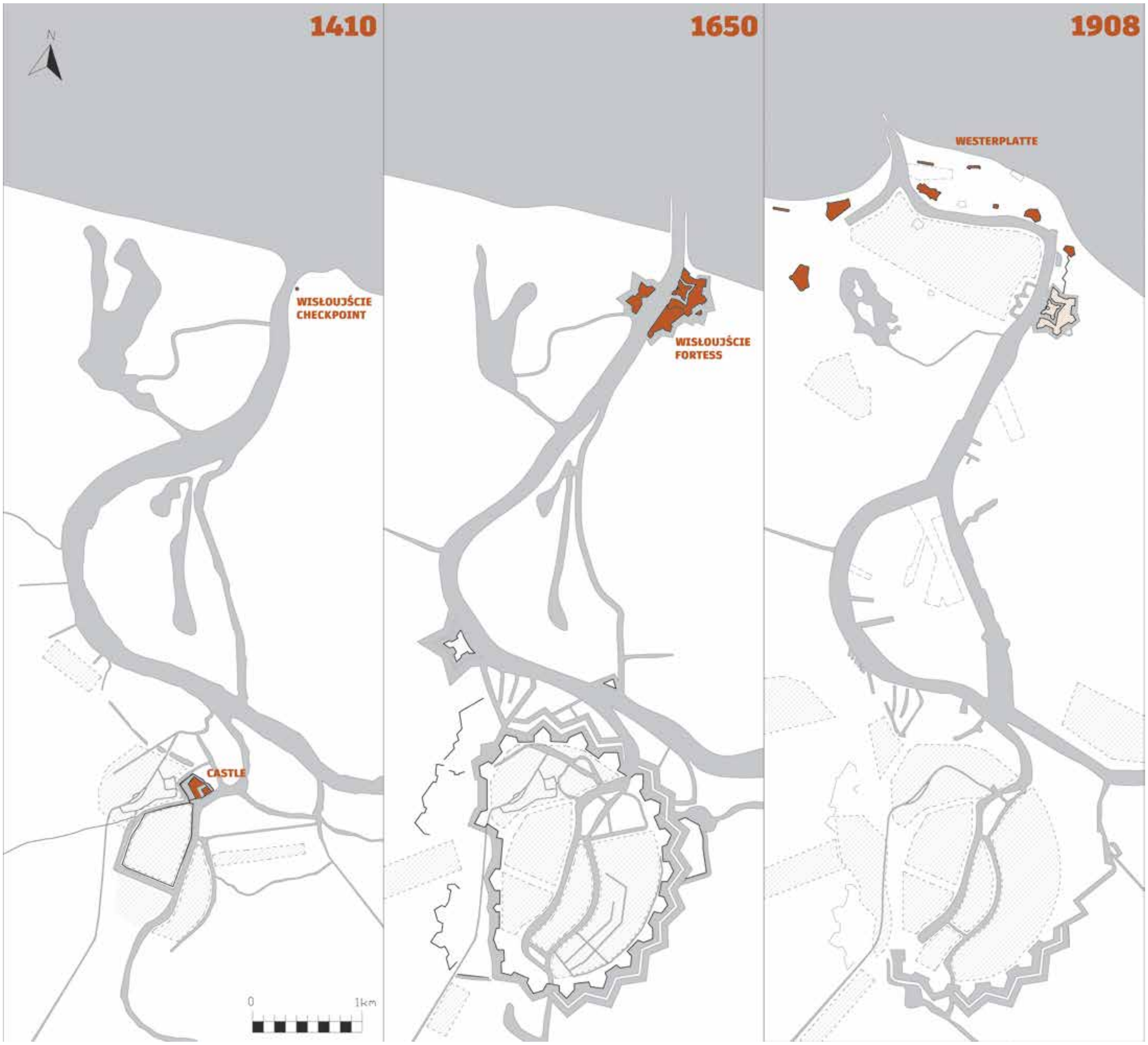

Fig. 03
Topografic map showing the remains of fortifications in the city of Gdańsk

Coastal and river fortification

A similar investment to increase the defensive capabilities could be observed in the fortification of the direct coastal region. Primary Wisłoujście Fortress (described in another article) and supportive strongpoints along the river and coast. Due to the issue of the Vistula Fortress being separated from the main perimeter of city defences, it was necessary to connect the two strongholds with military fortifications. In 1625, at the southern end of Ostrów Island, one of the entrenchments was constructed to initiate the process of linking the fortifications into the bigger system allowing for the communication of troops .

Fig. 04
Topografic model and map showing the remains of fortifications in the city of Gdańsk

In approximately 1639, a rampart with four bastions, resembling a type of fort carre, was constructed on the left bank of the Vistula River, known as the Great Limestone Rampart. Its primary objective was to reinforce and fortify the northern pass between Grodzisko hill and the left riverbank of the Vistula River with artillery coverage. Its strategic significance stemmed from its separation from the main ring of fortifications, serving as a forward military position with its rear adjacent to the river. To link Wisłoujście with the city, a series of redoubts were built along the canal of the yet-to-be-formed Holm island; the canal served as a moat in front of the road. Later, earth embankments were added to create a covered road, ensuring the safe passage of troops between Gdańsk and the Wisłoujście fortress. In 1652, the Great Limestone Rampart was diminished, retaining only its northern portion, which was then converted into an independent redoubt.

After the First Partition of Poland in 1772, Gdańsk found itself separated from Poland and operated as an extraterritorial enclave within the Prussian occupation zone. The border, partially aligned with the river and positioned in front of the city's bastion fortification, allowed Wisłoujście to remain on the Polish side. The new Prussian government took steps to establish a settlement in the river bend just before the estuary, aiming to oversee river traffic and customs, naming it Neufahrwasser (New Port). Prussian authorities fortified the settlement with a series of separate earthworks from the north and west. Between 1788 and 1790, they constructed four redoubts on Westerplatte to regulate access to the port of Gdańsk. Interestingly, these fortifications were not integrated into Gdańsk's fortification system and remained separated under prussian rule[1].

In 1814, mentioned before, the Prussians aimed to bolster existing fortifications in New Port by erecting a new fort, Fort Brosen. This fortification was intended to enhance the defense capabilities of the separate settlement. It is quite interesting because the Prussian colony was transformed into a small form of a defensive ring with multiple polygonal resistance points, thus creating another strong point in proximity to Gdańsk. The fort itself was a sizable polygonal-shaped earthwork with an internal circular brick-made redoubt-barracks. Wart was also equipped with gun emplacements and caponiers covering the moat in case of a frontal attack. Situated in the pass between the coast of the Baltic Sea and Lake Zaspa, it served as a strategic location. A similar earthwork was constructed on the Baltic coast to safeguard the river estuary and thereby control access to the port of Gdańsk was called the Port Battery, initially as the similar form of polygon shape earthwork fort in 1889.

An interesting aspect is that, due to its coastal location and the Prussian government's view that it held limited strategic value for defending the eastern border of the Prussian Empire, Gdańsk was never fully surrounded by a ring of forts, unlike other Polish fortress cities such as Toruń, Grudziądz, Malbork, Poznań, Wrocław, or Kostrzyn. There were only plans and considerations for such an investment. These plans focused on the construction of sections of a ring consisting of a couple of forts to enhance defense capabilities and protect Gdańsk from the northern part, between the coast and hills, which was always perceived as a weak spot for defense.

In the late 19th Century, as military developments progressed, existing structures became obsolete, necessitating the creation of new forms of military fortification. This marked the emergence of long-range artillery and mortar positions, known as batteries. The Prussian government, recognizing this need, decided to establish several coastal batteries. These batteries were strategically positioned to provide artillery fire covering a significant portion of the Gulf of Gdansk. They consisted of eight stationary batteries and five field batteries, which defended access to the mouth of the Vistula River and the Port of Gdansk.

Despite undergoing modernization, the fortification system was quickly deemed obsolete, prompting a gradual reduction or reconstruction effort starting in 1907. Some existing structures underwent reconstruction and extension, such as the resistance points along the left river bank: Port Battery, Village Battery, and Beach Battery. This period is characterized in excessive use of reinforced concrete as a material that is able to whistand the direct artillery fire much more sufficient that the masonry brick construction, thus many of the existing structures were rebuild using concrete constructions. The right shoulder of Port Battery was extended to accommodate a new artillery position for long-

[1] Samól (2023), *Where the Second World War in Europe broke out: the landscape history of Westerplatte*.

range 21cm cannons, altering its initial symmetric plan also with the increase of the crew quarters area. As previously mentioned, Fort Brosen underwent upgrades in its northern section, including the installation of an external battery emplacement known as Dorfbatterie (Village Battery), consisting of four 283 mm caliber howitzer positions and five shelters. Additionally, the existing fort was equipped with a narrow-gauge railroad and served as a munitions storage facility to support battery operations. In the case of the beach battery, upgrades resulted in a reduction from 6 fire stations to just 4. It is noteworthy that the Prussians utilized disappearing cannons, which were raised before firing and depressed for reloading after the projectile left the muzzle. The right bank of the river was fortified with two separate fortificatiions Bay Battery and Forest Battery. Construction of the third Dune Battery began before 1918, but it was left incomplete with the end of World War I.

The demilitarization of the Free City of Gdańsk after 1918 brought an end to all forms of fortifications around the city and its designated borders, following an agreement brokered by the League of Nations. This period lasted until the capture of Gdańsk by the Third Reich in 1939. The Nazis established emplacements for anti-aircraft purposes to protect the shipyards, which were crucial for the Nazi war machine. During the attack by the Red Army and the siege in March 1945, defenders hastily constructed field fortifications in an attempt to halt the advancing forces. However, most of the still-existing emplacements from the previous years, such as various batteries, were obsolete and did not play a significant role in the defense. This highlighted a shift in the war theater, where doctrines like blitzkrieg demonstrated the ease of bypassing the defensive potential of such fortifications.

Following the city's reintegration into Polish territory in 1945, the new communist government and the Ministry of Defense decided to construct a new type of coastal artillery system. This included long-range anti-naval gun emplacements, along with supporting infrastructure such as rangefinders, command posts, and barracks. Several strongpoints with fixed artillery batteries were established in the Gulf of Gdańsk, including one in the Stogi district. These batteries, like their predecessors, were tasked with the direct defense of the Port of Gdansk and the defense of the eastern basins of the Gulf of Gdansk. However, similar to other batteries, they eventually faced a gradual reduction in combat tasks and service, because at the time of construction they could be described as obsolete.By the 1970s, the emplacements had entered a phase of routine maintenance before being fully abandoned in 1977, marking the end of Gdańsk's fortification era.

State of preservation and importance

Due to factors such as the decline in military relevance, remote locations, and structural complexity, many fortifications and defensive complexes around the world are now falling into decay. One significant factor contributing to this decay is the evolution of warfare tactics and technology. As modern warfare has shifted away from traditional fortifications towards more mobile and technologically advanced strategies, the need for static defensive structures has diminished. Furthermore, the geographical locations of some fortifications present challenges for maintenance and preservation. Forts built in remote or harsh environments may face difficulties in accessing necessary resources for upkeep, leading to their gradual deterioration over time. As a result of these factors, many fortifications that once stood as symbols of strength and military prowess now stand as relics of a bygone era, gradually succumbing to the forces of nature and neglect. Efforts to preserve and protect these historical sites are essential not only for their cultural and historical significance but also for the lessons they offer about the evolution of warfare and human ingenuity.

The most fascinating aspect of repurposing fortifications in Gdansk is the transformation of the former hill fortification into an educational and open-air history museum institution called Hevellianum. Situated in the former encampment at the Grodzisko district, this institution plays a significant role in preserving the city's history. Conservation efforts have stabilized the damaged structures, preventing further decay. Restoration works have focused on preserving the authentic character of the complex. Within the casemates and munitions laboratories, a permanent exhibition showcases the history of the fortifications and the city of Gdansk. This initiative has provided Gdansk residents with an engaging space for recreation and education. Additionally, it has helped diminish the problem of neglect in this area, ensuring that the historical significance of the fortifications is recognized and appreciated by both locals and visitors alike.

Another approach is to preserve objects in a state of permanent ruin, such as the coastal batteries in Gdansk. One of these batteries has been incorporated into a park to increase its attractiveness. However, despite many efforts to adapt existing fortifications, challenges remain.Many important and historically significant sites are still awaiting conservation and adaptive reuse, with the potential to become vivid and authen. Structures such as the Jesuits' Rampart and the crownwork at Bishops Hill are among those most in need of such investment.

The peripheral fortifications situated in Gdansk hold significant scholarly interest as they represent tangible evidence of the evolution of military strategy and technology. These structures serve as poignant relics of history, embodying architectural heritage that reflects the city's strategic importance over the centuries. Furthermore, their adaptive reuse for educational purposes underscores their enduring relevance in contemporary society, providing valuable insights into both the past and present understanding of defense systems and urban development.

References

Samól W., Kowalski S., Woźniakowski A., Samól P. 2023, *Where the Second World War in Europe broke out: the landscape history of Westerplatte*, Gdańsk/Danzig, in *Land*, 12, 596.

Bakalarczyk S. 2021, *Rozwój przestrzenny Nowego Portu w latach 1772-1939*, in *Historie Gdańskich Dzielnic*, vol. 3, Nowy Port, pp. 67-108.

Kucharski K. 2021, *Oddziały wojskowe w Nowym Porcie na przełomie XVIII i XIX wieku (Military detachments, in New Port at the turn of the 18th and 19th centuries)*, in *Historie Gdańskich Dzielnic*, vol. 3, Nowy Port, pp. 129-150.

Paluchowski P. 2021, *Na zachodnim brzegu Wisły. Średniowieczne i nowożytne dzieje terenów późniejszego Nowego Portu (On the west bank of the Vistula. Medieval and modern history of the area of the later New Port)*, in *Historie Gdańskich Dzielnic*, vol. 3, Nowy Port, pp. 35-66.

Massalski R., Stankiewicz J. 1969, *Rozwój urbanistyczny i architektoniczny Gdańska (Urban and architectural development of Gdańsk)*, in *Gdańsk - jego dzieje i kultura*.

Stankiewicz J., Biskup K. 1998, *Fortyfikacje miejskie Gdańska od XVI do XIX wieku (City fortifications of Gdańsk from the 16th to the 19th Century)*, in *Gdańsk Pomnik Historii, teka gdańska* 3, pp. 82-114.

Biskup K. 1998, *Rejony ograniczeń budowlanych twierdzy gdańskiej w wiekach XIX i XX (Construction restriction areas of the Gdańsk fortress in the 19th and 20th centuries)*, in *Gdańsk Pomnik Historii, teka gdańska* 3, pp. 115-127.

Bukal G. 2012, *Fortyfikacje Gdańska i ujścia Wisły 1454-1793. Studium z dziejów nowożytnej architektury militarnej (Fortifications of Gdańsk and the Vistula estuary 1454-1793. Study in the history of modern military architecture)*, Grzegorz Bukal, Sopot, pp. 122.


Die belagrunge kunigklicher
Maiestat zu Polen des hauses
zur Weisselmunde fur danzik
geschehen im Augusto Anno
1577
Poln: schanze
Danzker schanze

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Gdańsk, like almost every historic port on the southern Baltic coast (e.g. Lübeck, Wismar, Stralsund, Szczecin/Stettin, Kołobrzeg/Kolberg, Königsberg, Klaipeda/Memel, Riga), was located at some distance from the coastline. This case was due to the need to use the system of rivers (Vistula, Motława, Radunia Canal) as a natural harbour, giving shelter to ships. The spatial development of the Gdańsk agglomeration in the 2nd half of the 14th Century resulted in part of the harbour (so-called Bollwerk in the Young Town, as well as timber yards by the Vistula River) having been outside the supervision and protection of the Gdańsk castle. As a result, a new checkpoint was established at the mouth of the Vistula to the Baltic Sea (Wisłoujście/Weichselmünde). In the following centuries, a coastal fortress was built there, giving the Gdańsk authorities complete control over the largest port of the Polish-Lithuanian Commonwealth.

Side page, Fig. 01
The Wreath and wooden rampart in 1577
Anonymous drawing from the Gdańsk Library of Polish Academy of Sciences.

State of the art

The Wisłoujście Fortress is a remarkable example of *architectura militaris*, representing a monument to some 400 years of fortification development from the late Middle Ages to the Prussian-French War. Although the first studies on the history of the fortress were written in the 19th Century by a few officers serving in Gdańsk[1], the essential work on the construction and development of the fortress is a monographic article by Jerzy Stankiewicz from 1956[2]. It was a summary of field research carried out in the Fortress after World War II, modifying many erroneous findings and hypotheses of earlier literature. In the 1960s and 1970s[3]. archaeological surveys were carried out in the fortress, continuing into the 21st Century[4] and contributing much detailed information. An attempt to summarise the state of knowledge about the fortress, together with an analysis of the numerous bastion designs from the 17th Century, was brought by the monograph of Grzegorz Bukal[5]. Undoubtedly, it is still the best guide to the archives on the modern fortifications of Gdańsk, but - due to the broad scope of the subject matter - leaves many research questions open.

Fig. 02
The Fort Carre in 1608
Part of I. van den Blocke's painting from the Council Chamber in the Main City Hall, currently the Museum of Gdańsk.

[1] Hoburg (1852), *Geschichte der Festungswerke Danzigs*; Hoenigk (1886), *Geschichte der Festung Weichselmünde bis zur preussischer Besitznehme 1793*; Koehler (1893), *Geschichte der Festungen Danzigs und Weichselmünde bis zum Jahre 1814 in Verbindung mit dem Kriegsgechichte der freien Stadt Danzig*.
[2] Stankiewicz (1956), *Nadmorska Twierdza w Wisłoujściu [Coast fortress in Wisłoujście]*, pp. 115-156; Stankiewicz (1956), *Twierdza w Wisłoujściu i niektóre problemy związane z jej odbudową*, pp. 177-187
[3] Zbierski (2000), *Twierdza morska w Wisłoujściu w świetle badań kompleksowych Pracowni Archeologicznej IHKM PAN i Centralnego Muzeum Morskiego [Coast fortress in Wisłoujście in the light of research conducted by the Archaeological Station of the Polish Academy of Sciences and Central Maritime Musuem]*, pp. 31-51.
[4] Dabal (2014), *Gdańsk. Twierdza Wisłoujście. Badania archeologiczne w latach 2013–2014 [Wisłoujście Fortress. Gdańsk. Archaeological and architectural investigations, 2013-2014]*; Kasprzak (2021), *Fortyfikacje Gdańska od schyłku średniowiecza do końca XIX wieku. Geneza, rozwój i przemiany przestrzenne umocnień Gdańska i Wisłoujścia. Studium archeologiczne [Fortifications of Gdansk from the end of the Middle Ages up to the end of the 19th century. Origins, development and spatial transformation of the forts in Gdańsk and Wisłoujście. Archaeological study]*.
[5] Bukal (2012), *Fortyfikacje Gdańska i ujścia Wisły 1454-1793 [Fortifications of Gdańsk and the mouth of Vistula River 1454-1793]*.

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Since 2018, researchers from the Faculty of Architecture at the Gdansk University of Technology have conducted systematic architectural research on successive elements of the fortress - the tower, the Wreath (circular brick bulwark), and the Carre Fort. The aim is to produce a monograph on the architecture of this fortress. So far, partial results have been published[6]. They allow a new look at the history of the fortress.

Brief history of the Wisłoujście fortress

The first checkpoint at the mouth of the Vistula River to the Baltic - the main waterway and, at the same time, the only entrance to the port of Gdańsk - was established in the second half of the 14th Century by the Teutonic Order. The development of the medieval agglomeration of Gdansk meant that the existing Teutonic castle could no longer control port traffic, which was particularly important due to the introduction of the pound duty (general tax in Prussia). For this reason, it was probably necessary to erect a wooden keep, at which the ***Mündemeister*** clerk officiated[7] .

In 1482, a brick lighthouse (about 17 metres high) was erected on the seashore, two storeys remaining in the walls of the present tower. For the first time, the lighthouse was provided with an additional rampart in 1517-1519 - its form is still debated, as archaeological research has not yielded conclusive results. Indeed, some brick construction was set around the lighthouse before 1560[8] .

In 1561, the Gdańsk authorities demolished the existing fortifications around the tower and built a sizeable standalone bulwark called the "Wreath" (completed in 1563). It was a four-storey fire tower with 32 artillery positions (on two levels) and a guard porch on the top. Its construction was supported by the town masonry workshop, which also worked by the remodelling of the Renaissance town hall tower[9] . Devoid of rooms to house the crew, it had to have a relatively small staff, augmented only in times of danger. Engineers employed by the city council soon recognised that the structure required some improvements - the transformation of the entrance on the lower level of the Wreath and the surrounding coastal gun tower with an additional wooden rampart (c. 1573).

In 1577, Gdańsk did not recognise the election of Stefan Batory as king of Poland, which led to the outbreak of civil war. Wisłoujście became the site of a struggle for control of the harbour - Polish troops stormed the Wreath twice in June and September 1577, but despite the damage, it did not fall. During the military actions, the square wooden rampart was enhanced with quasi-bastions in the corners and curtain wall designed by an officer of Gdansk mercenaries Hans Losemmert[10].

The rebuilding of Wisłoujście after its devastation in the 1577 war gave rise to the most intensive development period for the fortress. At first the Wreath, which had lost its defensive function, was reconstructed and

[6] Samól et al. (2021), *History of the Lighthouse of the Wisłoujście Fortress in Light of a 2018 Architectural Study*,, pp. 21-36; Samól et al. (2022), *Wreath from the Wisłoujście Fortress, Dating from the 1560s, and Its Transformation and Damage in the War of 1577 in the Light of Architectural Research from 2020–2022*; Bukal, Samól [in print], Architektura koszar w Twierdzy Wisłoujście w XVII wieku (Architecture of baracks in Wisłoujście Fortress in the 17th century).

[7] Samól (2023), *The novel findings abouth the Hussite's warfares in the Gdansk/Danzig suroundings in the late Summer of 1433*, pp. 43-48.

[8] Samól et al. (2022), *Wreath from the Wisłoujście Fortress, Dating from the 1560s, and Its Transformation and Damage in the War of 1577 in the Light of Architectural Research from 2020–2022*, pp. 62-79.

[9] Hirsch (1991), *Nowe wiadomości o Wieńcu twierdzy Wisłoujście (New information about the Wreath in the Wisłoujście Fortress)*.

[10] Samól et al. (2022), *Wreath from the Wisłoujście Fortress, Dating from the 1560s, and Its Transformation and Damage in the War of 1577 in the Light of Architectural Research from 2020–2022*, pp. 62-79.

Fig. 03
Wisłoujście Fortress in 1617
Drawing by A. Dickmann from the Gdańsk Library of Polish Academy of Sciences.

Fig. 04
Battle of Oliva (1627) seen from the Wisłoujście Fortress
Retrospective sketch by H. Böhme from the Kórnik Library of Polish Academy of Sciences.

overbuilt in favour of a barracks function. The re-arisen tower-lighthouse was covered with a new helmet in 1593, probably designed by Anton van Obberghen - the architect of the Kronstad royal castle reconstruction (Denmark)[11]. In the 1580s, the construction of a new Fort Carre also began, completed after amendments around 1602. A four-bastion fort was built on the plan of an irregular quadrangle - a layout modelled on Italian solutions[12], which had been applied in northern Europe since the mid-16th Century. The original design of the brick fortification was the work of Johann Schneider of Lindau, who was also active in Silesia[13].

The commencement of the wars of the Polish-Lithuanian Commonwealth with the Kingdom of Sweden (1598-1660) accelerated (significantly impacting) the fortification of Gdańsk - including Wisłoujście. The need to improve the fortress (including the curtain walls) was highlighted in Captain Ferrero's report from 1602. He criticised the small scale of erected bastions and recommended strengthening them[14] , but most of his advice was not carried out in the following years. Further changes to the Fort Carre were implemented after 1617, heightening the ramparts over the bastions, among other things.

Even before 1615, Fort Carre sought to surround the fort with additional encirclement - an additional small bastion on the beach and a supplementary outer barracks building was then created. This not-quite-thought-out establishment was transformed into a new ring of fortifications - the East Ramparts (1623/7-1634). In the 1st half of the 17th Century, Bastion II was still located on the beach[15]. Furthermore, due to the course of the Baltic coastline, the primary form of the Western Rampart was not found in front of the Fort Carre and the lighthouse but about 200 m upstream - opposite to the temporarily existing Keeler (Polish: *Kleszowy*) Ramparts[16].

Royal Prussia and Gdańsk's military situation caused described transformations of external ramparts. In 1627, a large corps of the Swedish army led by King Gustav Adolf entered the province, and his fleet began a blockade of Gdansk's port. Strengthening the Wisłoujście Fortress has become a matter of extreme urgency.

[11] Habela (1965), *Antonis van Obberghen. Architekt i fortyfikator flamandzki z przełomu XVI i XVII w. (Antonis van Obberghen. Flemish architekt and builder of fortification from the turn of the 16th century)*, Samól et al. (2021), *History of the Lighthouse of the Wisłoujście Fortress in Light of a 2018 Architectural Study*,.

[12] Stankiewicz (1956a), *Nadmorska Twierdza w Wisłoujściu (Coast fortress in Wisłoujście)*, Bukal (2012), *Fortyfikacje Gdańska i ujścia Wisły 1454-1793 (Fortifications of Gdańsk and the mouth of Vistula River 1454-1793)*.

[13] Lewicka (1998), *an Schneider z Lindau a twierdza w Wisłoujściu (Johann Schneider of Lindau and his connections with Wisłoujście Fortress)*.

[14] Bukal (2012), *Fortyfikacje Gdańska i ujścia Wisły 1454-1793 (Fortifications of Gdańsk and the mouth of Vistula River 1454-1793)*.

[15] Bukal (2012), *Fortyfikacje Gdańska i ujścia Wisły 1454-1793 (Fortifications of Gdańsk and the mouth of Vistula River 1454-1793)*.

[16] Stankiewicz (1956), *Twierdza w Wisłoujściu i niektóre problemy związane z jej odbudową*,.

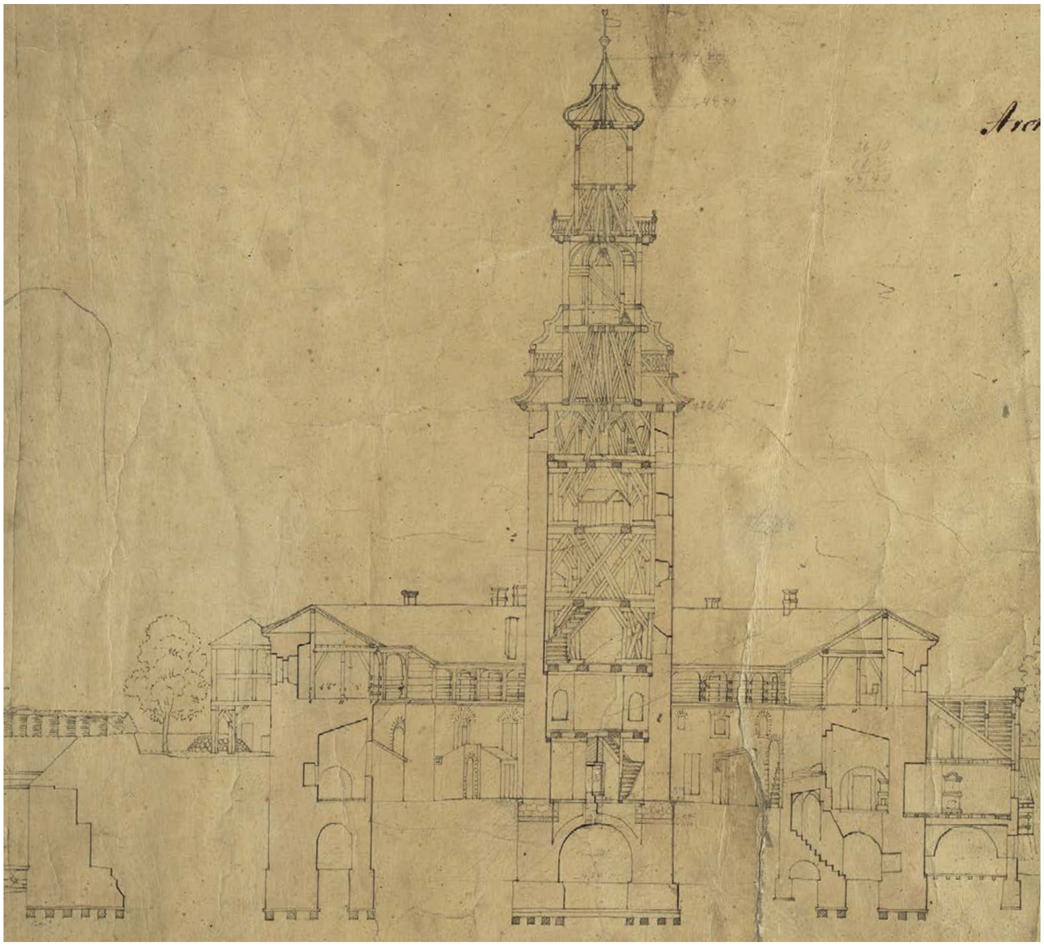

Fig. 06
Cross-section through the Wreath from ca. 1820
Anonymous engineer's drawing from the State Archive in Gdańsk.

Spatial changes in the area of the Vistula mouth (the founding of New Port after 1772 and the fortification of Westerplatte Island after 1783) necessitated the redesign of Wisłoujście, which in 1809 received a protruding rampart. For both the Prussians (1783-1807 and after 1814) and the French (1807-1814), it was crucial to secure the harbour against the expected Russian landing[19] . The Wisłoujście fortress was losing importance concerning modern fortifications and quay batteries located on the Westerplatte peninsula and at the New Port. In 1848-1855, a modern Seagulls' Rampart was built over the old buried mouth of the Vistula, linking the Wisłoujście Fortress with the complex of modern ramparts located at Westerplatte. The fortress was last modernised in the 1860s-70s. In the 19th Century, the shift of the coastline and the development of modern coastal fortifications resulted in the loss of the fortress's combat significance - it was treated primarily as a warehouse and barracks for the fortress complex of the entrance to the port of Gdańsk. It was also used as a jail for political convicts (e.g. Polish insurgents of 1831). The Western Fortress then lost its importance completely – military building restrictions had been suspended after 1886, and the whole structure was demolished before 1899. The last renovations were carried out[20].
After World War II, in 1920, the Free City of Gdansk became a demilitarised zone - the Wisłoujście Fortress

[19] Podruczny (2020) *Twierdze z papieru. Fortyfikacje pruskie w latach 1786-1807 (Forts of paper. Prussian fortifications in years 1786-1807)*, Nieuważny (2022), *Klucz do wszystkiego. Dzieje napoleońskiej twierdzy Gdańsk 1807-1814 [A key to everything. History of the napoleonic fortress Gdańsk 1807-1814]*.
[20] Samól et al. (2023), *Where the Second World War in Europe broke out. The landscape history of Westerplatte*.

Fig. 05
Plan of Wisłoujście Fortress from 1673
Drawing by A. Strackwitz from the State Archive in Gdańsk.

Moreover, in the middle of the 17th Century, several forts and a covered road connecting the Wisłoujście fortress with the city 3 km away were constructed[17].

Such a complex fortress with three separate circles of fortifications was difficult to defend and required a large crew. At least from the end of the 16th Century, the permanent crew of Wisłoujście numbered about 120 soldiers, but during sieges (the threat from Sweden), the fortifications were manned by an army of 1000-1500 men. For the permanent crew, barracks were built inside the Fort Carre - at the western curtain (c. 1620) and around the rim (c. 1627). The town engineer Jerzy Strakowski (George Strackwitz) supervised the work during this period. Additional soldiers' quarters were erected inside the Dutch-type bastions as required. In peacetime, these buildings were reduced (dismantled) and later restored - a unique barracks building from around 1800 has been preserved at Bastion II of the Eastern Bastion[18]. In 1655, the location of the Western Rampart was corrected by erecting it opposite Fort Carre and the lighthouse. This layout - abandoned and reduced at the beginning of the 18th Century (when the extent of the Western Rampart was reduced and the Eastern Rampart was partly spanned to form a wide mantle) - was hastily reconstructed at the end of the Great Northern War (before 1720).

[17] Stankiewicz (1956a), *Nadmorska Twierdza w Wisłoujściu (Coast fortress in Wisłoujście)*, Bukal (2012), *Fortyfikacje Gdańska i ujścia Wisły 1454-1793 (Fortifications of Gdańsk and the mouth of Vistula River 1454-1793)*.
[18] Bukal, Samól [in print], *Architektura koszar w Twierdzy Wisłoujście w XVII wieku (Architecture of baracks in Wisłoujście Fortress in the 17th century)*.

lost its military character. A yacht club was set up in its area, and a summer and fishing settlement was developed in the immediate vicinity. In late March 1945, the mannerist barracks at Fort Carre, the Wreath and the lighthouse (which partially collapsed in the winter of 1952.) were damaged during the Red Army's assault. These structures were rebuilt in 1956-1961 - however, many construction mistakes and controversial conservatory decisions were made due to the lack of documentation from before the destruction and the problems in interpreting the centuries-old architectural stratigraphy: the tower had never been topped with a crenellation before, the form of the reconstructed gun posts and windows in the Wreath were chaotic, even relics of the painted decoration in the barracks were destroyed [21].

The development of industrial plants in the neighbourhood and the port expansion caused further damage: part of Bastion I in the Eastern Bastion was dismantled, and there were even plans to demolish the entire ring of fortifications[22]. Although the building was handed over to the museum in 1975, more severe work began after the political transformation in Poland. After 1990, the gradual revalorisation of the fortress began, led by its host, the Gdansk Museum. A team from the Gdansk University of Technology has been conducting intensive field research since 2018 to develop a historical-architectural monograph of the building.

Wisłoujście Fortress is a unique monument to the development of coastal fortifications from the late Middle Ages until the end of the 19th Century. In its example, one can follow the transformation of permanent fortifications conditioned by the development of firearms. Due to the object's state of preservation - its authenticity and integrity - it was awarded the prestigious title of 'the monument of history' by the President of the Republic of Poland in 2020. Moreover, future efforts are planned to include the Fortress on the UNESCO World Heritage List.

References

Bukal G. 2012, *Fortyfikacje Gdańska i ujścia Wisły 1454-1793 (Fortifications of Gdańsk and the mouth of Vistula River 1454-1793)*, Bukal, Sopot.

Bukal G., Samól P. in print, *Architektura koszar w Twierdzy Wisłoujście w XVII wieku (Architecture of barracks in Wisłoujście Fortress in the 17th Century)*.

Dąbal J. (ed.) 2015, *Gdańsk. Twierdza Wisłoujście. Badania archeologiczne w latach 2013–2014 (Wisłoujście Fortress. Gdańsk. Archaeological and architectural investigations, 2013-2014)*, Muzeum Gdańska.

Habela J. 1965, *Antonis van Obberghen. Architekt i fortyfikator flamandzki z przełomu XVI i XVII w. (Antonis van Obberghen. Flemish architect and builder of fortification from the turn of the 16th Century)*, Gdańsk, PhD Thesis.

Hirsch R. 1991, *Nowe wiadomości o Wieńcu twierdzy Wisłoujście (New information about the Wreath in the Wisłoujście Fortress)*, in *Kwartalnik Architektury i Urbanistyki*, 36(3).

Hoburg K. 1852, *Geschichte der Festungswerke Danzigs*, Wedelsche Hofbuchdruckerei, Danzig.

[21] Stankiewicz (1956a), *Nadmorska Twierdza w Wisłoujściu [Coast fortress in Wisłoujście]*, pp. 115-156; Samól et al. 2021; Samól et al. (2022), *Wreath from the Wisłoujście Fortress, Dating from the 1560s, and Its Transformation and Damage in the War of 1577 in the Light of Architectural Research from 2020–2022*, pp. 62-79.

[22] Krośnicka, Wawrzyńska (2023), *How the Depths of the Danish Straits Shape Gdańsk's Port and City Spatial Development*, pp. 346-362.

Hoenigk F. 1886, *Geschichte der Festung Weichselmünde bis zur preussischer Besitznehme 1793*, Frederich Luckhardt, Berlin.

Kasprzak M. 2020, *Fortyfikacje Gdańska od schyłku średniowiecza do końca XIX wieku. Geneza, rozwój i przemiany przestrzenne umocnień Gdańska i Wisłoujścia. Studium archeologiczne (Fortifications of Gdansk from the end of the Middle Ages up to the end of the 19th Century. Origins, development and spatial transformation of the forts in Gdańsk and Wisłoujście. Archaeological study)*, PhD Thesis, Łódź–Gdańsk.

Koehler G. 1893, *Geschichte der Festungen Danzigs und Weichselmünde bis zum Jahre 1814 in Verbindung mit dem Kriegsgechichte der freien Stadt Danzig*, vol. 1: Bis zum Jahre 1734, Wilhelm Koebler, Breslau.

Krośnicka K., Wawrzyńska A. 2023, *How the Depths of the Danish Straits Shape Gdańsk's Port and City Spatial Development*, in *Urban Planning*, 8(3), pp. 346-362.

Lewicka-Cempa M. 1998, *Jan Schneider z Lindau a twierdza w Wisłoujściu (Johann Schneider of Lindau and his connections with Wisłoujście Fortress)*, in Molski P. (eds.), *Zespół forteczny Gdańsk-Wisłoujście. Problemy ochrony zespołów pofortecznych, Towarzystwo Przyjaciół Fortyfikacji*, Gdańsk, pp. 29-53.

Nieuważny A. 2022, *Klucz do wszystkiego. Dzieje napoleońskiej twierdzy Gdańsk 1807-1814 (A key to everything. History of the Napoleonic fortress Gdańsk 1807-1814)*, Muzeum Gdańska, Gdańsk.

Podruczny G. 2020, *Twierdze z papieru. Fortyfikacje pruskie w latach 1786-1807 (Forts of paper. Prussian fortifications in years 1786-1807)*, Tetragon, Warszawa.

Samól P. 2023, *The novel findings about the Hussite's warfares in the Gdansk/Danzig surroundings in the late Summer of 1433*, in *Pre-Modern Towns at the Times of Catastrophes. East Central Europe in a Comparative Perspectives*, Routledge, pp. 43-48.

Samól P., Hirsch R., Woźniakowski A. 2021, *History of the Lighthouse of the Wisłoujście Fortress in Light of a 2018 Architectural Study*, in *Wiadomości Konserwatorskie – Journal of Heritage Conservation*, 66, pp. 21-36.

Samól P., Hirsch R., Woźniakowski A. 2022, *Wreath from the Wisłoujście Fortress, Dating from the 1560s, and Its Transformation and Damage in the War of 1577 in the Light of Architectural Research from 2020–2022*, in *Wiadomości Konserwatorskie – Journal of Heritage Conservation*, 72, pp. 62-79.

Samól W., Kowalski S., Woźniakowski A., Samól P. 2023, *Where the Second World War in Europe broke out. The landscape history of Westerplatte, Gdansk/Danzig*, in *Land*, 12, 596.

Stankiewicz J. 1956a, *Nadmorska Twierdza w Wisłoujściu (Coast fortress in Wisłoujście)*, in *Kwartalnik Architektury i Urbanistyki*, 1(2), pp. 115-156.

Stankiewicz J. 1956b, *Twierdza w Wisłoujściu i niektóre problemy związane z jej odbudową*, in *Ochrona Zabytków*, 9(34), pp. 177-187.

Zbierski A. 2000, *Twierdza morska w Wisłoujściu w świetle badań kompleksowych Pracowni Archeologicznej IH-KM PAN i Centralnego Muzeum Morskiego (Coast fortress in Wisłoujście in the light of research conducted by the Archaeological Station of the Polish Academy of Sciences and Central Maritime Museum)*, in Stecewicz J. (eds.), *Twierdza Wisłoujście: Historia, teraźniejszość, przyszłość, Muzeum Historii Miasta Gdańska*, Gdańsk, pp. 31-51.

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The digitisation of fortified heritage, understood as a process of figuration of their current state and the construction of three-dimensional databases aimed at structuring and organising knowledge, requires a preliminary critical assessment of the methodologies and tools employed for data acquisition and representation. This assessment must consider the morphology and extension of the surface that needs to be digitised, as well as the time and objectives to be achieved. Considering the morphological complexity and the relative extension of Wisłoujście Fortress, this case study has allowed the experimentation with different digital acquisition process, through the extensive application of range-based and image-based instrumentation. The aim of the research is to develop a multi-scale three-dimensional database—at territorial, architectural, and detail levels—integrating the outputs derived from the different survey instruments into a coherent and comprehensive system. The fortress database then becomes a digital archive capable of describing, enhancing, and managing this extensive fortified system, which has served for centuries as an outpost protecting the city of Gdańsk against seaborne attacks.

Side page, Fig. 01
Fortress Layout
Planimetric view of the integrated point cloud of the fortress, where reflectance reveals portions of the articulated internal spaces of the fortified complex.

The remarkable defensive importance of the fortress is reflected in its spatial composition, which comprises an inner structure[1] - a bastioned quadrilateral with acute salient angles and linear sides - and a complex external earthwork, consisting of five bastions and completed with a ravelin. These two defensive lines are separated by a system of scarps and counterscarps, together with a moat fed by water from the *Martwa Wisła* River, one of the main branches of the Vistula. The entire defensive structure blends with the surrounding area, creating a strong intrinsic relationship between landscape and fortification.

[1] The inner fortress completes the existing defensive system, which is constituted by the circular watchtower. Within the bastioned quadrilateral, near the Circular Crown, the curtain wall facing the watercourse features what appears to be a hint of a strut.

Fig. 02
A glimpse of Wisłoujście Fortress
In the foreground, a polygonal bastion is visible, while in the background the entrance gate can be identified, marking the controlled access to the fortified complex. The image highlights the main morphological features of bastioned architecture in relation to the surrounding landscape and water system.

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Fig. 03
Fortress and Water System
Aerial view highlighting the relationship between the fortified system and the Martwa Wisła River. The fortress is strategically positioned along the waterway, playing a key role in both defence and the control of access to the harbour system.

Digital integreted acquisition of the fortress

In response to the morphological characteristics of the fortress, the survey campaign was planned to meet dual requirements: on one hand, the creation of a comprehensive database, and on the other, the need to conduct an extensive survey within a limited timeframe. The integrated survey was carried out using terrestrial (TLS) and mobile (MLS) laser scanners, integrated with photogrammetric survey techniques using Unmanned Aerial Vehicles (UAVs)[2]. The adopted terrestrial laser scanner system, Leica RTC360 , was calibrated considering a minimum number of scanning positions to complete a polygonal path for alignment control and to ensure sufficient coverage of the geometries and surfaces of the fortified structures. The instrument calibration was balanced based on three characteristics: point density, scan resolution quality, and colorimetric value of the point cloud data[3].

The extensive TLS acquisition trought TLS, aimed at obtaining a metrically reliable database to serve as a reference for integration with data from other instruments, was conducted in the external portions of the fortified quadrilateral, specifically the bastioned front and all defensive structures within its

[2] Bercigli , Bertocci (2017), *Digital Documentation of Masada Fortress in Israel: Integrated Methodologies of Survey and Representation.*
[3] De Marco, Parrinello (2021), *Management of mesh features in 3D reality-based polygonal models to support non-invasive structural diagnosis and emergency analysis in the context of earthquake heritage in Italy*.

Fig. 04
Fortress Elements and Spatial Articulation
From top left: view from the tower overlooking the waterway; detail of the curtain wall and bastion; aerial view of the central tower and circular barracks; interior view of the circular ring structure. The images highlight the morphological and spatial articulation of the fortress and its main architectural elements.

perimeter, resulting in an initial partial database[4]. Instead, the MLS documentation using the Leica BLK2GO instrument, with a focus on time-optimizing, covered all internal environments of the fortress, covered all internal environments of the fortress, integrating and complementing the TLS data. The entire fortified complex (in its accessible parts) was divided into different macro-zones of acquisition, with planned scanning paths based on the area's extent, the complexity of internal environments, and/or connections . The planning of scanning paths is necessary due to physical limitations arising from the morphology of the scenario, the architectural structure of the complex, and the characteristics of the Mobile Laser[5]. The earthworks of the outer defenses, considering their extension and complexity[6], were also acquired using mobile instrumentation[7]. To ensure proper alignment of datasets related to the two defensive levels (Internal fortress and external defenses), control TLS stations were previously

[4] The TLS database (Internal fortress and control scans in the outer defences) consists of 179 scans (average time per scan: 3 minutes, total number of points: 3,647,028,106, average density of 25 million points/sq m).
[5] Puente et al (2013), *Review of mobile mapping and surveying technologie*; La Placa (2021), Fast survey and digital databases of fortified systems for the tale of Venetian Stato da Mar.
[6] In the second bastioned defensive level, there is dense vegetation, and the profile of the earthworks, including the scarp and counterscarp, has inevitably changed from its original conception. The density of the vegetation, combined with the extent of this defensive system portion, would have required, for a TLS survey, a large number of scans, significantly impacting the overall timing of the survey.
[7] The MLS database of exterior earthworks consists of 24 scans (average time per scan: 7 minutes, total number of points: 1,014,782,291, average density of 8 million points/sqm).

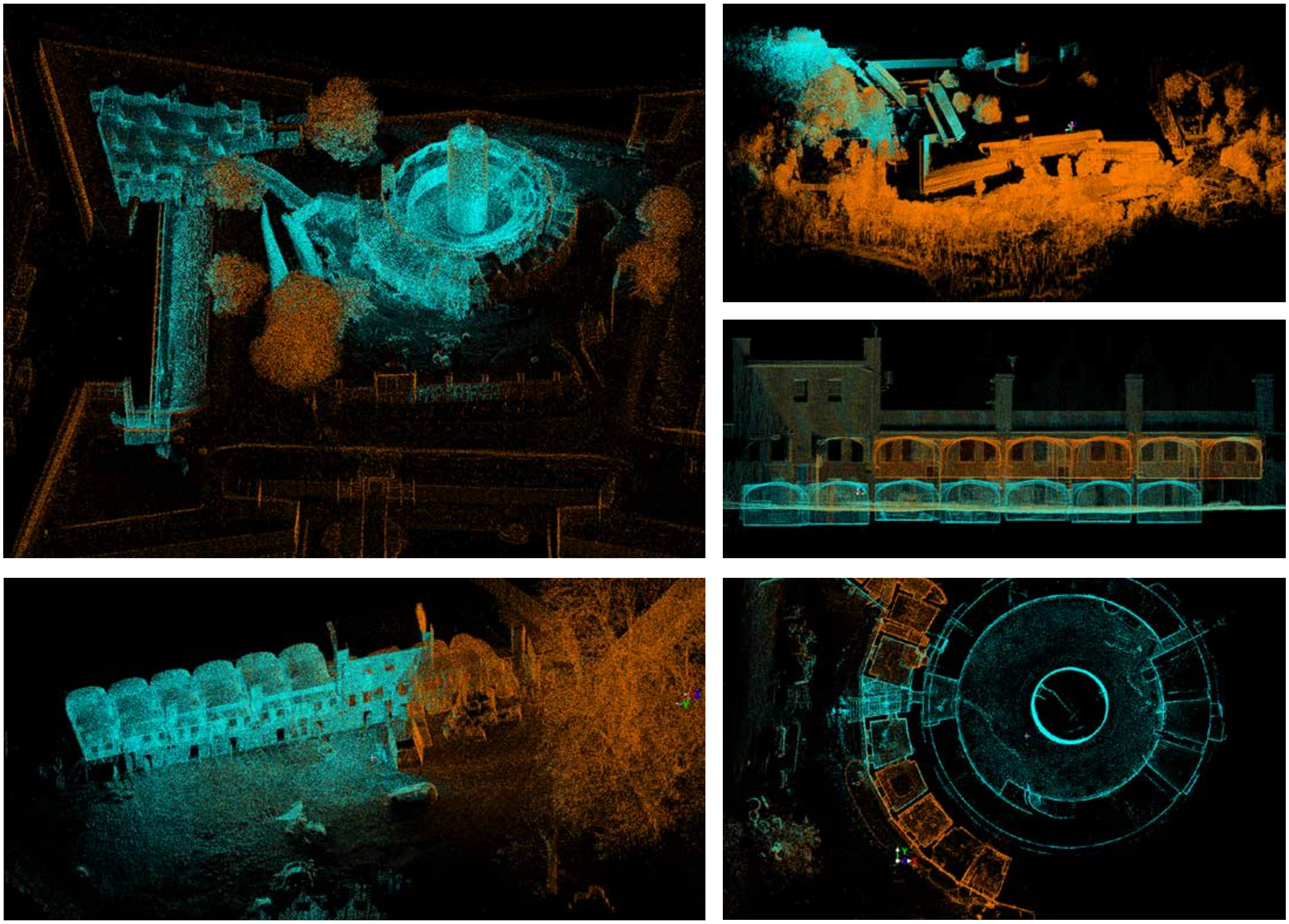


Fig. 05
Multi-sensor Data Registration
Cloud-to-cloud registration of TLS and MLS scans.

Side page, Fig. 06
Digital Database Construction
Diagram showing point clouds derived from multiple surveying techniques and the resulting integrated database.

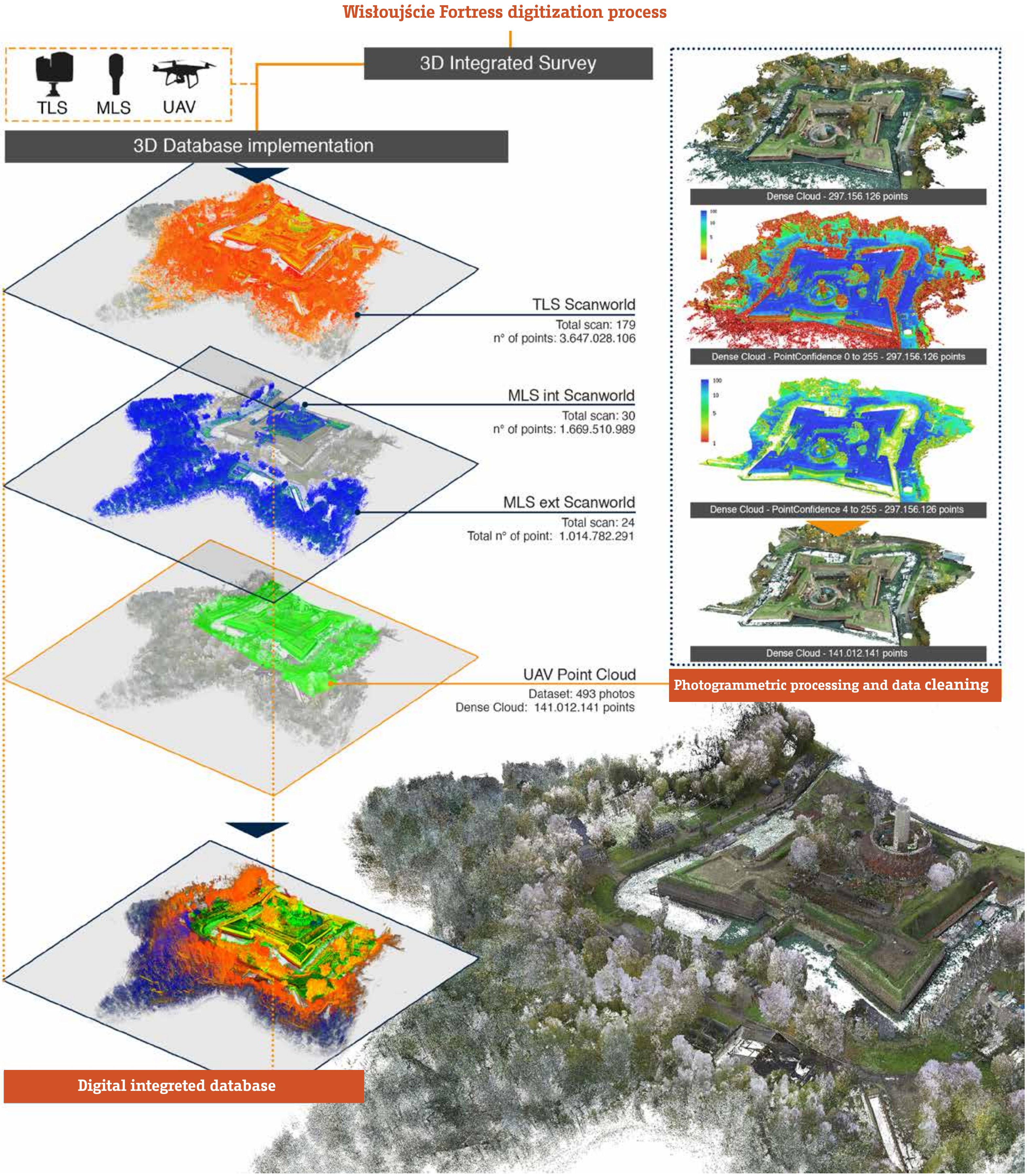
Next pages, Figs. 07, 08, 09, 10
Reading Spatial Structure
Selected views of the integrated point cloud.

set up to ensure the alignment and metric reliability of the datasets. To digitally acquire the upper portion of the Watchtower and the external areas of the bastioned fortress perimeter, inaccessible to the operator from the ground (especially on the side facing directly towards the watercourse), the acquisition was carried out using UAV instruments.

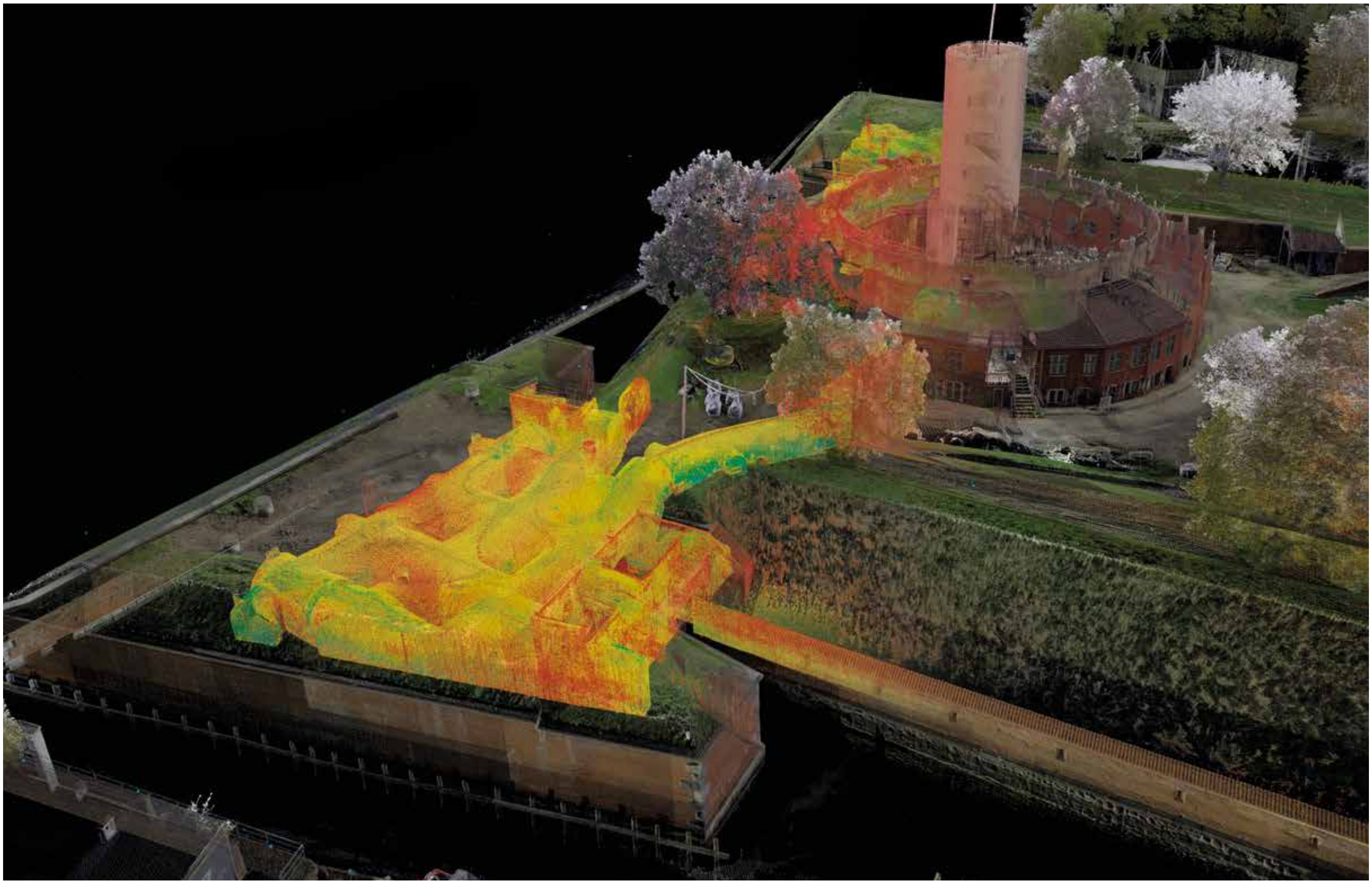
The acquisition phase involved planning several structured manual flights on two different scales: a detailed one around the Watchtower with the attached Circular Crown of the Barracks, and a territorial one that involved the bastioned quadrilateral and the outer defenses. For each flight, a radial path with variations in height was executed for both detailed and territorial scales. In total, 493 photographs were taken (Size 5472x3648, resolution 72dpi) with an overall overlap of 80/90%, using a DJI Mavic 2 Pro drone.

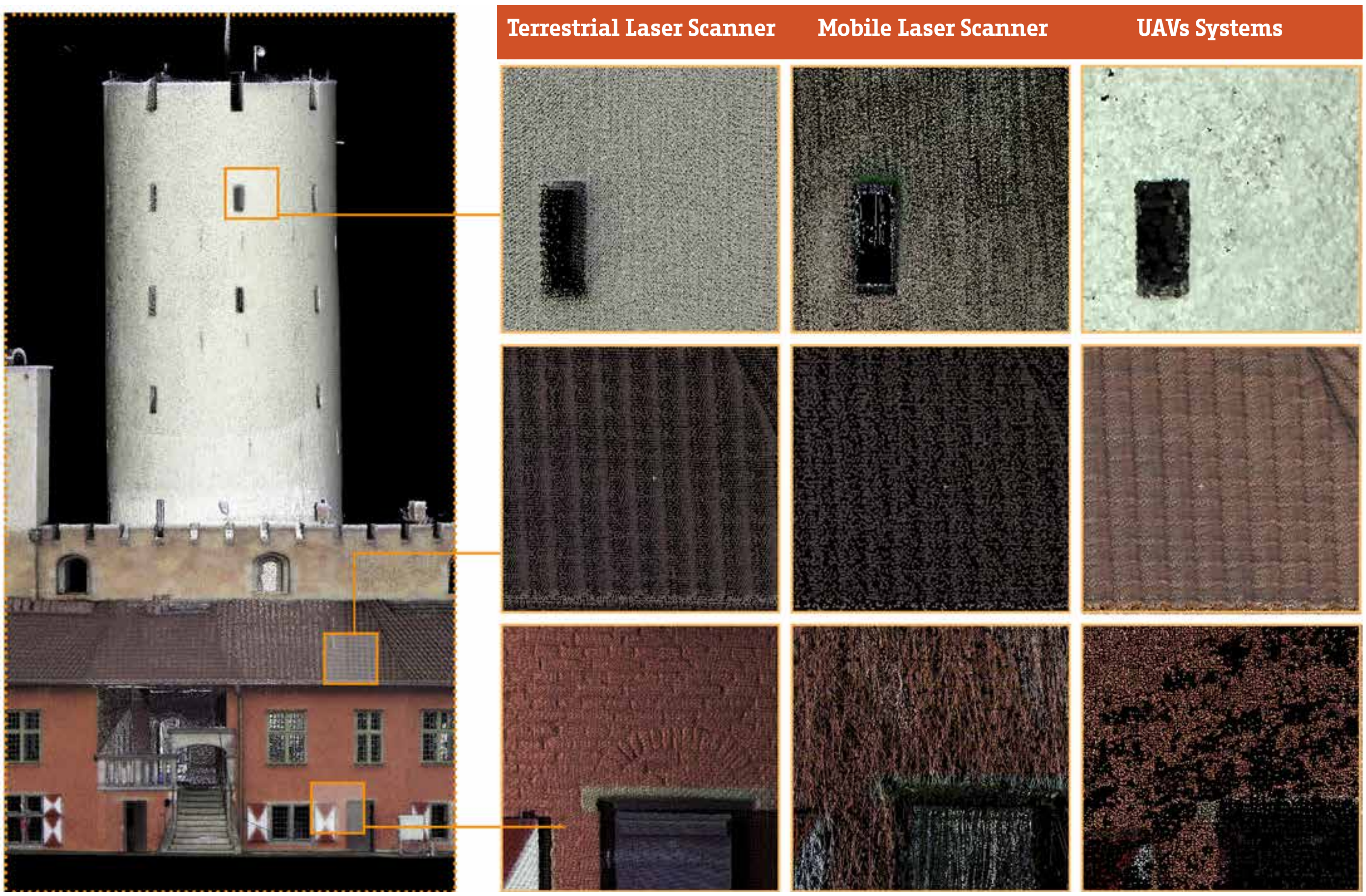
Post-production and validation of 3D database

The data registration procedure from the integrated survey certified and validated the database to support the investigation aimed at understanding the spatial complexity of the fortress and its geometric features. In the post-production phase, the various scans from MLS and TLS were aligned



Wisłoujście Fortress digitization process
3D Integrated Survey
TLS
MLS
UAV
3D Database implementation
TLS Scanworld
Total scan: 179
n° of points: 3.647.028.106
MLS int Scanworld
Total scan: 30
n° of points: 1.669.510.989
MLS ext Scanworld
Total scan: 24
Total n° of point: 1.014.782.291
UAV Point Cloud
Dataset: 493 photos
Dense Cloud: 141.012.141 points
Dense Cloud - 297.156.126 points
Dense Cloud - PointConfidence 0 to 255 - 297.156.126 points
Dense Cloud - PointConfidence 4 to 255 - 297.156.126 points
Dense Cloud - 141.012.141 points
Photogrammetric processing and data cleaning
Digital integreted database





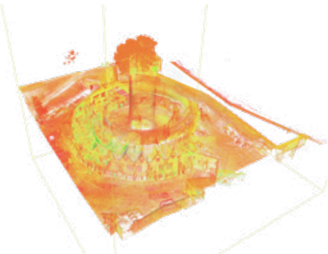


Fig. 11
Multi-sensor Data Density Comparison
Comparative analysis of point cloud density across TLS, MLS, and UAV acquisitions. The dataset reveals a height-dependent variation in data distribution, where terrestrial systems concentrate geometric resolution at lower levels, while aerial acquisitions enhance the sampling of upper surfaces, highlighting the complementary nature of multi-sensor integration.

Next pages, Figs. 12, 13
Reading Spatial Structure II
Selected views of the integrated point cloud.

through a visual "cloud-to-cloud" matching process using 3D point cloud processing software (Leica Cyclone Core)[8] . The registration process involved the creation of two separate scanworlds (TLS and MLS), which were later aligned. The UAV point cloud, aimed at obtaining a reliable point cloud that could be integrated with the point cloud obtained from TLS and MLS surveys, was processed using Agisoft Metashape software[9]. Within the software, following the processing of the sparse point cloud (203,644 points), based on the automatic recognition of homologous points from photographs, the dense point cloud was subsequently created and optimized. Optimization was carried out through a semi-automatic process of recognizing point overlap/displacement, by setting parameters in a range from 0 to 255, where the lowest value indicates low metric reliability[10].

Increasing the level of restriction, thus eliminating points with greater displacement/less reliability, some portions of the point cloud, however, exhibited a significant loss of data compromising the

[8] Bigongiari (2017), *El registro de la base de datos 3D*; Dell'Amico, Dellabartola (2024), *Georeferenziazione e analisi multilivello per la conoscenza e la rappresentazione digitale dell'isola di Madonna del Monte a Venezia*.
[9] Picchio (2020), *Acquisition protocols for UAV photogrammetric data – Comparison in methodological SfM procedures from architectural till urban scale*.
[10] The "Point Cloud Confidence" filtering tool allows, through an iterative process, the definition of threshold values for the reliability of point cloud data, expressed on a scale ranging from 0 to 255. This value is determined by the number of observations contributing to the reconstruction of each point (depth maps), thus indicating the robustness of the data. The aim is to remove less reliable or noisy points, improving the overall quality of the point cloud.

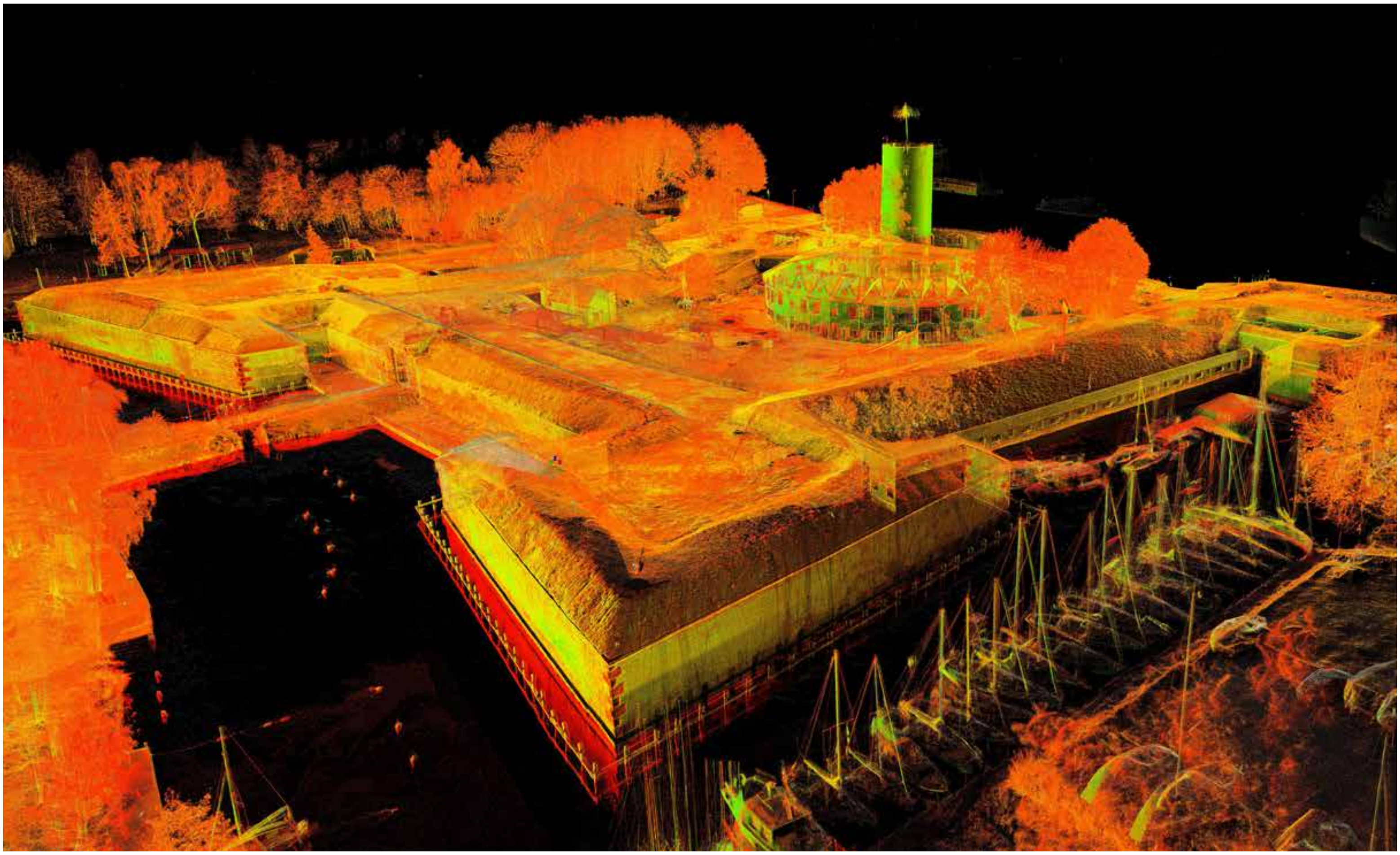
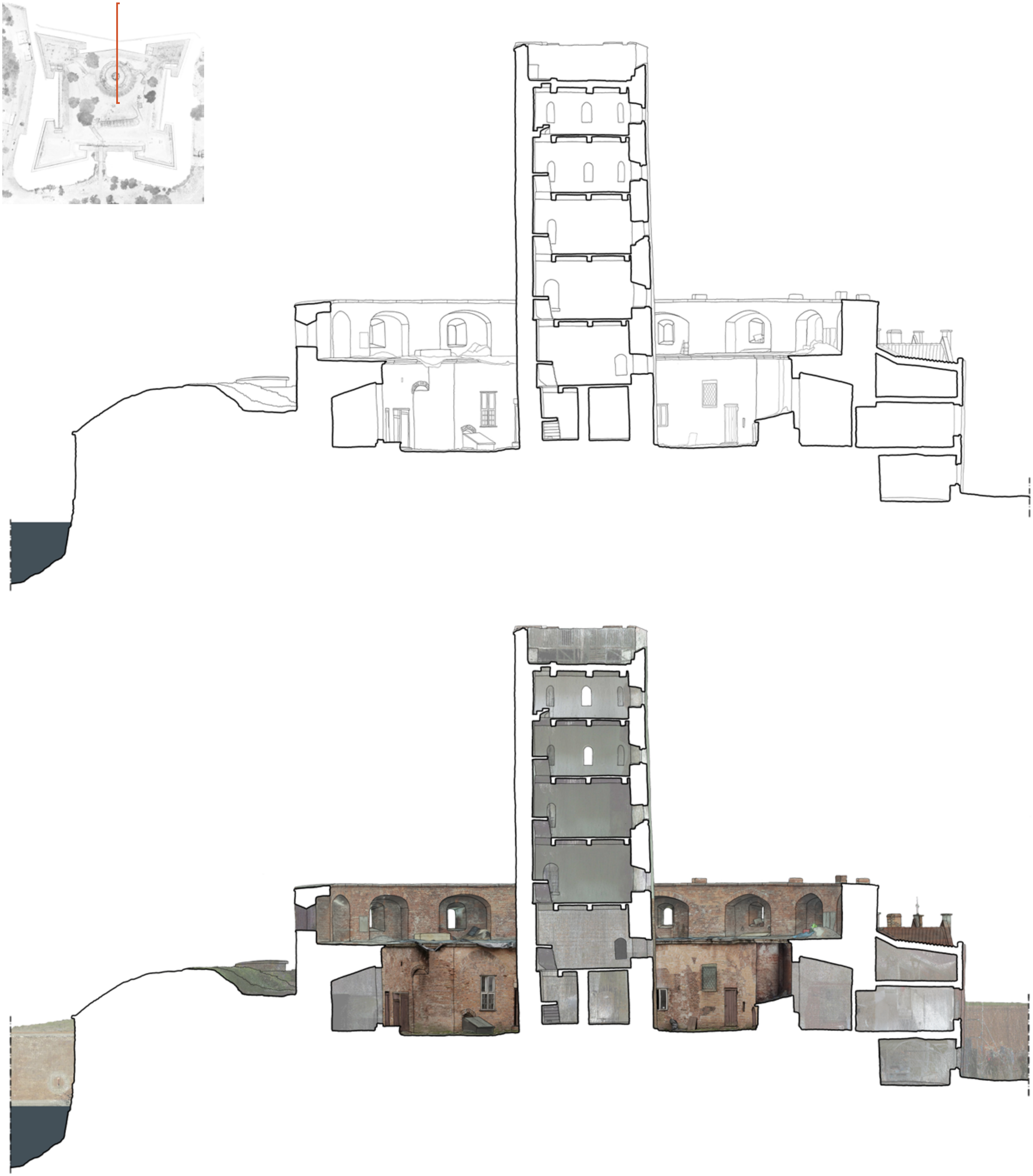


Fig. 14
Territorial Articulation of the Fortified System
The integrated point cloud enables the interpretation of the relationship between the fortified system and the surrounding territory, showing how the defensive geometry adapts to the morphology of the site and the water system.

Next pages, *Fig. 15*
Longitudinal Section of the Tower and Circular Ring Structure
The section highlighting the vertical articulation of the tower and its relationship with the internal ring. (Drawing credit: Alberto Pettineo)

readability of the point cloud. A discretization was then performed, using intermediate parameters (4-255), and balancing the output by eliminating only the portions of the point cloud in the range (0-4) considered unreliable and not qualitatively useful[11]. The optimized point cloud was then referenced and scaled based on the TLS point cloud, identifying notable morphological points in the photogrammetric point cloud. The spatial survey post-production process included referencing instrumental datasets to a common UCS (User Coordinate System). The process was executed by defining common morphological targets between TLS+MLS and UAV point clouds. TLS spatial data ensured accurate referencing and consistent metric reliability (1-2 cm) in the final point cloud. The UAV point cloud showed a metric variance of 2-3 cm compared to discrete TLS surfaces. The documentation activities carried out at the Wisłoujście Fortress have led to the development of a multi-scale three-dimensional digital database, integrating the outputs acquired through different survey technologies. The database provides a holistic and coherent representation of the fortified system, enabling a simultaneous reading of its spatial configuration, construction logic, and state of conservation[12]. Within this framework, the database is configured as a knowledge infrastructure capable of supporting multiple levels of analysis,

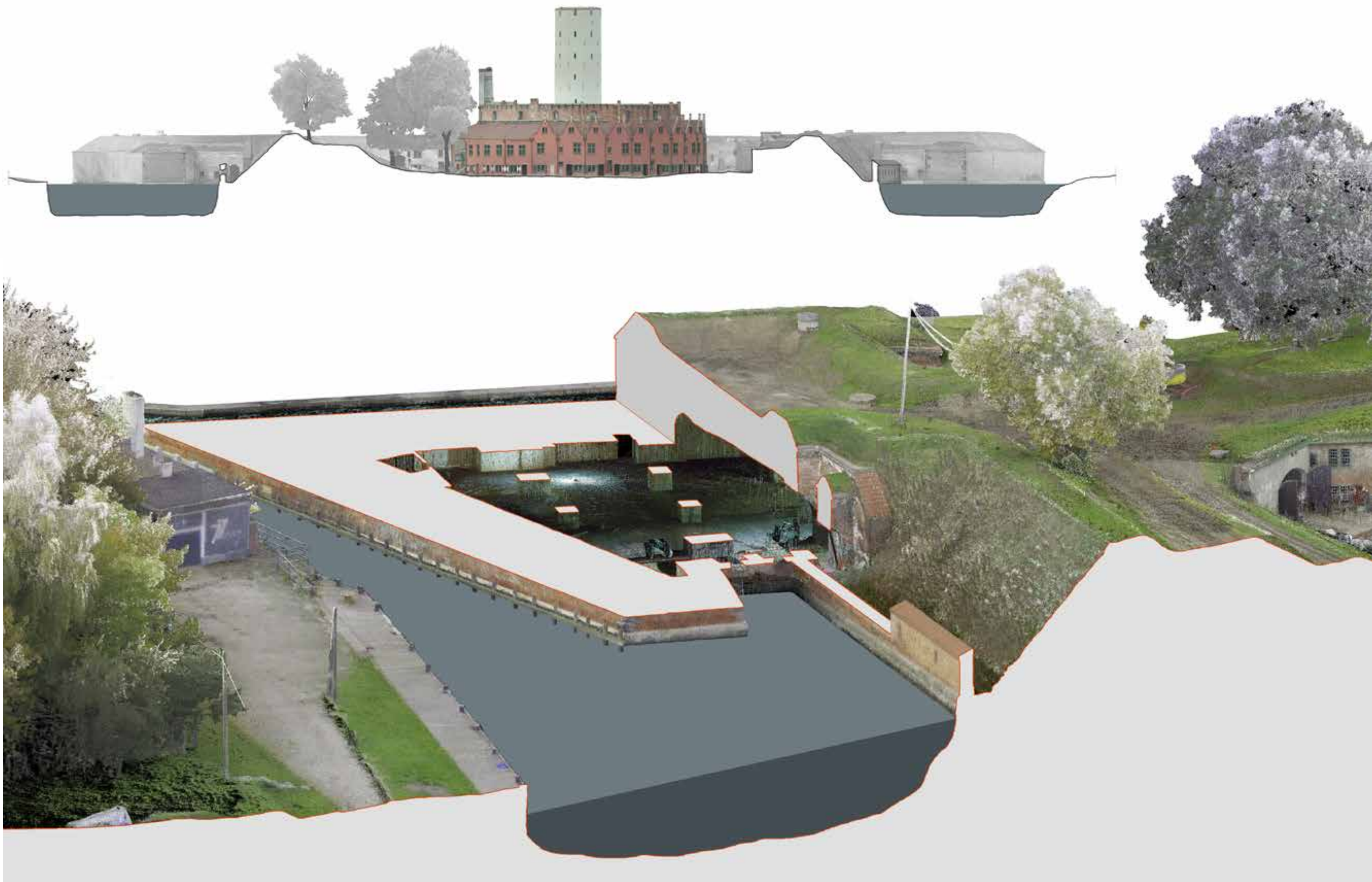
[11] Following the parameters and the characteristics of the point cloud: 0-255, dense cloud: 297,156,126 points; 2-255, dense cloud: 195,578,302 points; 4-255, dense cloud: 141,012,141 points; 8-255, dense cloud: 75,766,281 points.
[12] Pancani, Bigongiari (2023), *Rilievo architettonico remote sensing della Fortezza della Verruca sui Monti Pisani.*



from two-dimensional technical representations to three-dimensional visualisation and interrogation of the point cloud[13]. This dual dimension allows, on the one hand, the extraction of metric and morphological information, and on the other, enables advanced forms of digital interaction, in which survey data becomes an active tool for investigation. In this sense, the point cloud can support interpretative processes, such as the identification of transformations, alterations, and relationships among the different defensive components.

The integration of multi-resolution datasets, structured according to different levels of detail, enables a scalable approach to the analysis of the fortress. At the territorial scale, the system allows the positioning of the site within broader defensive networks and landscape dynamics, contributing to the construction of

[13] Franczuk et al (2022), *Direct use of point clouds in real-time interaction with the cultural heritage in pandemic and post-pandemic tourism on the case of Kłodzko Fortress.*

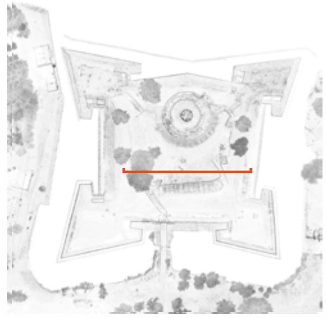


knowledge paths and cultural valorisation strategies. At the architectural and element scale, the database supports detailed analyses of structural conditions, material decay phenomena, and construction techniques, providing a reliable basis for conservation-oriented interventions.

The survey experience has represented a significant testing ground for the integrated use of different acquisition methodologies, highlighting the potential of combined workflows in addressing the complexity of fortified architectures.The results of the research define the methodological and operational foundations for the implementation of future interventions, including planned conservation strategies, monitoring activities, and digital dissemination processes.

Fig. 16
Axonometric section of the fortress
The drawing provides a multiscalar reading of the system, highlighting the interaction between architectural structures, terrain morphology, and fortified elements. (Drawing credit: Alberto Pettineo)

Fig. 17
Cross-section with Elevation of the Tower and Circular Ring Structure
The representation highlights the spatial and compositional relationship between the horizontal enclosure and the vertical element. (Drawing credit: Alberto Pettineo)



References

Bercigli M., Bertocci S. 2017, *Digital Documentation of Masada Fortress in Israel: Integrated Methodologies of Survey and Representation*, in *Proceedings of the 45th Annual Conference on Computer Applications and Quantitative Methods in Archaeology CAA2017*, pp. 413-423.

Bigongiari M. 2017, *El registro de la base de datos 3D, in El palacio del Generalife: del levantamiento digital al proyecto de gestión: cuaderno de trabajo para la documentación arquitectónica*, Pavia University Press, Pavia, pp. 84-89.

De Marco R., Parrinello S. 2021, *Management of mesh features in 3D reality-based polygonal models to support non-invasive structural diagnosis and emergency analysis in the context of earthquake heritage in Italy*, in *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 46, pp. 173-180.

Dell'Amico A., Dellabartola G. 2024, *Georeferenziazione e analisi multilivello per la conoscenza e la rappresentazione digitale dell'isola di Madonna del Monte a Venezia*, in Cardaci A., Picchio F., Versaci A. (eds.), ReUSO 2024. *Documentazione, restauro e rigenerazione sostenibile del patrimonio costruito*, Publica, pp. 475-485.

Franczuk J., Boguszewska K., Parrinello S., Dell'Amico A., Galasso F., Gleń P. 2022, *Direct use of point clouds in real-time interaction with the cultural heritage in pandemic and post-pandemic tourism on the case of Kłodzko Fortress*, in *Digital Applications in Archaeology and Cultural Heritage*, 24, e00217.

La Placa S. 2021, *Fast survey and digital databases of fortified systems for the tale of Venetian Stato da Mar*, in *AIP Conference Proceedings*, 2428(1), AIP Publishing.

Calle A. E. B., Leserri M., Rossi G., Rivera J. S. W. 2024, *Documentación y conocimiento de la "Torre del Reloj" Cartagena de Indias para su reconstrucción grafica*, in *Mimesis, Journal of Science of Architectural*, 4(4), pp. 17-24.

Pancani G., Bigongiari M. 2023, *Rilievo architettonico remote sensing della Fortezza della Verruca sui Monti Pisani*, Toscana (Italia), in M. G. Bevilacqua, D.Ulivieri (eds.), *Defensive Architecture of the Mediterranean* / Vol. XV, Pisa University Press, , Pisa, pp. 1105-1112.

Parrinello S., De Marco R., Doria E. 2023, *Analysis and definition of intervention strategies for the conservation of the boundary walls in Verona*, in Bevilacqua M. G., Ulivieri D. (eds.), *Defensive architecture of the Mediterranean, vol. XV*, Pisa University Press, Pisa, pp. 1113-1121.

Picchio F. 2020, *Acquisition protocols for UAV photogrammetric data – Comparison in methodological SfM procedures from architectural till urban scale*, in Barba S., Dell'Amico A., Limongello M., Parrinello S. (eds.), *D-SITE – Drones-Systems of Information on culTural hEritage – For a spatial and social investigation*, Pavia University Press, Pavia, pp. 70-79.

Puente I., González-Jorge H., Martínez-Sánchez J., Arias P. 2013, *Review of mobile mapping and surveying technologies*, in *Measurement*, 46(7), pp. 2127-2145.

Fortifications of 19th and 20th centuries

Sasper - See
Retranchement
Schanze VI
Schanze V
Schanze IV
Schanze III
Schanze II
Schanze I
Vorstadt
NEUFAHRWASSER
Fort Bousmard
Fort Quarree
Hafen-Schleuse
Hafen Canal
Westerplatte
Strand-Batterie II.
Strand-Batterie I.
Altes Fahrwasser
Rayon-Grenze

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Side page, Fig. 01
Fragment of the map of the Gdańsk Fortress showing the appearance of the coastal fortifications in the late 1850s (Secret State Archives in Berlin)

Gdańsk, an important economic centre located at the mouth of the Vistula to the Baltic Sea, based its development mainly on its role as a port city. In fact, the historic city and harbour were located approximately 7 km from the coast, at the point where the Vistula was joined by its smaller tributary, the Motława. In a defensive context, this was both an advantage (less risk of an unexpected attack on the city from the sea) and a threat of easy blockage of naval communication in the event of an enemy seizing the Vistula estuary. For this reason, already in the Middle Ages a watchtower existed there - the later Wisłoujście Fortress, around which further fortifications were developed. They were always a clearly separate and partly autonomous part of the Gdańsk fortifications.

Coastal fortifications of Gdańsk before 1815

After the Napoleonic Wars, Gdańsk was granted to the Kingdom of Prussia by the arrangements of the Congress of Vienna in 1815. The complex of coastal fortifications then consisted of the Wisłoujście fortress, and earthen ramparts built in the years 1789-1791 on the then island of Westerplatte as part of the Prussian fortified camp blockading the city[1]. These fortifications were extended between 1803 and 1806 during the preparations for war. At that time, the reconstruction of the outer bastion ring of the Wisłoujście fortress (Eastern Rampart), enlarged towards the sea by an earthen redoubt (Seagull Redoubt), was begun, and two new ramparts and a tenaille work were built on the New Port side[2].

During the period of the first Free City (1807-1814), the French took over and extended Gdańsk's fortifications. Among other things, they fortified the section of the Vistula connecting the city with Wisłoujście from the east. In place of the earlier line of small redoubts, a long wall with a moat, the hexagonal Redoubt Hautpoul and the three-bastion Napoleon's Fort were built between Ostrów Island and Wisłoujście Fortress[3]. The reconstruction of the Eastern Rampart of the Wisłoujście fortress was completed and the Western Rampart (named Fort Montebello) was rebuilt[4]. The fortifications of Westerplatte and the Vistula mouth passed the test, repelling the Russian assault in 1813.

[1] Podruczny (2020), *Twierdze z papieru, Fortyfikacje pruskie w latach 1786-1807 (Fortresses of paper, Prussian fortifications 1786-1807).*
[2] Bukal (2012), *Fortyfikacje Gdańska i ujścia Wisły 1454-1793 (Fortifications of Gdańsk and the mouth of Vistula River 1454-1793)*; Stankiewicz (1956), *Nadmorska twierdza w Wisłoujściu (Seaside fortress in Wisłoujście).*
[3] Gosch F. (2003), *Festungsbau an Nordsee und Ostsee, Die Geschichte der deutschen Küstenbefestigungen bis 1918.*
[4] Strzok (2006), *Fortyfikacje XIX-wiecznego Gdańska (Fortifications of 19th century Gdańsk)*, pp. 48-60.

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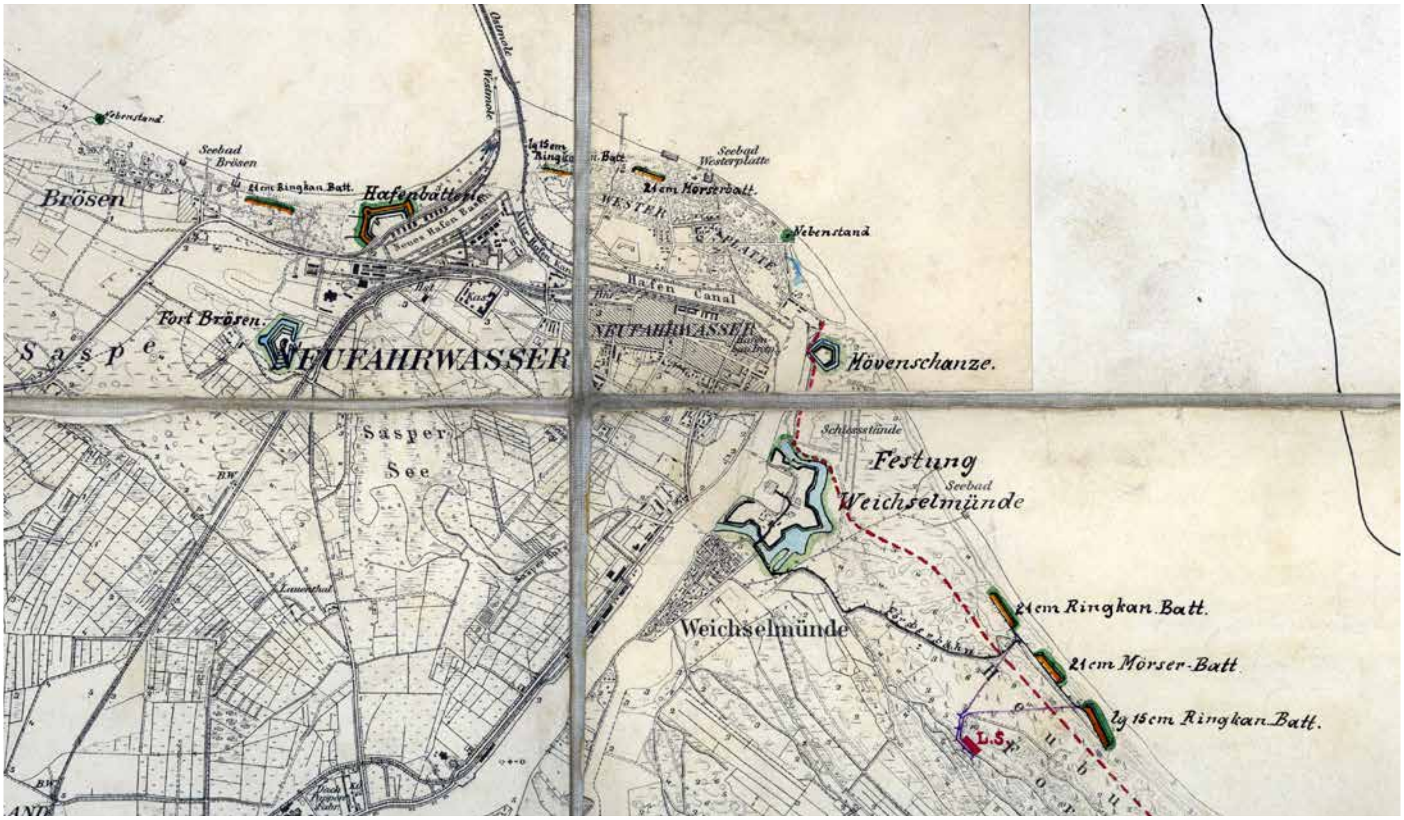
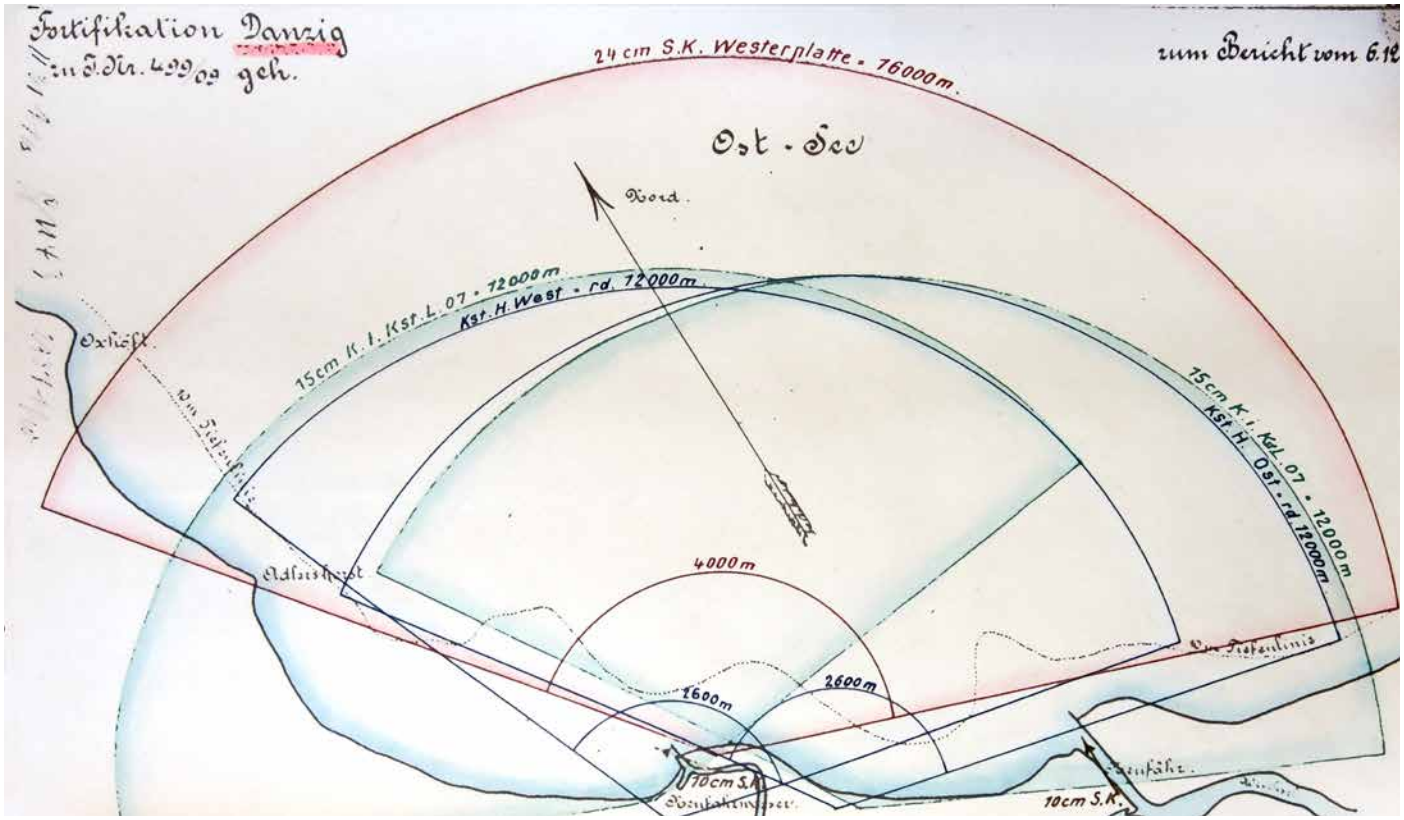


Fig. 02
Fragment of the map of the Gdańsk Fortress showing the appearance of the coastal fortifications in the late 1850s
(Secret State Archives in Berlin)

Development between 1815 and 1919

During the first three decades of Prussian rule, no significant construction work was carried out on the coastal fortifications of Gdańsk, confining itself mainly to the maintenance and repair of the older fortifications, including those erected by the French[5]. The impulse for modernisation and expansion was the change in nautical conditions caused by the breakthrough of the new Vistula estuary in 1840 in the Gorki area. The cut-off section of the river, called the Dead Vistula, was henceforth much more convenient for shipping. The old estuary was soon filled in, creating the Westerplatte peninsula, and traffic was routed through the harbour channel, which had been a bypass for the previously silted-up estuary to the sea[6]. In order to secure strategic locations, a new Seagull Redoubt (Möwenschanze, 1844-1846) was built as a link between the fortifications of Westerplatte and the Wisłoujście fortress, as well as a fort defending the new mouth of the Vistula and the lock cutting off the Dead Vistula (Fort Neufähr, 1845-1850). The French Fort Lacoste halfway to the city was also rebuilt (1847-1850), now renamed Fort Kakreuth. The planned fort at Westerplatte was not built, but in the mid-1850s earthen coastal batteries were constructed there[7]. With the railway line being brought to New Port (Neufahrwasser) and the port infrastructure there being developed, construction of two new works to guard it from the west began in the

[5] Rolf (2000), *Die Entwicklung des deutschen Festungssystems seit 1870. Vollständige und bearbeitete Ausgabe des Manuskriptes*.
[6] Samól et al. (2023), *Where the Second World War in Europe broke out. The landscape history of Westerplatte*; Woźniakowski (2019), *Historia i materialne relikty fortyfikacji Westerplatte sprzed 1920 r. (History and material relics of the pre-1920 fortifications of Westerplatte)*.
[7] Hirsch (2009), *Początki fortyfikacji nadbrzeżnych Gdańska (The beginnings of the Gdańsk coastal fortifications)*, pp. 35–46.



late 1860s: the Brzeźno Fort (Fort Brösen) and the Port Battery (Hafenbatterie). Their construction was interrupted by the outbreak of the Franco-Prussian War, for which they were provisionally prepared for defence[8]. At the same time, most of the older fortifications underwent minor modernisations related to the introduction of rifled artillery into general use. Numerous structures were built into the earthen ramparts for the storage of gunpowder and the preparation of ammunition, as well as shelters for the cannons[9]. In 1876, the coastal fortifications were reinforced with stationary artillery. New cannons on coastal lavatories, together with ammunition magazines, were mounted on the ramparts of the Seagull Redoubt (two 21 cm and one 15 cm), the Port Battery (three 21 cm and two 15 cm), and the completely rebuilt Beach Battery (four 15 cm)[10]. Another reconstruction was carried out between 1888 and 1890, when the batteries' armament was strengthened and unified. The Port Battery was enlarged by lengthening its right front, where six 21 cm cannons were placed. In exchange for the Beach Battery, destroyed by storms in 1881, a new battery was built, also for four 15 cm cannons, later enlarged to six. The least changes affected the Seagull Redoubt, now armed with three 21 cm cannons[11]. By the end of the 19th Century, Danzig's

Fig. 03
Plan from 1909 with the ranges of the planned batteries
(Military Archives in Freiburg)

Fig. 04
Schematic map showing the current state of the historic coastal fortifications
Yellow: fortifications from before 1815 (1, Wisłoujście Fortress); red: fortifications from 1815-1919 (2 – Seagull Redoubt, 3 - Port Battery, 4 - Beach Battery, 5 - Village Battery, 6 - Forest Battery, 7 - Dune Battery); blue: fortifications from World War II (8 - Bohnsack Battery); green: post-war fortifications (9 – 25th Fixed Artillery Battery). Circles indicate auxiliary fire control objects.

[8] Hirsch (1995), *Bateria Portowa w Gdańsku - historia i stan obecny (The Port Battery in Gdańsk - history and present state)*, pp. 7–12; Hirsch (2009), *Początki fortyfikacji nadbrzeżnych Gdańska (The beginnings of the Gdańsk coastal fortifications)*.
[9] Biskup (2000), *Szaniec Wschodni Twierdzy Wisłoujście (Eastern Rampart of the Wisłoujście Fortress)*.
[10] Biskup et al. (1994), *Zespół fortyfikacji i zabudowy terenu - Szaniec Mewi. Karta ewidencyjna zabytku (Complex of fortifications and buildings of the area – Seagull Redoubt. Monument registration card)*; Woźniakowski (2019), *Historia i materialne relikty fortyfikacji Westerplatte sprzed 1920 r. (History and material relics of the pre-1920 fortifications of Westerplatte)*, pp. 276-303.
[11] Woźniakowski (2009), *Zarys historii rozwoju fortyfikacji nadbrzeżnych Gdańska w latach 1887-1919 (Brief history of the development of Gdańsk's coastal fortifications between 1887 and 1919)*, pp. 47-61; Woźniakowski (2019), *Historia i materialne relikty*

Fig. 05
Seagull Redoubt
View of the wall with the gate.
(Arkadiusz Woźniakowski, 2007)
Fig. 06
Old gun emplacement of the 21 cm cannon battery in Brzeźno
(Arkadiusz Woźniakowski, 2018)
Fig. 07
Beach Battery in Brzeźno
(Arkadiusz Woźniakowski, 2018)
Fig. 08
Village Battery in Brzeźno. One of the ammunition traverses
(Arkadiusz Woźniakowski, 2018)

importance as a land fortress was declining, but growing as an important shipyard centre and naval base[12]. In addition, rapid advances in military technology meant that further reinforcements of the coastal defences were soon necessary. New coastal batteries, initially provisory, were gradually developed to a permanent form. Their positions stretched from the Stogi area to Brzeźno. In the 1890s, two batteries for 21 cm mortars, two batteries for 21 cm cannons and one battery for 15 cm cannons were organised. At the turn of the 19th Century the system was supplemented by lighter batteries, partly of a mobilisation nature (for 9 and 12 cm field guns; intended to be armed and manned only in the event of a danger of an attack on the fortress). The mortar batteries were given advanced observation points connected to a telegraphic communication network[13]. At the beginning of the 20th Century, the armament of the fixed coastal batteries consisted of a total of 70 guns (28 pieces of 9 and 12 cm field guns, 30 pieces of 15 and 21 cm stationary guns and 12 pieces of 21 cm mortars). The configuration of the batteries was based on a fairly uniform scheme, adopted from older fortifications. The barbette gun emplacements were set in a straight line about 25 m apart and were separated by traverses that housed ammunition magazines or shelters for the crew. The mortar batteries had a similar linear arrangement and were additionally hidden behind a high dune embankment[14].

By 1905, the breastworks of the gun emplacements and ammunition magazines in the old batteries were reinforced to protect them from the stronger shells of the ship's artillery[15]. However, further developments in artillery and naval technology (especially introducing the new Dreadnought-class ships) prompted study work on an another thorough modernisation of the existing coastal defence system. In 1907, the following concept was adopted: pairs of complimentary howitzer and cannon batteries were planned on the flanks of the harbour entrance. Howitzers with steep trajectory of a projectile flight were to fight against armoured ships, while cannons with higher rate of fire and flatter trajectory were to fight against lighter and faster ships. The system was to be supplemented with a long-range cannon battery, lighter

fortyfikacji Westerplatte sprzed 1920 r. (History and material relics of the pre-1920 fortifications of Westerplatte), pp. 276-303.

[12] Strzok I.Z. (2006), *Fortyfikacje XIX-wiecznego Gdańska (Fortifications of 19th century Gdańsk)*, pp. 48-60.

[13] Rolf (2000), *Die Entwicklung des deutschen Festungssystems seit 1870. Vollständige und bearbeitete Ausgabe des Manuskriptes.*

[14] Dudek (2006), *Fortyfikacje nadbrzeżne Gdańska w pierwszej połowie XX w. (Coastal fortifications of Gdańsk in the first half of the 20th century)*, pp. 61-69; Woźniakowski (2009), *Zarys historii rozwoju fortyfikacji nadbrzeżnych Gdańska w latach 1887-1919 (Brief history of the development of Gdańsk's coastal fortifications between 1887 and 1919)*, pp. 47-61.

[15] Rolf (2000), *Die Entwicklung des deutschen Festungssystems seit 1870. Vollständige und bearbeitete Ausgabe des Manuskriptes.*.

barrage batteries, blocking port entrances directly, and searchlight positions. The new batteries were to be located in close proximity to the older fortifications, sometimes directly overbuilt, which reduced the investment costs and allowed the existing infrastructure to be partly reused[16]. First two batteries for four 15 cm cannons each were built in 1909-1910. The cannons were mounted on disappearing carriages, allowing for better cover for the gun emplacements and crew during loading - a rare solution in Germany (only five such batteries were built), but quite popular in the United States and the United Kingdom, for example. The battery on the eastern side (Bay Battery, Buchtbatterie), was built just behind the old 15 cm cannon battery, which was buried in the foreground. The western battery at Brzeźno (Beach Battery, Strandbatterie) was fitted into the old 21 cm gun battery, leaving the wing shelters and two gun platforms out of it. Both batteries were completed according to the same design, with the four cannons set on a single monolithic reinforced concrete block, which housed the ammunition stores and crew shelterst. In 1911, two 28 cm howitzer batteries were completed, which were moved back inland to better camouflage the firing positions. The eastern battery in Stogi was named Forest Battery (Forstbatterie), and the western battery in Brzeźno - Village Battery (Dorfbatterie). The latter was established in close proximity to Fort Brzeźno and used its facilities as ammunition stores. Because of the lower threat of direct fire, the howitzer positions were exposed, protected only by an armoured mask. Five free-standing reinforced-concrete traverse shelters were built between the gun emplacements to store ammunition and shelter the crew. In 1910-1912, a barrage battery for four 10.5 cm guns (Molenbatterie) was built at Westerplatte, on the bank of the harbour channel. Structurally it was similar to the 15 cm cannon battery and was, in a way, a scaled-down version of it[17]. Howitzer batteries required a complex fire control system, involving targeting from at least two points on the coast that were several kilometres apart, allowing the distance to the target to be determined with great precision. Basically, each battery had a main fire control post with a nearby compass position and two side fire control posts, located on the wings at a distance of approximately 2 to 7 km. Due to the nature of the coastline, the Village Battery was given an additional main and compass post. The main and side posts were essentially very similar to each other. They were low single-storey shelters, equipped with a periscope sight in the armoured dome and a plotting room with an adequate number of niches for telephonists. The 15 cm cannon batteries had rangefinder posts added to the sides of the battery blocks in 1912-1913. In addition, each battery had a position with a searchlight located on the coast. The artillery operations were coordinated by a commanding officer from a special two storey command shelter located at Westerplatte. Finally, to directly

[16] Dudek (2006), *Fortyfikacje nadbrzeżne Gdańska w pierwszej połowie XX w. (Coastal fortifications of Gdańsk in the first half of the 20th century)*, pp. 61-69; Woźniakowski (2009), *Zarys historii rozwoju fortyfikacji nadbrzeżnych Gdańska w latach 1887-1919 (Brief history of the development of Gdańsk's coastal fortifications between 1887 and 1919)*, pp. 47-61.

[17] Dudek (2006), *Fortyfikacje nadbrzeżne Gdańska w pierwszej połowie XX w. (Coastal fortifications of Gdańsk in the first half of the 20th century)*, pp. 61-69; Dudek (2009), *Fortyfikacje Wojskowej Składnicy Tranzytowej na Westerplatte 1933-1939 (Fortifications of the Military Transit Depot at Westerplatte 1933-1939)*, pp. 63-83; Woźniakowski (2009), *Zarys historii rozwoju fortyfikacji nadbrzeżnych Gdańska w latach 1887-1919 (Brief history of the development of Gdańsk's coastal fortifications between 1887 and 1919)*, pp. 47-61.

protect the entrance to the harbour channel, two stationary torpedo batteries were built on its left bank[18]. Construction of the long-range battery (Dune Battery, Dünenbatterie) did not begin until 1917. It was located in the Stogi area and was to be armed with two modern 24 cm railway guns with a range of 26,600 m. It did not reach combat readiness before the end of the war and only part of the planned facilities were completed.

Coastal fortifications of Gdansk after 1918 and their current state

In accordance with the Treaty of Versailles, Gdańsk was declared a free city in 1920 and all military facilities, including fortifications, were disarmed. Some of the coastal batteries were dismantled as part of this process, some during the later port investments. Until the outbreak of World War II no fortifications were built in Gdańsk, apart from the specific fortifications of the Polish extraterritorial ammunition depot at Westerplatte, which deserve a separate study[19]. The military importance of Gdańsk greatly diminished in favour of Gdynia, which during the occupation became the main German naval base in the region. In addition to the anti-aircraft batteries, only one coastal battery for four 15 cm cannons was established in the Gdańsk area, on Sobieszewska Island, closing the access to the port from the east (Bohnsack Battery). During the Cold War, the Polish Navy organised a system of coastal defence in the Bay of Gdańsk area with numerous batteries. One of these, the 25th Fixed Artillery Battery, was built in 1951-1957 near Wisłoujście on the site of old German batteries from the turn of the 20th Century. It was armed with four 130mm cannons and had numerous auxiliary shelters (a total of 15 objects, including adapted old ones). It was decommissioned in 1971 because of the expansion of the port[20]. At present, the state of preservation of the historic coastal fortifications in the Gdańsk area varies. This is firstly due to the nature of the development of these fortifications and the frequent practice of replacing older structures with newer ones as military technology evolved. The second and currently main threat to them is their location next to industrial port areas and the related investment pressure. Many of the structures have already been demolished for this very reason, while others are now directly threatened by it. Of the oldest fortifications from the discussed period, only the relics of the Seagull Redoubt and the Port Battery have survived. The fewest traces remain of relatively simple and small batteries from the end of the 19th Century - the remains of the only one can be seen in Brzeźno next to the newer Beach Battery. The 20th Century batteries made of reinforced concrete are the best preserved: on the western side the Beach and Village Battery, and on the eastern side relics of the Forest Battery, unfinished Dune Battery and the cold-war battery, as well as fire control shelters scattered widely along the coast[21].

[18] Woźniakowski (2009), *Zarys historii rozwoju fortyfikacji nadbrzeżnych Gdańska w latach 1887-1919 (Brief history of the development of Gdańsk's coastal fortifications between 1887 and 1919)*, pp. 47-61; Woźniakowski (2019), *Historia i materialne relikty fortyfikacji Westerplatte sprzed 1920 r. (History and material relics of the pre-1920 fortifications of Westerplatte)*, pp. 276-303.
[19] Dudek (2009), *Fortyfikacje Wojskowej Składnicy Tranzytowej na Westerplatte 1933-1939 (Fortifications of the Military Transit Depot at Westerplatte 1933-1939)*, pp. 63-83.
[20] Dudek (2006), *Fortyfikacje nadbrzeżne Gdańska w pierwszej połowie XX w. (Coastal fortifications of Gdańsk in the first half of the 20th century)*, pp. 61-69.
[21] Woźniakowski (2016), *Fortyfikacje pasa nadmorskiego w Gdańsku - „historia znikania" (Fortifications of the coastal strip in Gdańsk - a "history of disappearance")*, pp. 21-26.

Despite this, the surviving remnants form an interesting and valuable group of monuments depicting the development of coastal fortifications in the 19th and 20th centuries.

References

Biskup K. 2000, *Szaniec Wschodni Twierdzy Wisłoujście (Eastern Rampart of the Wisłoujście Fortress)*, in *Twierdza Wisłoujście - historia, teraźniejszość, przyszłość*, Gdańsk, pp. 61-66.

Biskup K., Narębski L., Hirsch R. 1994, *Zespół fortyfikacji i zabudowy terenu - Szaniec Mewi. Karta ewidencyjna zabytku* (Complex of fortifications and buildings of the area – Seagull Redoubt. Monument registration card)

Fortyfikacje Gdańska i ujścia Wisły 1454-1793 (Fortifications of Gdańsk and the mouth of Vistula River 1454-1793), Sopot.

Bukal G. 2012, *Fortyfikacje Gdańska i ujścia Wisły 1454-1793 (Fortifications of Gdańsk and the mouth of Vistula River 1454-1793)*, Sopot.

Dudek M. 2006, *Fortyfikacje nadbrzeżne Gdańska w pierwszej połowie XX w. (Coastal fortifications of Gdańsk in the first half of the 20th Century)*, in *Fortyfikacje Gdańska*, red. G. Bukal, Gdańsk, pp. 61-69.

Dudek M. 2009, *Fortyfikacje Wojskowej Składnicy Tranzytowej na Westerplatte 1933-1939 (Fortifications of the Military Transit Depot at Westerplatte 1933-1939)*, in *Fortyfikacje nadbrzeżne Zatoki Gdańskiej*, Tarnowskie Góry, pp. 63-83.

Gosch F. 2003, *Festungsbau an Nordsee und Ostsee, Die Geschichte der deutschen Küstenbefestigungen bis 1918*, Hamburg, Berlin, Bonn.

Hirsch R. 1995, *Bateria Portowa w Gdańsku - historia i stan obecny (The Port Battery in Gdańsk - history and present state)*, in *INFORT* nr 9, nr 2, pp. 7-12;

Hirsch R. 2009, *Początki fortyfikacji nadbrzeżnych Gdańska (The beginnings of the Gdańsk coastal fortifications)*, in *Fortyfikacje nadbrzeżne Zatoki Gdańskiej*, pp. 35-46.

Podruczny G. 2020, *Twierdze z papieru, Fortyfikacje pruskie w latach 1786-1807 (Fortresses of paper, Prussian fortifications 1786-1807)*, Warszawa.

Rolf R. 2000, *Die Entwicklung des deutschen Festungssystems seit 1870. Vollständige und bearbeitete Ausgabe des Manuskriptes*, Tweede Exloermond.

Samól W., Kowalski S., Woźniakowski A., Samól P., 2023, *Where the Second World War in Europe broke out. The landscape history of Westerplatte*, Gdańsk/Danzig, in *Land* 12, 596.

Stankiewicz J. 1956, *Nadmorska twierdza w Wisłoujściu (Seaside fortress in Wisłoujście)*, in *Kwartalnik Architektury i Urbanistyki*, t.I, nr 2, pp. 115-156.

Strzok I.Z. 2006, *Fortyfikacje XIX-wiecznego Gdańska (Fortifications of 19th Century Gdańsk)*, in *Fortyfikacje Gdańska*, red. G. Bukal, Gdańsk, pp. 48-60.

Woźniakowski A. 2009, *Zarys historii rozwoju fortyfikacji nadbrzeżnych Gdańska w latach 1887-1919 (Brief history of the development of Gdańsk's coastal fortifications between 1887 and 1919)*, in *Fortyfikacje nadbrzeżne Zatoki Gdańskiej*, pp. 47-61.

Woźniakowski A. 2016, *Fortyfikacje pasa nadmorskiego w Gdańsku - „historia znikania" (Fortifications of the coastal strip in Gdańsk - a "history of disappearance")*, in *Społeczeństwo i fortyfikacje - dawniej i dziś*, red. G. Urbanek, Poznań, pp. 21-26.

Woźniakowski A. 2019, *Historia i materialne relikty fortyfikacji Westerplatte sprzed 1920 r. (History and material relics of the pre-1920 fortifications of Westerplatte)*, in *Materialne pozostałości konfliktów i zbrodni XX wieku w świetle najnowszych badań archeologicznych*, Gdańsk, pp. 276-303.

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Side page, Fig. 01
Remains of Port Battery.

Amidst the realm of architectural heritage structures, fortifications present a distinctive challenge owing to their inherent and specific functionality, rendering them resistant to alterations and susceptible to potential neglect and decay. Their existence also introduces difficulties related to preservation, maintenance, public safety, and accessibility. In accordance with heritage conservation principles[1] and recognizing the outdated nature of their function, physically reconstructing fortifications may be deemed unnecessary. Consequently, the essence of experiencing these integral heritage objects can be captured through digital tools[2]. In the pursuit of initiating actions for enhancement and valorization, this research centers on implementing an operational workflow geared towards rediscovering military heritage using the potential offered by digital technologies. The investigative process entails integrating various survey methodologies to attain the most comprehensive and detailed understanding of the heritage artifact[3].

The research unfolds in three distinct methodological steps: an initial phase of historical analysis, a subsequent phase involving a digital survey of the current structure, and a final phase in which a 3D model is developed to compare historical sources with contemporary data. This contribution specifically delves into the second and third phases, elucidating the methodology and outcomes of digital survey activities.

State of art

Nowadays, the Port Battery stands as a distinctive ruin, visible from the cliffs that stretches along the Baltic Sea coast in Gdańsk. Situated within the protected precincts of Gdańsk's Port's free customs area, the Battery owes its relatively well-preserved state to the restricted access that shielded it from theft and vandalism. Unfortunately, the battery itself bears substantial damage, a consequence of insufficient conservation efforts and shortsighted actions by the seaport.

These actions were geared towards accommodating communication needs for trucks operating on the quays, leading to further deterioration and the dismantling of remnants from the original fortification.

[1] Jokilehto (2007), *History of Architectural Conservation*.
[2] Pierdicca et al. (2016), *Virtual reconstruction of archaeological heritage using a combination of photogrammetric techniques: Huaca Arco Iris, Chan Chan, Peru.*
[3] Parrinello et al. (2019), *Documenting the cultural heritage routes. The creation of informative models of historical Russian churches on upper Kama region.*

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Fig. 02
Remains of Port Battery

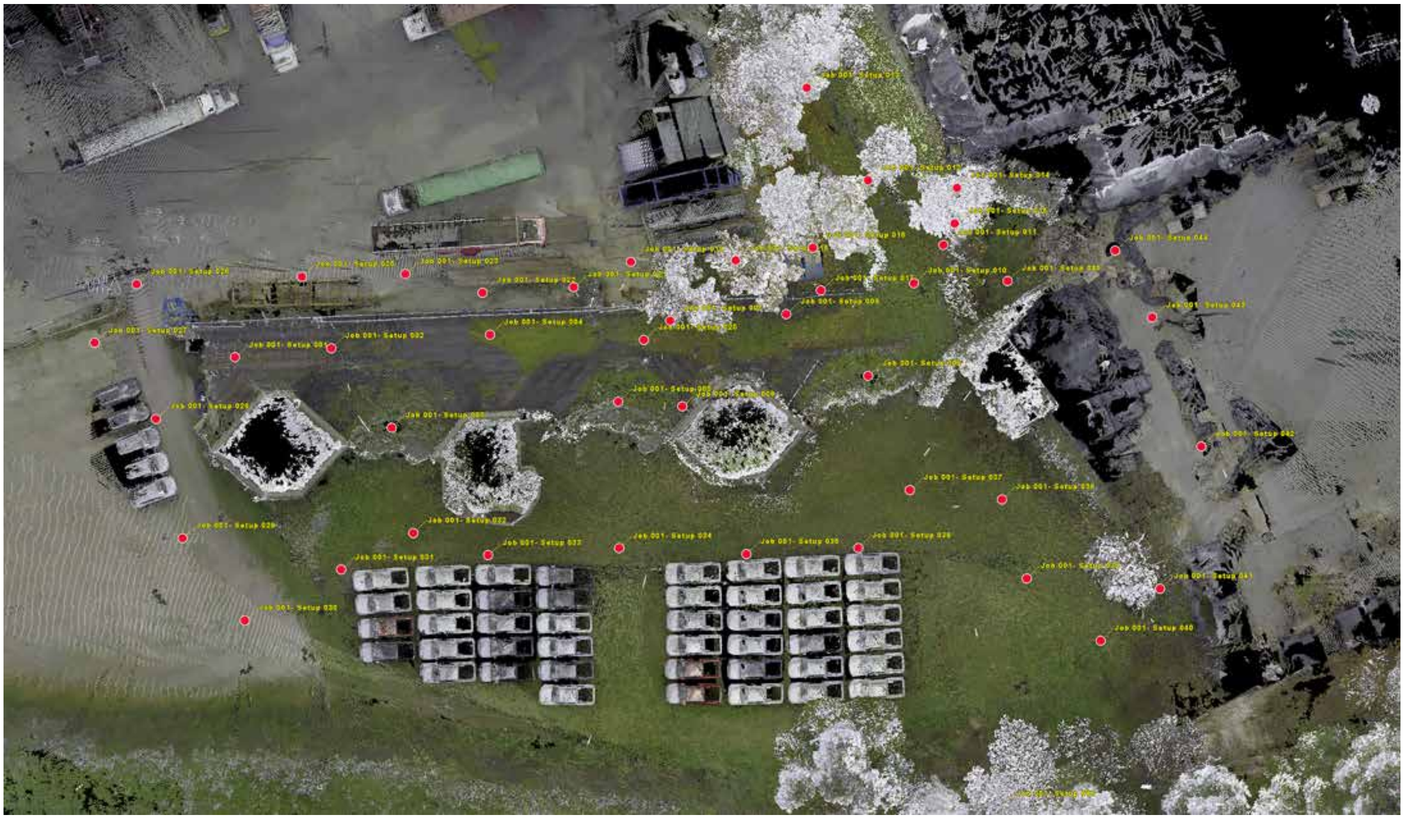
Regrettably, this has left the battery with a rather impaired appearance[4].

Positioned within a confined and regulated seaport zone, the survey of the Port Battery had to be executed swiftly to avoid disruption to dockworker activities. In response, the authors undertook a comprehensive examination of the battery and its surroundings, leveraging mobile equipment that facilitated the completion of the survey and data acquisition within a single working day. Preceding the survey, the team meticulously evaluated methods and acquisition strategies for each mobile device, as well as for GPS and TLS instrumentation. These measures were crucial in ensuring the metric reliability of the digital product[5].

Digital acquisition of Port Battery

The Port Battery and its surroundings underwent their inaugural digital survey, utilizing a range of instruments to swiftly compile a comprehensive documentation of the area. The TLS LiDAR (RTC360) acquisition campaign focused on documenting the external walls and surroundings of the structure. Following a polygonal path parallel to the outer walls, the operator executed 49 scans. The use of polygonal paths played a crucial role in minimizing and compensating for metric errors during post-production alignment (max. error: 1-2 cm). Interior surveying employed MLS LiDAR (BLK2GO), with the operator completing 7 closed paths, overlapping one another at an average distance of 2 meters from architectural surfaces[6]. These paths originated from outside the battery to ensure the acquisition of morphological points necessary for integrating TLS data. To georeference the dataset, a topo-

[4] Hirsch (1995), *Bateria Portowa w Gdańsku - historia i stan obecny*, pp. 7-12; Hirsch (1996), *Bateria Nadmorska*, pp. 22-23;Woźniakowski, Hirsch (2023), *Studies of 19th Cen.tury defensive architecture using traditional and digital research methods on the examples of coastal fortifications in Poland*.
[5] Picchio, Pettineo (2023), *Digitalizzare, ricostruire e fruire il Castello di Montorio: un tassello nella definizione della rotta culturale dei castelli scaligeri*, pp. 1123-1130.
[6] Dell'Amico (2021), *Mobile laser scanner mapping system's for the efficiency of the survey and representation processes*, pp. 199-205.



graphic acquisition campaign was conducted using Leica Geosystem GNSS GS07 to acquire GPS point coordinates. These points were strategically placed along the battery's boundary and roof to establish a polygonal network, ensuring better control and error compensation. Due to area access restrictions, drone usage was prohibited, necessitating a ground-based approach for photogrammetric acquisition and processing operations[7]. Using photogrammetric techniques from the ground, operators captured 671 photographs with approximately 70% overlap between contiguous photos. The 24.2 MP full-frame Panasonic Lumix S5 mirrorless camera maintained a constant focal length of 20 mm during acquisition, resulting in a ground sample distance (GSD) below 0.02. The camera's large sensor facilitated enhanced light collection, contributing to increased image quality and aiding the software algorithm in constructing the 3D photogrammetric model[8]. The digital duplicate obtained revealed data gaps in certain coverage areas, which were partly addressed by integrating laser instrumentation data. However, challenges persisted, such as the degraded condition of some architectural portions (e.g., missing concrete covers for artillery positions in battery ruins) and substantial vegetation on the flat roof and access ramps. The data from the acquisition phase underwent processing for individual datasets, eventually being integrated into a single global point cloud. Subsequently, post-production processes were initiated to define digital models of the Port Battery.

Fig. 03
Spatial Arrangement of Scan Positions on Terrestrial LiDAR Point Cloud visualized in Leica Cyclone Software

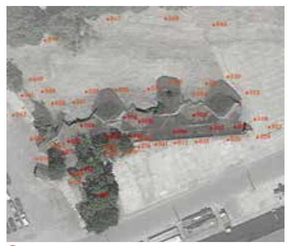


Fig. 04
Integration of TLS and MLS datasets

[7] Remondino (2011), *Heritage recording and 3D modeling with photogrammetry and 3D scanning.*
[8] Parrinello, Picchio (2015), *The complex of San Lorenzo del Chagres in Panama: historical development and survey project for the documentation of the Caribbean fortress.*

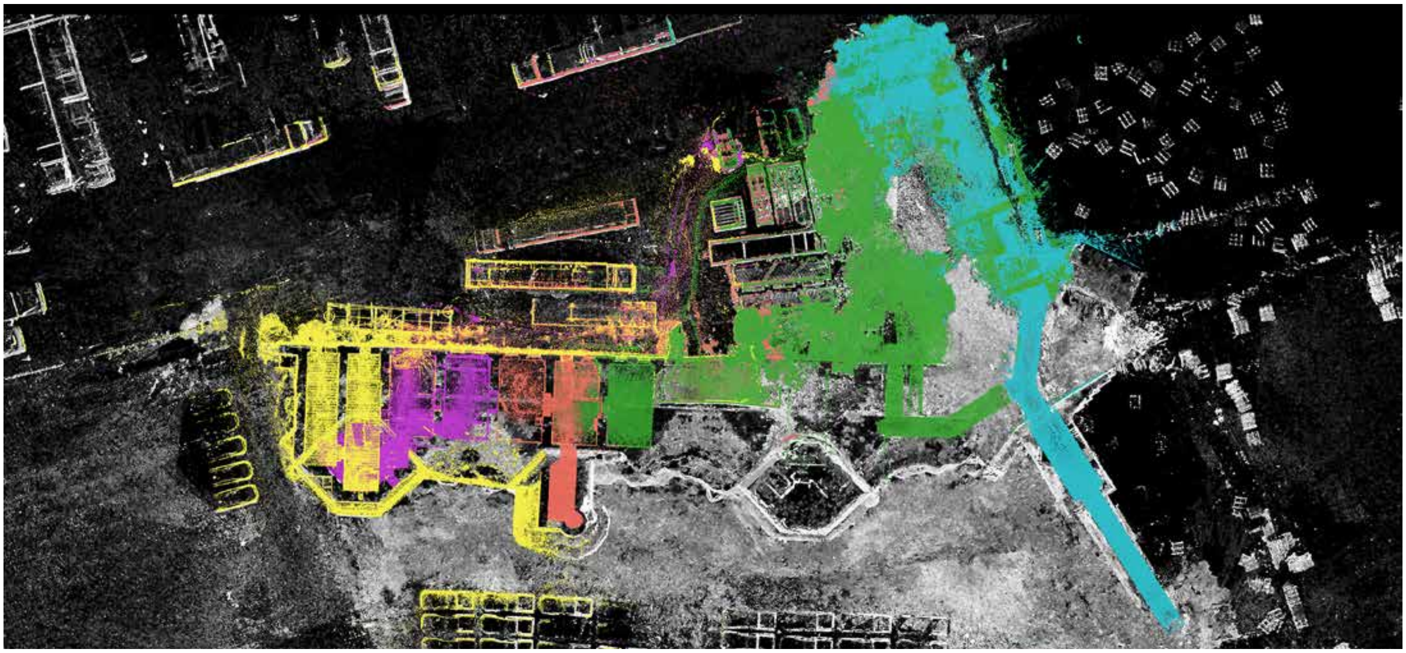


Fig. 05
Integration of TLS and MLS datasets. Interiors of battery

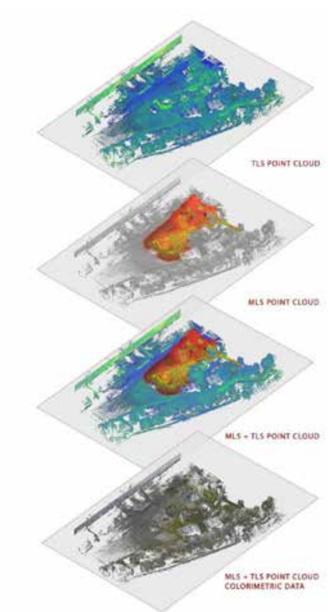


Fig. 05
Port Battery point cloud databases

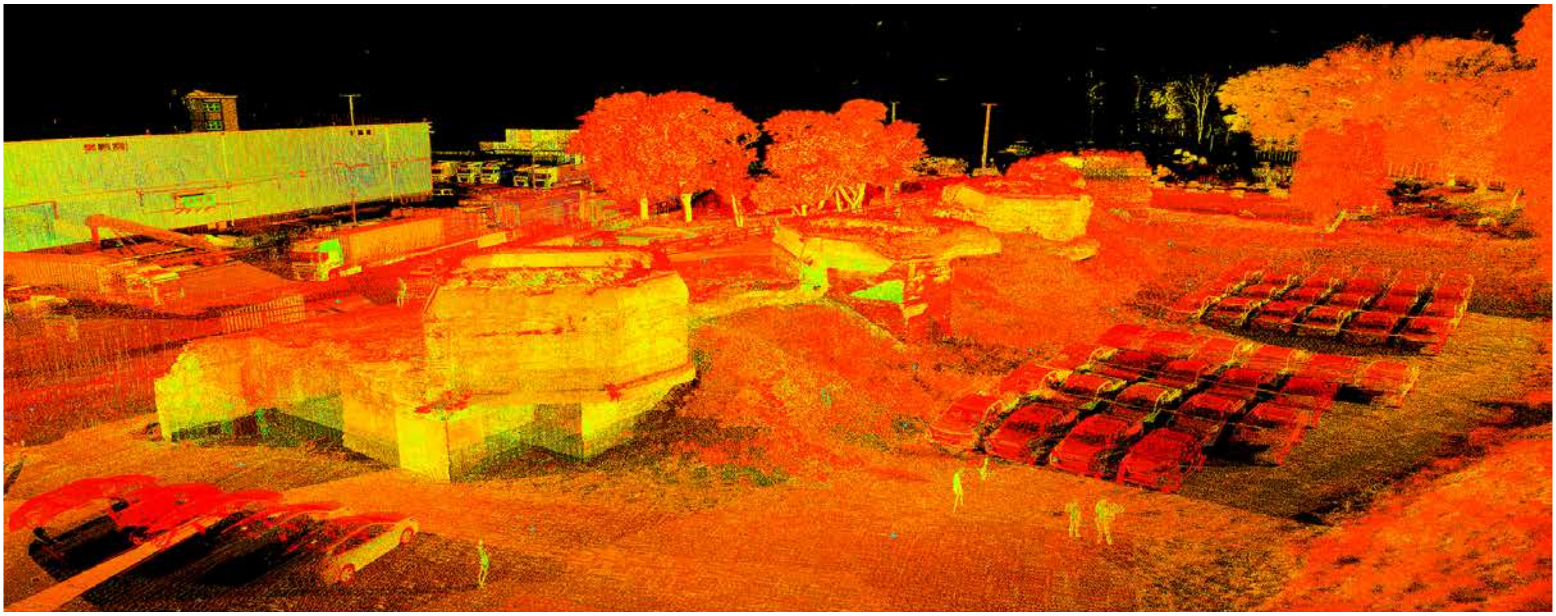
Fig. 06
Results of TLS and MLS point cloud registration, with different visualization filters (density, RGB), process in Leica Cyclone Software

Postproduction phase

The dataset underwent individual database processing based on the respective instrumentation (TLS and MLS). Following referencing through morphological points and cloud-to-cloud alignments using Leica Cyclone software, the point clouds from TLS and MLS datasets were seamlessly merged into a unified global point cloud. TLS scans, enriched with RGB data, provided detailed colorimetric information crucial for decay mapping and structural preservation evaluations[9]. In comparison, MLS exhibited a lower density—less than 2 million points/square meter—with accompanying RGB information. The MLS data displayed reasonable reliability compared to TLS, boasting average deviations of 3-10 cm at both architectural and detail levels.

Georeferencing of the integrated point cloud was accomplished using on-site GPS points. In Leica Cyclone software, the .txt coordinates of all points were imported as a point system, designating the position related to the GPS point as a vertex. This GPS coordinate point system served as the reference scan word ("homeword") for the registration alignment process. Consequently, all vertices within the point cloud were accurately "shifted" into the correct coordinate system, with an average deviation of 10-15 cm. It's important to note that the error obtained may be influenced by the chosen position/number of points and the instrumentation. The model used carried an average default error of 2-10 cm, compounded by potential inaccuracies in the instrument's bubble setting, manually performed by the operator. Subsequent to this georeferencing process, the acquired data underwent further processing to generate mesh models using the point cloud-to-mesh technique (Kowalski et al., 2023). These models were simplified and optimized to facilitate visualization in a 3D graphical engine, preparing the data for eventual 3D printing.

[9] Doria et al. (2022), *Heritage documentation and management processes: Castiglioni Chapel in Pavia.*



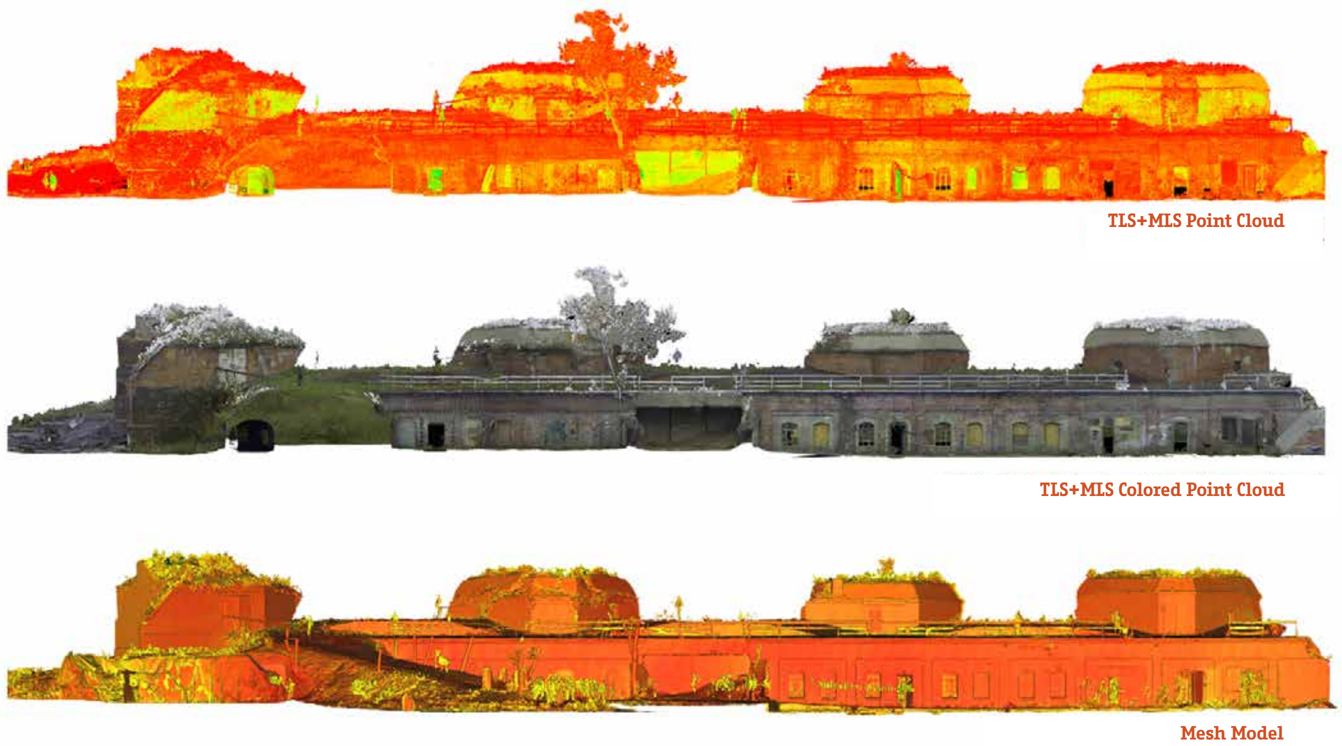


Fig. 07
Transformation of integrated scan to mesh model. Elevations of Port Battery Remains

3D Reconstruction based on historical sources

The initial step in digital reconstruction involved creating a terrain model. Lidar scans from the Polish Geoportal open-access database were imported into ArcGIS, and the mosaic method combined these scans to produce a seamless raster elevation map.

This map was then transformed into isolines using the "contour" function, with a contour line interval of 0.5m. The resulting dataset was exported as a .dwg file and imported into Rhinoceros 7 software. Utilizing the "extractPT" function on the isolines generated a dense point cloud, subsequently transformed into a highly accurate NURBS-curve terrain model using the "patch" function with a high stiffness value. The generated terrain model was compared to historical studies.

For achieving precision in architectural reconstruction, TLS and MLS point cloud data were utilized. The point cloud was converted into a mesh using the open-source software "CloudCompare."

The "Poisson Reconstruction" function in the same software automatically generated a mesh with an Octree depth set at 12 and scalar field density output. The resulting mesh was colored based on meta-information in the point cloud. A scalar field filter was applied to separate excess mesh faces, yielding a precise and distinct mesh suitable for further processing[10]. The final mesh, containing 28,288,693 triangular faces after trimming, was imported into Rhinoceros 7.

Unconnected elements were removed, and the "fill mesh holes" function was applied to ensure better watertightness. The data, terrain models, laser mesh scans, and historical sources, were then aligned in a single 3D software. Robert Hirsch and Arkadiusz Woźniakowski's research guided the historical reconstruction. To diversify the part of the actually preserved fortification (modeled based on

[10] Nocerino et al. (2020), *Surface reconstruction assessment in photogrammetric applications.*

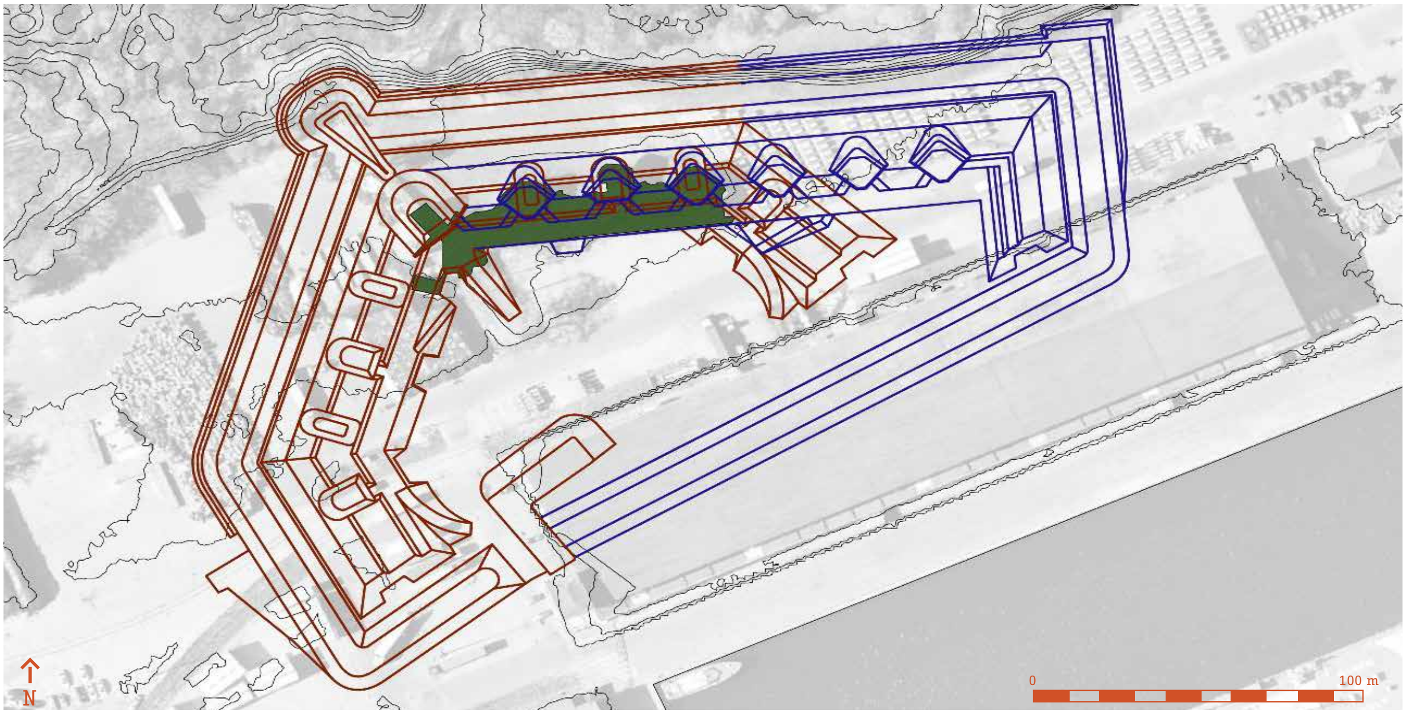


Fig. 08
Mapping scheme of Port Battery
Green - Preserved and scanned part, Red - Phase 1, Blue - Phase 2.

reality-based data in mesh) from the assumed one, the rest of the model was represented with simplified shapes and textures.

To integrate Virtual Reality (VR) into the research, Oculus head-mounted display glasses connected to a PC via Oculus Link cable were used. Enscape visualization plugin, chosen for its user-friendly nature compared to Unity and Unreal engines, facilitated immersive VR experiences. The VR immersive and entertaining approach to Cultural Heritage can promote a deeper understanding and appreciation of history and former architecture[11]. Virtual reality can be a powerful tool also in terms of academic didactics[12], enabling students to explore and study historical architecture in a way that would not be possible through traditional methods. However, VR complements physical objects and sites, offering additional layers of interpretation and interactivity, emphasizing its role as a supplement rather than a replacement for physical exhibitions[13]. The specific 3D modeling methodology used during the reconstruction phase enables also the application of research findings for various uses. A digital closed solid polysurface-based model can be in fact created to produce scaled reconstructions, with potential uses that differ from those of VR.

For instance, it can highlight the preserved and missing parts of the heritage site, for example by

[11] Ferdani et al. (2020), *3D reconstruction and validation of historical background for immersive VR applications and games: The case study of the Forum of Augustus in Rome*.
[12] Kowalski et al. (2020), *Teaching architectural history through virtual reality, in World Transactions on Engineering and Technology Education*.
[13] Selmanović et al. (2020), *Improving accessibility to intangible cultural heritage preservation using virtual reality, in Journal on Computing and Cultural Heritage.*

Fig. 09
Digital scann based reconstruction of remaining elements of Port Battery

publishing models in online accessed sites allowing for interaction, like Sketchfab; or it can be 3D printed, enabling a physical didactic use. Although the research uses already established methodologies and tools, it is applied to a case study that has never been digitally documented before. The research, from the analysis of historical sources via the digital acquisition of the built environment to the post-production processes of the data, allowed a virtual reconstruction of the once integral fortification structure, enabling the understanding and visualisation of the historical changes. The products obtained so far suggest the broader potential of the research. The digital model created in such a matter can serve as a valuable tool to create open-air museological solutions for heritage objects that are incomplete, altered, destroyed, or complex, using modern technologies such as virtual reality. It can be used to educate and engage interested viewers with the heritage site uniquely and interactively, offering a new perspective on the past.

References

Dell'Amico A. 2021, *Mobile laser scanner mapping system's for the efficiency of the survey and representation processes*, in *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XLVI-M-1-2021, pp. 199-205.

Doria E., Galasso F., Morandotti M. 2022, *Heritage documentation and management processes: Castiglioni Chapel in Pavia*, in Acta IMEKO, 11(1).

Ferdani D., Fanini B., Piccioli M. C., Carboni F., Vigliarolo P. 2020, *3D reconstruction and validation of historical background for immersive VR applications and games: The case study of the Forum of Augustus in Rome*, in *Journal of Cultural Heritage*, 43, pp. 129-143.

Hirsch R. 1995, *Bateria Portowa w Gdańsku - historia i stan obecny*, in *Infort. Biuletyn Miłośników Fortyfikacji*, 9, pp. 7-12.

Hirsch R. 1996, *Bateria Nadmorska*, in *Spotkania z zabytkami*, 20(3), pp. 22-23.

Jokilehto J. 2007, *History of Architectural Conservation*, Routledge.

Kowalski S., Samól P., Szczepański J., Dłubakowski W. 2020, T*eaching architectural history through virtual reality*, in *World Transactions on Engineering and Technology Education*, 18(2), pp. 197-202.

Fig. 10
Digital reconstruction in Virtual Reality enviroment with Oculus Quest 2 headset

Kowalski S., La Placa S., Pettineo A. 2023, *From archives sources to virtual 3D reconstruction of military heritage - the case of study of Port Battery*, Gdańsk, in *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XLVIII-M-2-2023, pp. 885-893.

Nocerino E., Stathopoulou E. K., Rigon S., Remondino F. 2020, *Surface reconstruction assessment in photogrammetric applications*, in *Sensors*, 20(20), 5863.

Parrinello S., Picchio F. 2015, *The complex of San Lorenzo del Chagres in Panama: historical development and survey project for the documentation of the Caribbean fortress*, in *Defensive architecture of the Mediterranean: XV to XVIII centuries*, vol. II, Editorial Universitat Politècnica de València, pp. 265-272.

Parrinello S., Picchio F., De Marco R., Dell'Amico A. 2019, *Documenting the cultural heritage routes. The creation of informative models of historical Russian churches on upper Kama region*, in *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XLII-2/W15, pp. 887-894.

Picchio F., Pettineo A. 2023, *Digitalizzare, ricostruire e fruire il Castello di Montorio: un tassello nella definizione della rotta culturale dei castelli scaligeri*, in Bevilacqua M. G., Ulvieri D. (eds.), *Defensive architecture of the Mediterranean*, vol. XV, Pisa University Press, Pisa, pp. 1123-1130.

Pierdicca R., Frontoni E., Malinverni E. S., Colosi F., Orazi R. 2016, *Virtual reconstruction of archaeological heritage using a combination of photogrammetric techniques: Huaca Arco Iris, Chan Chan, Peru*, in *Digital Applications in Archaeology and Cultural Heritage*, 3(3), pp. 80-90.

Remondino F. 2011, *Heritage recording and 3D modeling with photogrammetry and 3D scanning*, in *Remote Sensing*, 3(6), pp. 1104-1138.

Selmanović E., Rizvic S., Harvey C., Boskovic D., Hulusic V., Chahin M., Sljivo S. 2020, I*mproving accessibility to intangible cultural heritage preservation using virtual reality*, in *Journal on Computing and Cultural Heritage (JOCCH)*, 13(2), pp. 1-19.

Woźniakowski A., Hirsch R. 2023, *Studies of 19th Cen.tury defensive architecture using traditional and digital research methods on the examples of coastal fortifications in Poland*. Architectus (in print), originally presented at the ArchReSci conference, 23-25 March 2023

On digital transposition practices


GDANSK

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Side page, Fig. 01
An Imaginary Gdańsk
The image presents a fictional interpretation of Gdańsk, where iconic elements of the city—towers, historic buildings and recognisable landmarks—are reassembled into a single three-dimensional model, enriched by imaginative colours and combined into a unified and evocative visual representation.

Playing represents a cognitive and symbolic process through which individuals construct and attribute meanings to their surrounding reality. Play is a form of semiotic activity that allows individuals to experiment with roles, rules, and symbolic structures, contributing to the development of abstract thought and mental representation, Vygotsky (1933)[1]. Through simulation and interaction with objects and contexts, the subject assigns new values to seemingly neutral elements, transforming the playful experience into a dynamic system of signification. Highlights how play creates an autonomous symbolic space, a "magic circle" in which participants reinterpret the norms of social reality. This process fosters experiential learning, stimulating the use of symbols, metaphors, and narratives that enrich the construction of meaning. Play functions as a hermeneutic device in urban and pedagogical contexts, allowing individuals to decipher their environment through interaction and experimentation, thus attributing new meanings to physical and cultural spaces. From a psychological perspective, Piaget (1951) emphasizes that symbolic play facilitates knowledge construction by transforming the environment into a system of signs with which children and adults actively engage[2]. Thus, the ludic dimension is not merely recreational but serves as an epistemic process mediating between the subject and reality, continuously redefining the meaning of objects and situations based on experience and context. The relationship between play and image unfolds within a semiotic and cognitive dimension, where visuality plays a central role in meaning-making. In the context of serious games, visual language becomes a strategic element for learning, simulation, and narrative construction. Serious games leverage the immersive power of images to stimulate problem-solving processes, engaging players in experiences that transcend mere entertainment and acquire educational, social, or formative value. Interactive visualization enables the exploration of abstract and complex concepts through an intuitive interface, where the image supports comprehension and engagement[3]. In the theory of images, serious games can be interpreted as iconic systems that do not merely represent reality but actively construct meaning through interaction[4]. The image is no longer a static entity but a dynamic device that changes according to the player's actions, establishing an ongoing dialogue between the subject and the virtual environment.

[1] Vygotsky (1933), *Play and Its Role in the Mental Development of the Child, in Soviet Psychology*, pp. 62-76.
[2] Piaget J. 1951, *Play, Dreams and Imitation in Childhood, Re printed Routledge.*
[3] McGonigal (2011), *Reality Is Broken: Why Games Make Us Better and How They Can Change the World.*
[4] Mitchell (1994), *Picture Theory: Essays on Verbal and Visual Representation.*

Referee List (DOI 10.36253/fup_referee_list)
FUP Best Practice in Scholarly Publishing (DOI 10.36253/fup_best_practice)
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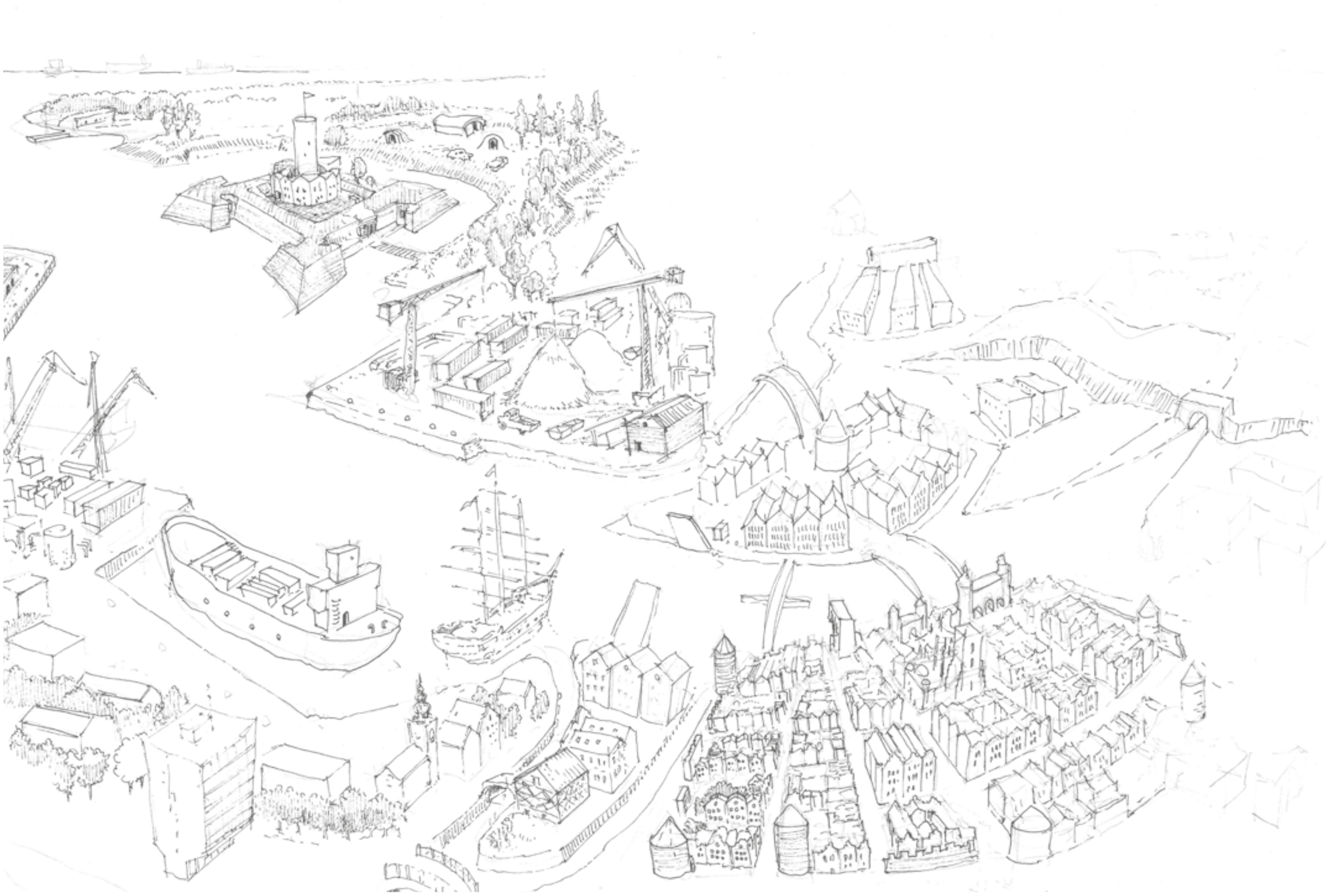


Figs. 02, 03
Hand Drawing as a Tool for Reinterpretation
The process of imagining and reinterpreting Gdańsk begins with hand drawing, as an initial act of synthesis through which the city is discretised and its most characteristic elements are selected and reassembled. This drawing by Sandro Parrinello represents the first step in constructing a conscious and interpretative vision of the place.

In this sense, play and image share a performative nature: both do not simply describe reality but transform it through active participation.

Gamification and serious games employ the persuasive power of images to enhance user engagement and retention, as demonstrated by Gee's (2007) studies on situated learning in educational video games. The image, through a combination of graphic, symbolic, and interactive elements, acts as a medium that connects the ludic dimension with cognitive processes, influencing meaning-making and the perception of the virtual world. In urban contexts, augmented reality (AR) and location-based games transform physical space into an interactive interface, where digital imagery overlays the real world, redefining the perception and significance of places.

When structured within a theoretical and technological framework, the interaction between play and image can translate into a conceptual and operational model guiding the design of immersive experiences in virtual urban environments. Serious games, due to their ability to integrate ludic dynamics with educational and formative objectives, provide a structure in which the visual representation of urban space is not merely a reflection of reality but an interactive construction capable of generating meaning. Such a model is based on three interconnected levels: the semiotic level, which defines the rules for constructing meaning through images and interaction; the cognitive level, which establishes the modes of learning and user participation; and the technological level, which determines representation and navigation choices within the simulated space. The model theory, play offers a context in which individuals can experiment with hypothetical scenarios through interaction with a system of rules and images, constructing new representations of urban space and memory Johnson-Laird's (1983).

When transposed into a three-dimensional environment, such as a digital twin of a city or a VR-based simulation, spatial perception is enriched with new layers of sensory and interpretative experience. A 3D city model used in a serious game is not a mere geometric reproduction but an interactive ecosystem where users can explore, modify, and reinterpret the urban landscape. This approach aligns with the theories of embodied cognition, which assert that learning and spatial understanding occur through direct interaction with the environment, whether real or virtual.

Within an immersive experience, the virtual city transforms into a dynamic palimpsest, where players can traverse historic streets, reconstruct lost buildings, interact with historical and sociocultural data, or even simulate future scenarios. Technologies such as augmented reality (AR) and virtual reality (VR) amplify this immersion, allowing users to experience the city as a constantly evolving environment.

Applying a 3D model in an urban serious game also opens new perspectives for heritage valorization, public participation in planning processes, and interactive learning. Through simulation, the player is not merely a spectator but an active agent who can explore the interconnections between space, history, and meaning. Such a model redefines how we perceive the city and serves as a tool for constructing new ways of interacting with it, laying the foundation for more conscious and inclusive urban design.

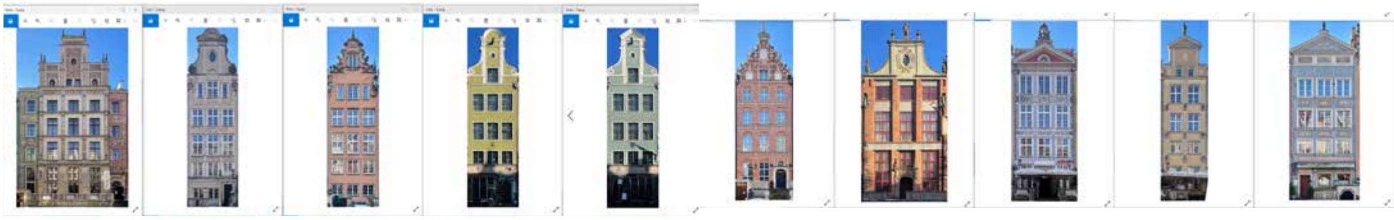
3D modeling represents a revolution in how we perceive and interact with urban environments. Thanks to advanced technologies such as photogrammetry, laser scanning, and Building Information Modeling (BIM), it is possible to create high-fidelity digital representations of urban spaces, allowing for a deeper understanding of their structure, history, and cultural significance[5]. 3D modeling is not merely a scientific documentation tool but also plays a crucial role in preserving the historical and cultural memory of cities, offering new perspectives on urban space representation and perception[6]. In this context, 3D modeling serves as a bridge between past and present, uniting technology, culture, and community in a collective effort to preserve the cultural identity of cities and ensure that architectural heritage is documented, enhanced, and passed down to future generations[7].

Advanced 3D modeling techniques, including photogrammetry, laser scanning, and Building

[5] Banfi et al. (2020), *L'arco della Pace di Milano e la sua memoria storica: dal rilievo 3D e HBIM alla mixed reality (VR-AR) / The Arch of Peace of Milan and its historic memory: from 3D survey and HBIM to mixed reality (VR-AR)*, pp. 1660-1677; Verdoscia et al. (2021), *La documentazione digitale del patrimonio costruito attraverso l'A-BIM. Il caso studio delle Terme di Diocleziano, Roma*, pp. 617-645.

[6] Parrinello (2024), *Forma e linguaggio. La comunicazione nell'interazione grafica*, in *TRIBELON. Journal of Drawing and Representation of Architecture, Landscape and Environment*, pp. 4-11..

[7] De Marco, Galasso (2023), *Digital survey and 3D virtual reconstruction for mapping historical phases and urban integration of the fortified gates in the city of Pavia*.



Figs. 04, 05, 06
A Textured Vision of an Imagined City
The virtual model has been mapped using photographs of the city's urban facades, generating a series of views that convey an oneiric and imaginative interpretation of Gdańsk, where reality is reassembled into a dreamlike and evocative urban landscape.

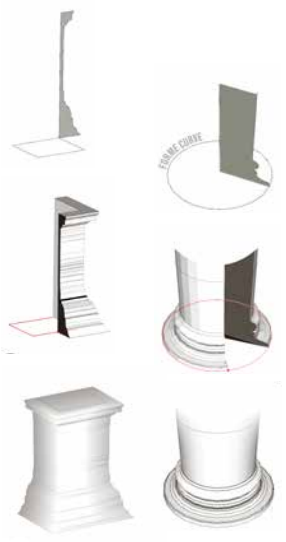
Information Modeling (BIM), allow for high-fidelity digital representations of urban environments. These technologies rely on remote sensing principles and spatial data acquisition, capturing architectural and structural details with extreme precision.

Photogrammetry uses Structure from Motion (SfM) algorithms to process high-resolution images and generate detailed three-dimensional models. Laser scanning, particularly Light Detection and Ranging (LiDAR) technology, produces highly dense point clouds, which are essential for structural analysis and conservation restoration. Integration with Geographic Information Systems (GIS) further enables the georeferencing of 3D models, providing a spatial framework that is crucial for land management and urban planning. Beyond the technical aspects, 3D modeling plays a key role in preserving historical memory. The perception of place is influenced by multidimensional factors, including social context, history, architecture, colors, and climate. Iconic elements, such as the Colosseum in Rome or the Eiffel Tower in Paris, hold a dominant position in the collective imagination and assume a hierarchical role in spatial representation. The prioritization of architectural elements in a three-dimensional model is not only a matter of metric accuracy but also of historical and cultural significance.

Some 3D modeling projects adopt a semiotic and phenomenological approach, emphasizing the perceptual and symbolic dimensions of urban space. In these cases, digital representation is not solely based on geometric data but integrates the historical and social value of buildings and infrastructure. This approach enables the creation of evocative models that highlight the emotional bond between inhabitants and their environment, contributing to the construction of an urban narrative that transcends mere physical documentation. The historic center of Gdańsk, Poland, is a site of significant historical and cultural interest, characterized by layers of architectural influences. An experimental project investigated the translation of urban perceptions into 3D models through a comparative diachronic analysis.

The methodological approach, which was selective and interpretative in nature, employed archival documentation and collected data, excluding direct community involvement in the modeling phase.
The 3D modeling strategy did not focus solely on the faithful geometric reproduction of urban artifacts but instead emphasized key elements significant to urban narrative and collective memory preservation. The selection prioritized: facades of residential buildings (representing social history), monumental gateways (strategic and symbolic), the water system (city-resource relationship), defensive walls (war memory), and a Ferris wheel (a modern element). This selection was conducted through documentary analysis (historical cartography, photographs, drawings).
The modeling process integrated various data acquisition techniques: photogrammetry (high-resolution images for 3D models of facades and monuments) and laser scanning (geometric structure of buildings and infrastructure). The combination of these technologies resulted in a 3D model that balances geometric accuracy with descriptive richness. The choice of selective rather than comprehensive reproduction enhanced the readability and significance of the model, emphasizing the site's distinctive elements.
The result is a three-dimensional model that does not function as a digital replica but as a synthetic interpretation of Gdańsk's historical complexity. The final composition combines historical and contemporary elements, highlighting the potential of 3D modeling as a tool for cultural heritage communication and diachronic reflection. This innovative approach enhances historical heritage and

Figs. 07, 08
Compressed Distances in an Oneiric Gdańsk
These views of the model present a city where distances are deliberately shortened, echoing a dreamlike dimension in which distant places are brought into close proximity. Above, the Vistula fortress emerges as a landmark, while below the Crane Gate along the Motława River is reimagined in deep purple tones, reinforcing the surreal and evocative character of the representation.



Figs. 09, 10
Golden gate model
3D models were also developed from survey data. The sequence above illustrates the rendering process, from the initial wireframe model to the fully textured model in Lumion, while on the side the different base elements of the model are explored and defined.

promotes accessibility. The 3D model of Gdańsk, in addition to serving as a support for research and education, functions as a tool for tourism promotion and strengthening the connection between the local community and its environment. Its ability to communicate the essence of a place through digital representation makes it an effective tool for preserving and transmitting collective memory.

The Gdańsk project demonstrates how, through a selective and methodological approach, 3D modeling generates digital models that, beyond mere geometric reproduction, serve as interpretative tools for cultural heritage. In this perspective, 3D modeling proves essential for the preservation and transmission of urban memory, fostering awareness of the historical and cultural value of the built environment. Despite the numerous advantages offered by 3D modeling for the preservation of urban memory, its large-scale adoption faces several challenges that limit its widespread implementation. One of the main obstacles is the high cost of advanced technologies, which includes not only the purchase of hardware and software tools but also the resources required for their maintenance and updates. Additionally, the complexity of modeling processes necessitates specialized training, which is often not easily accessible, making investment in educational programs essential for the training of qualified professionals. Another challenge concerns the management and storage of digital data, as high-resolution three-dimensional models generate vast amounts of information that must be securely and accessibly preserved over time. The need for format standardization and interoperability across different platforms represents another critical aspect, particularly in terms of collaboration between institutions, public bodies, and private entities. However, the technological landscape is rapidly evolving, and many of these barriers are gradually diminishing. Advances in artificial intelligence, combined with the development of open-source software and increasingly intuitive tools, are making 3D modeling more accessible even to organizations with limited resources. Advanced machine learning algorithms are already demonstrating their potential in automating complex processes, such as the virtual reconstruction of historical buildings from archival images or fragmented scans. Looking ahead, the integration of 3D modeling with artificial intelligence and machine learning could further revolutionize the field. These technologies will not only automate the digital reconstruction of historical sites with ever-increasing detail but also develop predictive models capable of analyzing the structural degradation of buildings and suggesting targeted conservation interventions.

At the same time, the continuous evolution of augmented reality (AR) and mixed reality (MR) promises to transform the digital city experience, making it even more immersive and interactive. Applications based on these technologies will enable citizens and tourists to explore historical urban environments from a new perspective, overlaying virtual reconstructions onto real spaces and enriching their understanding of historical and architectural contexts.

3D modeling, through technologies such as photogrammetry and laser scanning, is fundamental for digitizing urban heritage, going beyond mere geometric reproduction. It integrates historical and social

Fig. 11
Golden Gate 3D Model Detail
The image presents a view of the 3D model of the Golden Gate, focusing on the placement of the statues set along the balustrade crowning the roof. Rendered in Lumion, the model highlights the careful integration of architectural detail within the digital reconstruction.

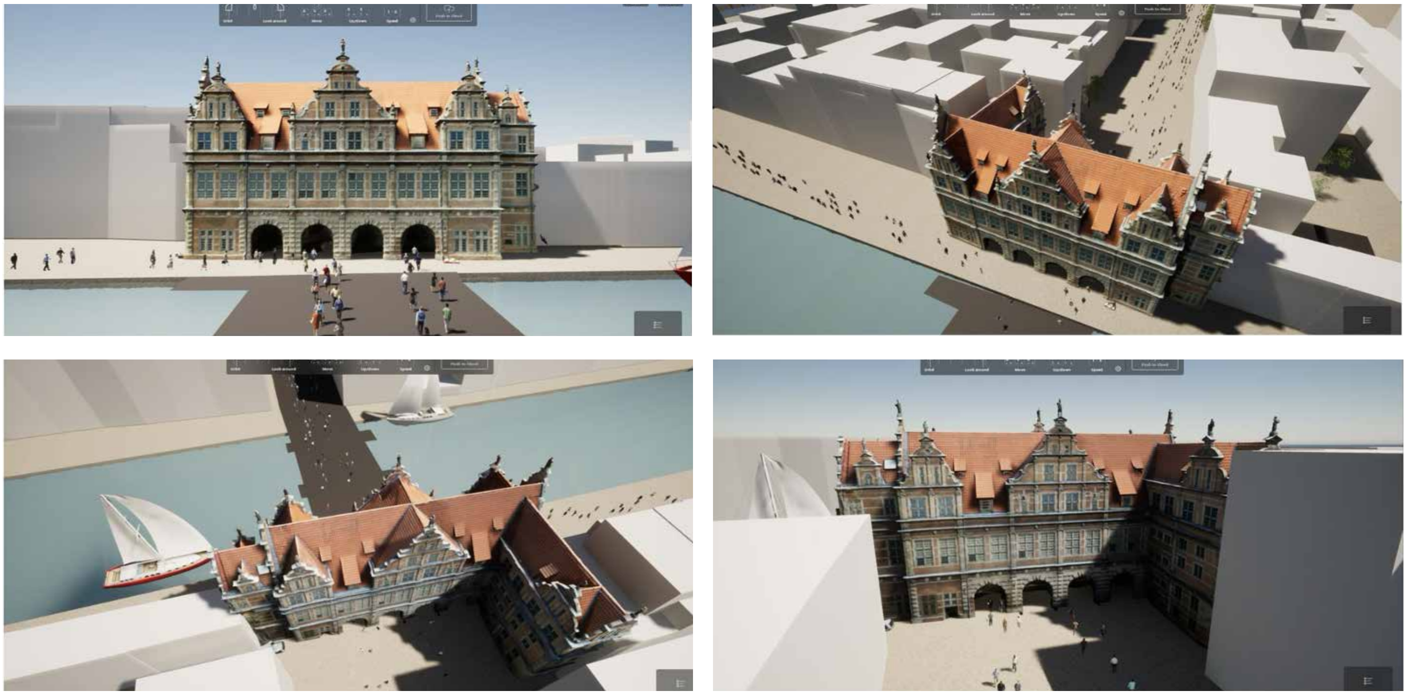


Fig. 12
Photogrammetric Model of the Green Gate
The images show selected views of the Green Gate, reconstructed through photogrammetric processing from drone-based acquisition. The model is integrated within the virtual environment of Gdańsk, contributing to the overall digital system of the city.

values, as demonstrated in the Gdańsk case study, where selected elements narrate a stratified history. While challenges such as costs and complexity persist, AI and machine learning offer automated and accessible solutions. These innovations, alongside augmented/mixed reality, promise an immersive experience, transforming how we interact with the digital city.

3D modeling thus emerges as a key tool for preserving urban memory, fostering awareness and appreciation of our cultural context. Its future lies in the integration of technical precision, historical interpretation, and emotional engagement, making it increasingly essential for transmitting heritage to future generations. By transcending physical reproduction, it provides an interpretative and layered reading of the urban fabric, with transformative potential for research, education, and tourism. The evolution toward more accessible, automated, and interactive models will ensure greater dissemination and a significant impact on the management and preservation of our collective memory.

References

Banfi F., Oreni D., Bonini J. A. 2020, *L'arco della Pace di Milano e la sua memoria storica: dal rilievo 3D e HBIM alla mixed reality (VR-AR) / The Arch of Peace of Milan and its historic memory: from 3D survey and HBIM to mixed reality (VR-AR)*, in Arena A., Arena M., Brandolino R. G., Colistra D., Ginex G., Mediati D., Nucifora S., Raffa P. (eds.), *Connettere. Un disegno per annodare e tessere / Connecting. Drawing for weaving relationships. Atti del 42° Convegno Internazionale dei Docenti delle Discipline della Rappresentazione*, FrancoAngeli, Milano, pp. 1660-1677.

De Marco R., Galasso F. 2023, *Digital survey and 3D virtual reconstruction for mapping historical phases and urban integration of the fortified gates in the city of Pavia*, Italy, in Defensive Architecture of the Mediterranean, vol. XV, Pisa University Press, Pisa

Fig. 13
Overview of the Ideal Model of Gdańsk
The image presents a comprehensive view of the idealised model of Gdańsk, where selected architectural elements and urban fragments are brought together into a unified composition, expressing a synthetic and interpretative vision of the city.

Gee J. P. 2007, *What Video Games Have to Teach Us About Learning and Literacy*, Palgrave Macmillan, New York.

Huizinga J. 1938, *Homo Ludens: A Study of the Play-Element in Culture*, Routledge, Boston.

Johnson-Laird P. N. 1983, *Mental Models: Towards a Cognitive Science of Language, Inference, and Consciousness*, Harvard University Press, Cambridge.

McGonigal J. 2011, *Reality Is Broken: Why Games Make Us Better and How They Can Change the World*, Penguin Press, New York.

Mitchell W. J. T. 1994, *Picture Theory: Essays on Verbal and Visual Representation*, University of Chicago Press; Chicago.

Parrinello S. 2024, *Forma e linguaggio. La comunicazione nell'interazione grafica*, in *TRIBELON. Journal of Drawing and Representation of Architecture*, Landscape and Environment, 1(2), pp. 4-11.

Piaget J. 1951, *Play, Dreams and Imitation in Childhood*, Re printed Routledge ,London.

Verdoscia C., Musicco A., Buldo M., Tavolare R., Pepe N. 2021, *La documentazione digitale del patrimonio costruito attraverso l'A-BIM. Il caso studio delle Terme di Diocleziano, Roma / The Digital Documentation of Cultural Heritage through A-BIM. The Case Study of the Baths of Diocletian, Rome*, in Arena A., Arena M., Mediati D., Raffa P. (eds.), *Connettere. Un disegno per annodare e tessere. Linguaggi Distanze Tecnologie / Connecting. Drawing for weaving relationship. Languages Distances Technologies. Atti del 42° Convegno Internazionale dei Docenti delle Discipline della Rappresentazione*, FrancoAngeli, Milano, pp. 2686-2703.Barsalou L. W. 2008, Grounded cognition, in *Annual Review of Psychology*, 59, pp. 617-645.

Vygotsky L. S. 1933, *Play and Its Role in the Mental Development of the Child*, in Soviet Psychology, 12(6), pp. 62-76.

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Building Information Modeling (BIM) can be described as digital representation of a building that includes graphical and non-graphical information about its design, construction, materials, life cycle, maintenance, performance and technology. This technology has undergone several stages of development over the past few decades[1], and from around 2015 different governments started to mandate BIM Levels in the Architecture, Engineering, and Construction (AEC) industry[2].

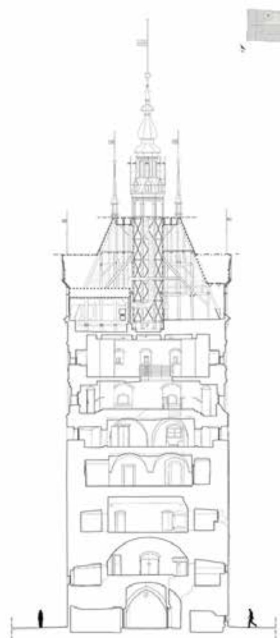
In recent years BIM is also becoming increasingly popular in the heritage sector because it allows the recording and preserving of essential data from historic buildings, with flexibility and timeliness that traditional techniques such as paper-based drawings did not allow to such an extent. However, using BIM technology in this field (known as Heritage Building Information Modelling or HBIM) is still a novel tool in terms of built heritage documentation. Although, currently there are no widely recognized standards for producing HBIM models, much analysis and research done on heritage modeling show that photogrammetry and laser scanning techniques were the most popular modern-day methods of developing a Heritage BIM model[3].

This technology allows the capturing of existing historical features and built conditions in detail. Such documentation provides the opportunity to visualize and simulate the site using Virtual Reality (VR) or Augmented Reality (AR) technologies, which can help to generate interest in heritage sites and provide a new experience of History without causing more wear and tear damage[4].

This was actually the case in the work performed on the Prison Tower in Gdańsk, and it involved several steps with the workflow structured in many phases. Converting the acquired data to HBIM involved a complex process of data import, 3D modeling, and the addition of historical context and information.

Side page, Fig. 01
Prison Tower
Point cloud view.

Fig. 02
Prison Tower section
Vector drawing of the section of the prison tower traced from the point cloud data.



[1] Eastmanet al. (1974), *An Outline of the Building Description System*; Latiffi et al. (2014), *The Development of Building Information Modeling (BIM) Definition*.
[2] Hijazi, Omar (2017), *Level of Detail (LOD)* Specifications, *Standards and File-format Challenges in Infrastructure Projects for BIM Level Three*; Rebolj et al. (2017), *Point cloud quality requirements for Scan-vs-BIM based automated construction progress monitoring*, pp. 143-154.
[3] Yang et al. (2020), *Review of built heritage modelling: Integration of HBIM and other information techniques*, pp. 350-360.
[4] Balzani, Maietti (2017), *Architectural Space in a Protocol for an Integrated 3D survey aimed at the documentation, representation and conservation of Cultural Heritage*, pp. 113-122.

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Prison tower HBIM digital twin

With regard to those developments in the use of digital techniques for the virtualization of Cultural Heritage, such as HBIM, within the Prometheus project an attempt has been made to analyze the potential offered by this informative, parametric, and collaborative methodology by applying it to several case studies on the territory of Gdańsk. In particular, within this section, a series of HBIM experiments conducted on the Prison Tower complex and aimed at the creation of its informative digital-twin are presented.

From the workflow point of view, the first stages of analysis of the building and its main components were crucial, during which a sort of conceptual model was defined and subdivided according to a hierarchical and semantic scheme of the various types of architectural objects present. These analyses, preliminarily visual on-site, were then also carried forward on the virtual outputs developed from the previous digital survey phases. The analysis of the point cloud processed by the laser-scanner survey and the related CAD graphical outputs developed on the basis of this, made it possible to create a proper coded database of the architectural elements that form the Prison Tower according to their structural function (such as walls, floors, roofs, windows, doors etc.).

Once the hierarchical and semantic framework of the building was defined, it was possible to proceed with the parametric modeling of the individual components within a BIM environment. For this experimentation, the BIM management capabilities of Autodesk Revit software were exploited, within which all the informative and parametric modeling processes of each architectural component were carried out. To proceed with their BIM reconstruction, both the processed 2D CAD assets (plans, elevations, sections, details etc.) and the complete point cloud developed from the laser-scanner survey were first linked within this platform. These assets thus became the geometric-morphological bases on which the various parametric elements were developed. Through Scan-to-BIM processes, all the main architectural structures of the Prison Tower (walls, floors, roofs) were thus created first, trying to maintain - given the irregularity of some of them - an adequate Level Of Accuracy (LOA) between the modeled geometries and the point cloud (with deviations of max 5 cm)[5].

Fig. 03
Scan to HBIM
Preliminary analysis conducted on the building and its architectural elements.

[5] Agustin, Quintilla (2019), *Virtual reconstruction in BIM technology and digital inventories of heritage*, pp. 25-31.

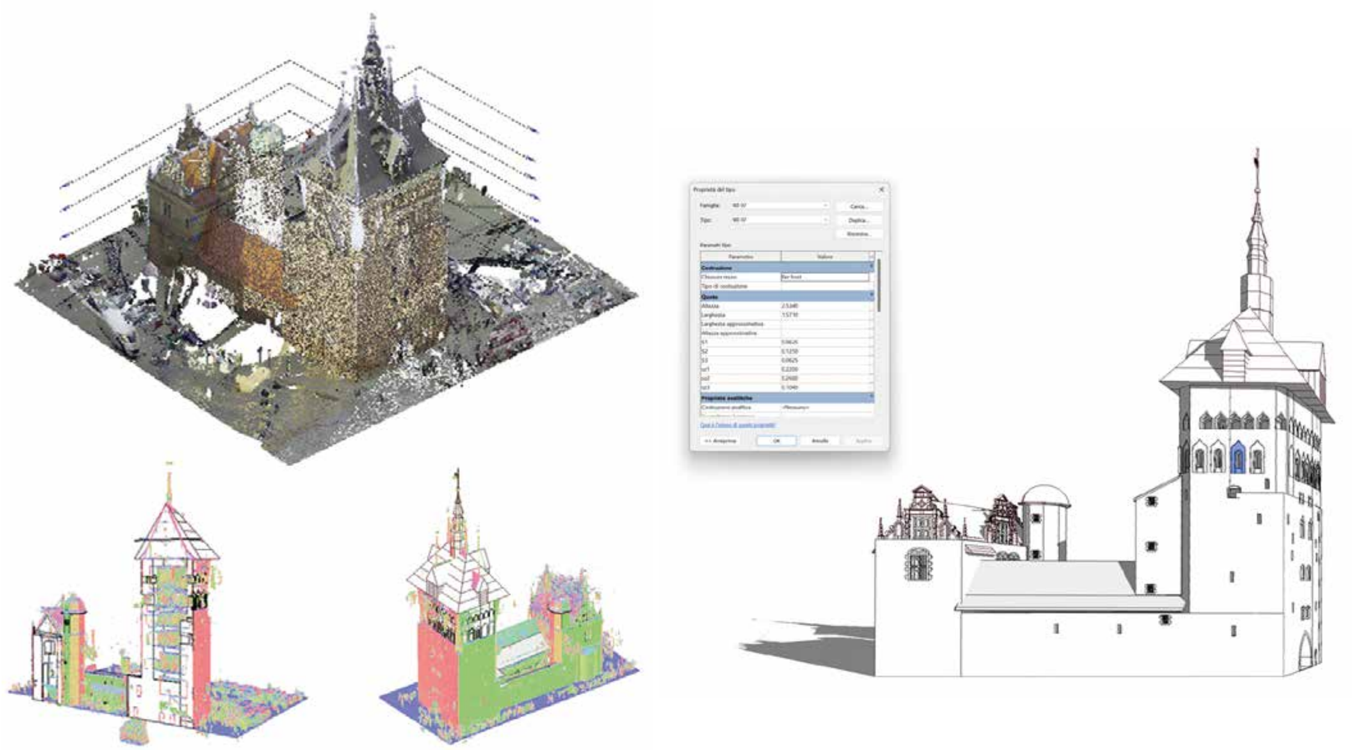

Fig. 04
Scan to HBIM
Setup of the laser-scanner point cloud to be used as a metric basis in HBIM environment.

Extremely relevant was then the work done on the creation of the individual parametric families related to the openings (doors, portals, windows etc.). For these objects, a series of CAD-to-BIM processes were carried out, through which the entire system of openings was reconstructed in a parametric and potentially informatized way.

In conclusion, this HBIM workflow made it possible to develop a real three-dimensional database of information, useful both for digital documentation of the building for possible restoration work, but also for the preparation of 3D assets to support virtual fruition systems intended for storytelling experiences[6] .

Drone photogrammetric 3D model

In order to obtain a digital-twin of the Prison Tower that would ensure not only a reliable metric-morphological basis but also a proper colorimetric and material adherence of its structures, a SfM photogrammetric survey was carried out using a drone. In particular, for this case study, the features of the UAV device DJI Mini Pro 3 were exploited. Through this drone, about 200 photographs were acquired, providing an almost complete coverage of the external surfaces of the Prison Tower. Through specific processes conducted within a dedicated photogrammetry software, these images were processed and aligned with each other creating first a descriptive color point cloud of the study object, and then, through triangulation of the points, a three-dimensional mesh mapped with the texture obtained the data from the photographs[7].

The textured 3D model obtained from this aerophotogrammetric survey thus made it possible to

[6] Accettulli, Farinati (2021), *Historical Bim: la metodologia applicata agli edifici.*
[7] Forgione et al. (2022), *San Massimo di Forcona (AQ), un polo di potere. Primi dati dalla lettura archeologica delle architetture*, pp. 189-216.

Fig. 05
Prison Tower.
Methodological steps for creating the 3D aerophotogrammetric drone model of the Prison Tower.

Next page, Fig. 06
Prison Tower.
Close-range photogrammetric models of the main architectural elements.

obtain a highly realistic asset that could be used both for virtual fruition systems (AR-VR) and for the creation of 2D drawings, such as orthophotoplans of the various elevations.

AR Web fruiton systems

AR (Augmented Reality) is an innovative technology with enormous potential that has already achieved remarkable results in various fields. AR web digital models, as an extension and application of AR technology, show us a brand new digital world that blends reality and virtuality, creating unprecedented interactive experiences[8].

The basic principle of AR web digital models is to superimpose virtual digital content onto the real world, allowing users to interact with virtual objects. These virtual objects can be 3D models, images, videos, or other forms of digital content, presented to users through AR devices such as smartphones, smart glasses, or head-mounted displays. The unique feature of this technology is that it can combine virtual objects with the real environment, allowing users to see and manipulate virtual objects in reality, creating a more immersive experience for users.

In this case study, the Prison Tower was digitally recorded and modeled, then the AR browsing and interaction of the digital model was implemented using Sketchfab[9] (a web graphics library-based network model sharing platform). Through the AR function provided by this platform, users can place the model in the "real world" in a virtual situation and enjoy the model in 360° through their smartphones.

AR web digital models have a wide range of applications. In the field of education, it can change

[8] Fanini et al. (2023), *Augmented Reality for Cultural Heritage*, pp. 391-411.
[9] https://sketchfab.com

traditional learning methods by integrating virtual 3D models into practical teaching environments, enabling students to understand and learn more intuitively. It can be used for virtual design and simulation, improving product manufacturing efficiency and quality. In the entertainment field, it can be used to enhance gaming experiences and real-time interaction, bringing more fun and challenges to players[10].

VR fruition systems

Virtual reality is increasingly being used and applied in the presentation of heritage structures. Immersive technologies allow people to immerse themselves in a prepared scene, allowing them to explore and understand the facility being presented. The majority of VR platforms are based on game rendering engines to achieve high quality effects[11].

One of the aims was to implement a 3D model of the Prison Tower, which was made using a photogrammetry method and its integration into the virtual environment, as well as to create a real-time visualization and animation showing the facility. Typically, models generated with photogrammetric tools have complex geometry, for this reason there is very often a need to optimize the model, especially for large objects or scenes. In the case presented here, this was not necessary, as the visualization and animation creation involved only a few objects whose scale and level of detail was not high enough to significantly slow down the work.

The visualizations and video were produced with Twinmotion software, which is based on the game rendering engine, the Unreal Engine. It is a real-time visualization tool and allows the export of images, panoramas, 360 scenes and animations. Twinmotion has a library of realistic 3D models and materials

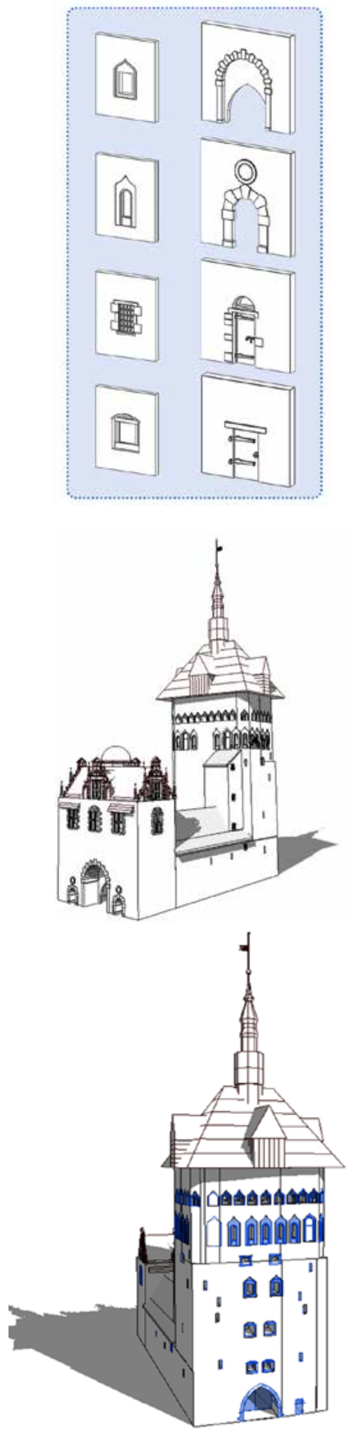

Fig. 07
HBIM
The digital twin of the Prison Tower and the informative and parametric database of its elements

[10] Nee, Ong (2023), *Springer Handbook of Augmented Reality.*
[11] Gorkovchuk et al. (2021), *Integration of complex 3D models into VR environments: case studies from archaeology*, pp. 232-236.

which allows the creation of high-quality visualizations. In the mentioned software, it is not possible to open a scene with a photogrammetric model directly, but it is sufficient to export the model to a format, e.g. OBJ, and in Twinmotion use the "Import" function to load the model. Once the model has been imported, the scene can be completed with selected objects from the libraries until the desired effect is achieved. By using this tool, it was possible to create realistic visualizations and animations showing the Prison Tower, which was the subject of the survey.

This allowed for a better understanding of the building. It facilitated the study of details of the building, especially those inaccessible to the eye from a human perspective[12].

The results of the works related to the case study of the Prison Tower in Gdańsk presented within this chapter, have contributed to investigating and deepening the experimentation of methodologies and practices of digital transposition of architectural data for the creation of informative and virtual fruition systems.

In particular, it has been shown how the application of parametric HBIM and aerial-photogrammetric SfM modeling approaches has enabled the setting up of 3D assets that can be implemented both within additional informative databases, and in specific game-engine platforms intended for virtual fruition.

These systems, such as Augmented Reality (AR) or Virtual Reality (VR), also ensure, not only immersive and real-time navigation of the processed 3D models and associated information, but more importantly, support public-engagement with the object of study and the dissemination of the results of Cultural Heritage researches, such as these carried out within the Prometheus project[13].

Fig. 08
Prison Tower.
Methodology for implementing the photogrammetric 3D model within the AR/VR-platform Twinmotion.

[12] Theodoropoulos, Antoniou (2022), *VR Games in Cultural Heritage: A systematic Review of the Emerging Fields of Virtual Reality and Culture Games.*
[13] Parrinello (2023), *Narrazioni digitali per la memoria dello scavo archeologico,* pp. 154-171.

References

Accettulli E., Farinati P. 2021, *Historical BIM: la metodologia applicata agli edifici*, Tecniche Nuove, Milano.

Agustin L., Quintilla M. 2019, *Virtual reconstruction in BIM technology and digital inventories of heritage*, in *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLII-2/W15, pp. 25-31.

Balzani M., Maietti F. 2017, *Architectural space in a protocol for an integrated 3D survey aimed at the documentation, representation and conservation of cultural heritage*, in *Diségno*, 1, pp. 113-122.

Eastman C., Fisher D., Lafue G., Lividini J., Stoker D., Yessios C. 1974, *An outline of the building description system, Institute of Physical Planning*, Carnegie-Mellon University.

Fanini B., Pagano A., Pietroni E., Ferdani D., Demetrescu E., Palombini A. 2023, *Augmented reality for cultural heritage*, in Nee A. Y. C., Ong S. K. (eds.), Springer Handbook of Augmented Reality, Springer, Cham, pp. 391-411.

Forgione A., Arrighetti A., Brusaporci S., Lumini A. 2022, *San Massimo di Forcona (AQ), un polo di potere. Primi dati dalla lettura archeologica delle architetture*, in *Archeologia dell'Architettura*, XXVII(1), pp. 189-216.

Gorkovchuk J., Gorkovchuk D., Luhmann T. 2021, *Integration of complex 3D models into VR environments: case studies from archaeology*, in *Proceedings of the joint international event 9th ARQUEOLÓGICA 2.0 & 3rd GEORES*, Valencia, pp. 232-236.

Hijazi A. A., Omar H. A. 2017, *Level of detail (LOD) specifications, standards and file-format challenges in infrastructure projects for BIM level three*, in *WIT Transactions on the Built Environment*, 169, pp. 143-154.

Latiffi A. A., Brahim J., Fathi M. S. 2014, *The development of building information modeling (BIM) definition*, in *Applied Mechanics and Materials*, 567, pp. 625-630.

Nee A. Y. C., Ong S. K. 2023, *Springer Handbook of Augmented Reality*, Springer, Cham.

Parrinello S. 2023, *Narrazioni digitali per la memoria dello scavo archeologico*, in Maltomini F., Parrinello S. (eds.), *ARSINOE 3D: Riscoperta di una città perduta dell'Egitto greco-romano*, Firenze University Press, Firenze, pp. 154-171.

Rebolj D., Pučko Z., Čuš Babič N., Bizjak M., Mongus D. 2017, *Point cloud quality requirements for scan-vs-BIM based automated construction progress monitoring*, in *Automation in Construction*, 84, pp. 323-334.

Theodoropoulos A., Antoniou A. 2022, *VR games in cultural heritage: a systematic review of the emerging fields of virtual reality and culture games*, in *Applied Sciences*, 12(17), 8476.

Yang X., Grussenmeyer P., Koehl M., Macher H., Murtiyoso A., Landes T. 2020, *Review of built heritage modelling: integration of HBIM and other information techniques*, in *Journal of Cultural Heritage*, 46, pp. 350-360.

digital transposition practices and immersive 3D Visualisation Lab. experimentation for CH dissemination

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Side page, Fig. 01
Scanned Long Lane in Gdańsk rendered in the BigCAVE

There is no doubt that virtual reality has great potential in architectural and urban activities. The ability of exploring the interior of a virtual apartment by a person looking for a place to live is already widely used by developers. Similarly, an architect can show the investors very realistically what the buildings designed for them will look like in the future. But is prototyping the only way to use virtual reality by architects and urban planners? The aim of this study is to present various applications of virtual reality in the work of architects, urban planners and people dealing with cultural heritage in general, both those mentioned above and others that have already been implemented, but also potential ones. The authors of this study are not architects, but virtual reality specialists. Therefore, it is worth treating this study as a hint on where architects, urban planners and other cultural heritage professions can use virtual reality.

Immersive 3D Visualization Lab

All architectural and cultural heritage applications of virtual reality described in this chapter were implemented by the authors who are employed in the Immersive 3D Visualization Lab (I3DVL) located at the Faculty of Electronics, Telecommunications and Informatics of the Gdańsk University of Technology[1]. Most of these applications can be run in the virtual reality devices called CAVEs (Cave Automatic Virtual Environment) available in the lab. The CAVE is a room whose walls are 3D projection screens requiring only putting light stereoscopic glasses known from 3D cinemas on the user's head. People inside the CAVE are surrounded by 3D images that visualize a coherent scene. Thanks to this, they have the impression of staying in a virtual world created by a computer. This impression is intensified by tracking the head of the simulation participant and generating images from its perspective. Moving within the CAVE therefore causes adequate movement in the virtual world. Movement and other interactions in the virtual world can also be achieved using tracked controllers equipped with buttons and joysticks. You can get similar effects using virtual reality headsets. However, this requires putting about half a kilogram of optoelectronic equipment on the head. Additionally, with them on our heads we cannot see our own body, the controller held in our hand, or other simulation participants, only their artificial-looking avatars.

[1] Lebiedź (2022), *Virtual immersive environments*, pp. 151-170 (Appendix: pp. 261-277); Lebiedź , Mazikowski (2014), *Innovative Solutions for Immersive 3D Visualization Laboratory*, pp. 315-319.

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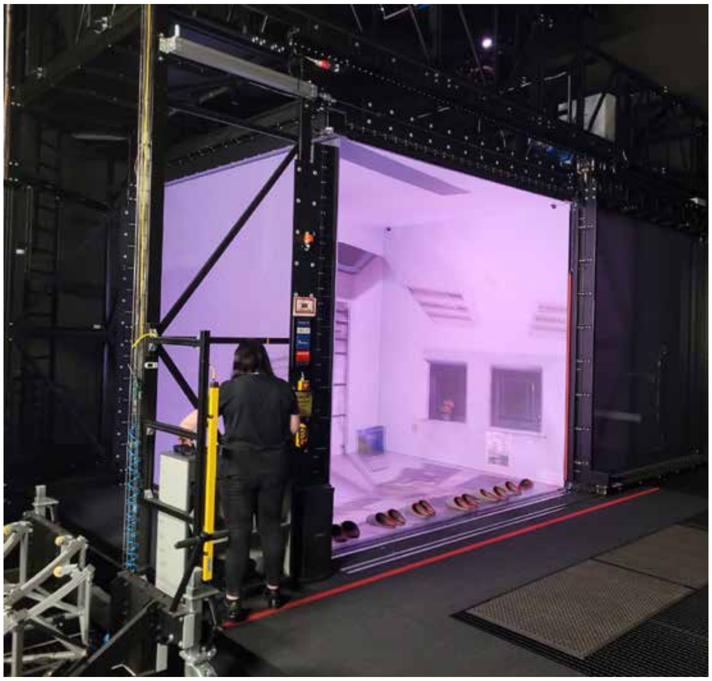

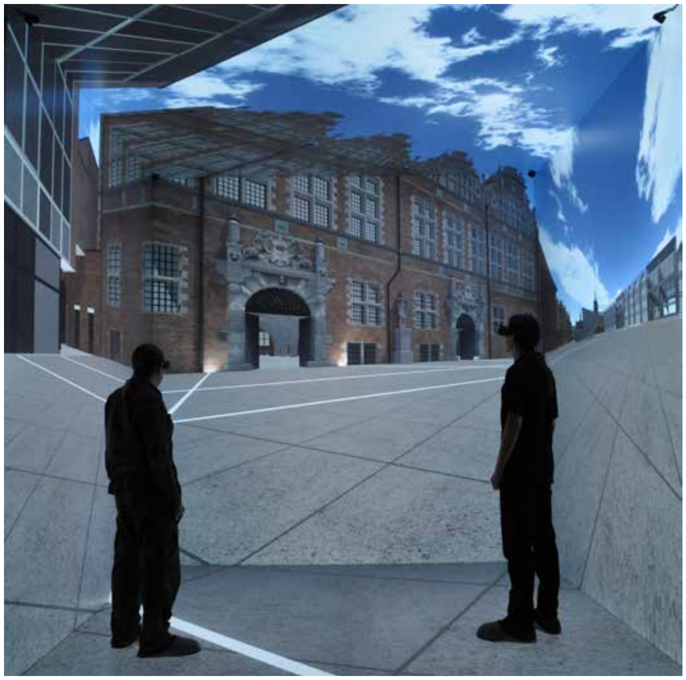

Fig. 02
The BigCAVE room system installed in the Immersive 3D Visualization Lab

Fig. 03
Virtual walk through the Coal Market rendered in the BigCAVE

Worse still, if you turn your head, the image must be modified, while in the CAVE it waits on the side screen. Although the delay in generating a new image is currently negligible, headset users often complain of various types of ailments, which are very rare in CAVEs. The main CAVE of the I3DVL is the cubic BigCAVE consisting of four walls, a ceiling and a floor. It is the fully immersive CAVE because the virtual world is visible to the simulation participant in all directions. In addition to standard controllers, in this CAVE you can move freely in the virtual world with your legs using a spherical walk simulator that works like a hamster wheel. The lab has also the MidiCAVE with three walls and a floor, as well as a motion capture system that allows full-body interaction with the virtual world. Over a hundred applications have already been developed for the lab. They were prepared for BigCAVE and MidiCAVE, but the third CAVE called MiniCAVE was used to implement and test them. The MiniCAVE is composed of four 27-inch 3D monitors (imitating three vertical walls and a horizontal floor) and can be used by programmers in a sitting position, which allows them to easily use the keyboard and mouse.

Application of virtual reality in cultural heritage dissemination

Virtual reality can support many different disciplines of human activity. It would be difficult to find a discipline where the capabilities of virtual reality would be useless. Its usefulness applies especially to areas such as the dissemination of cultural heritage or architecture and urban planning. The following applications for these areas can be distinguished: 3D visualization, designing, training, analysis and shaping of behaviour. We will discuss them briefly below.

Fig. 04
Virtual tour of the Vistula Mouth Fortress and its surroundings rendered in the BigCAVE

Fig. 05
Video game in the virtual Vistula Mouth Fortress rendered in the BigCAVE

3D visualization

The most obvious and, consequently, the most popular application of virtual reality is 3D visualization. It can be used for prototyping, reproduction or reconstruction. We describe below the virtual prototyping completed and used to show the investors around a virtual building or complex of buildings still at the design stage, to agree on the details of the project before their implementation or to show them its several variants in order to choose the variant to be constructed. In turn, the virtual reproduction of an existing object allows for planning its renovation or reconstruction. It also enables simulation of various situations, including crisis situations, and training of staff operating the digitized facility. This type of object reconstruction is often called a digital twin. Virtual reconstruction, however, can be used for educational or scientific purposes to present the appearance of a non-existent or re-edified object. The virtual presentation of an object may also be associated with showing its non-visual parameters, such as the movement of the air stream around the object, heat flows in it or the strength distribution of its structure. Such a presentation of abstract quantities allows the recipient to better understand the visualized phenomenon in the context of the properties of the object, e.g. its geometric form.

Designing

The applications presented in the previous section usually refer to a static scene that can only be explored. However, you can imagine a situation in which the creator (e.g. architect) designs an object by constructing it in virtual space. Of course, it is difficult to imagine replacing CAD software with all its design support mechanisms by a virtual reality platform with similar functionality, especially since one should be concerned whether interaction in virtual reality will be much more troublesome than operating a keyboard and a 2D mouse on a desktop.



Fig. 06
BigCAVE with a training application for assembling an industrial robot

Fig. 07
BigCAVE with the visualization of the sacristy of the St. Nicholas's Church in Gdańsk

Fig. 08
3D projection in the auditorium of the image seen by the participant of the simulation in the BigCAVE

However, creating an initial, simplified concept of the planned facility in three dimensions seems to be an attractive solution, especially in the case of team design. The key for this type of applications is to develop an appropriate interface (hand gestures, maybe special controllers?) acceptable to designers thanks to its naturalness and low movement requirements. Such a convenient interface can only be developed in close cooperation with designers.

Training

Virtual reality can be successfully used in the training of technical services operating the object (e.g. specific building or some kind of buildings). The development of a building inspector trainer simulator, where various construction defects in a building could be arranged, seems very promising. An analogous SUSI survey simulator for ship inspection[2] developed by DNV – an international accredited registrar and classification society shows the great potential of this type of solutions in training and verification of skills. Another example of virtual training may be the descriptive geometry projection demonstrator currently being developed in the I3DVL. By observing the construction of individual views in three dimensions, the student will be able to understand them faster. This application should make it easier for students to develop their spatial imagination. Virtual reality applications that teach various specific tasks are also possible, such as maintaining a linden wood sculpture or servicing a tower clock. It should also be noted that training on procedures in crisis situations using virtual reality is an irreplaceable tool. Virtual reality allows for practical training in a way that is safe for people and the object. It is also relatively inexpensive compared to a physical training ground.

Analysis and shaping of behaviour

By using properly prepared virtual reality applications, it is also possible to examine people's feelings and behaviours in various environments and even try to shape these behaviours. Observation of behaviour can be used, for example, to verify by future users proposed solutions or determine the arrangement of various functions (such as garbage cans) in the designed space. Shaping attitudes can be achieved by preparing certain tasks in virtual reality (e.g. in the form of video games) in which undesirable behaviours make it difficult to achieve the goal. However, the preparation of such applications should be done very carefully

[2] Żrodowski (2015), *Application of Survey Simulator for Museums*, pp. 147-152.

Fig. 09
Introduction to the 3D presentation of the image seen by the participant in the simulation in the BigCAVE.

Fig. 10
Exploring in the BigCAVE the virtual sacristy of the St. Nicholas's Church in Gdańsk

and in constant consultation with psychologists, so as not to achieve effects that are counterproductive. On the other hand, this approach is very promising when it comes to eliminating anti-social and anti-ecological attitudes, especially among children who love to compete in various games. Virtual littering in a game involving the search for some artefacts in some space may result in difficulties in the form of having to walk through piles of the same type of garbage that slow down the movement.

Examples of applications

In the previous section, we outlined the possibilities offered by virtual reality in architectural and urban designing and the dissemination of cultural heritage. In this section, we will present virtual reality applications already implemented in the I3DVL using Unity game engine[3]. These tools can be treated as examples of the applications described in the previous section. They are all the result of cooperation between VR specialists and architects or similar professions.

Virtual urban prototyping

The Gdańsk Museum commissioned architects from the Academy of Fine Arts in Gdańsk to develop landscape plan for the area around the Vistula Mouth Fortress (Polish: Twierdza Wisłoujście). Students of the Faculty of Architecture supervised by the AFA professor prepared an appropriate visualization using Sketchup. Then, four students of the Faculty of Electronics, Telecommunications and Informatics at the Gdańsk University of Technology adapted this visualization to the CAVEs in the I3DVL[4]. In the application you can observe the surroundings of the fortress from the perspective of a pedestrian, but you can also fly virtually, viewing them from a bird's eye view.

Virtual architectural prototyping

One of the first applications for the CAVE in the I3DVL was the Inception. The application presents

[3] Lebiedź (2023), *Virtual reality as a tool for development and simulation. Research projects and experience of the Gdańsk University of Technology*, pp. 1-6; Lebiedź, Redlarski (2016), *Applications of Immersive 3D Visualization Lab*, pp. 69-74.
[4] Dzierżko-Bukal, Lebiedź (2018), *Urban prototyping in CAVE. Cooperation between the Academy of Fine Arts in Gdańsk and the Gdańsk University of Technology*; Lebiedź (2019), *Virtual reality support for the projects carried out in the AFA in Gdańsk*, Pielak et al. (2018), *3D Model Making Patterns for Active Architectural Visualization – Guidelines for graphic designers cooperating with software developers*, Pielak et al. (2018), 3D *Model Preparing Patterns for Interactive Urban Visualization – Guidelines for graphic designers preparing 3D models for virtual reality applications.*

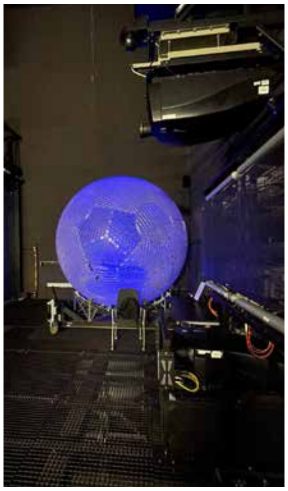

Fig. 11
Entering the BigCAVE requires putting on slippers over your shoes (you walk on the screen)

Fig. 12
Spherical gait simulator

a virtual reconstruction of the I3DVL building's exterior and interior, that was modelled in 3D based on the building's architectural designs. User of the application can freely walk through all rooms and observe their contents, like the arrangement of furniture or technical equipment. This includes the main room with the CAVE that showcases the screens, the steel construction holding them, the projector arrangement and the metal technical floor suspended a few meters above the room's floor, to make space for the projectors below the bottom screen. The name Inception came from this virtual CAVE which is interactive and can be set to display a different part of the building on the virtual screens.

Virtual reality aided investor decision

A few years ago, the Faculty of Architecture of the Gdańsk University of Technology organized a competition for the development of the western frontage of the Coal Market square (Polish: Targ Węglowy) in Gdańsk. Three groups of students of this faculty developed their concepts, which were then placed in the CAVE environment by an academic teacher of the Faculty of Electronics, Telecommunications and Informatics at the Gdańsk University of Technology[5]. In the application, you can wander around and view the Coal Market from a pedestrian's perspective and teleport to the roofs of nearby buildings to see the scene from a bird's eye view.

Video game as a popularization of cultural heritage

The 14th-Century Vistula Mouth Fortress (Polish: Twierdza Wisłoujście) is the oldest coastal fortress of the Polish seacoast. Throughout history, it has been besieged and attacked many times and has served various functions: it protected the port of Gdańsk and ships on their way there, it was the berthing site of the Polish fleet, a guardhouse, a lighthouse, a prison, and even the headquarters of a sailing club. Using photogrammetry, the team from the Faculty of Civil and Environmental Engineering of the Gdańsk University of Technology prepared a model of the fortress (both interior and exterior)[6], which was then used to create an application for the CAVE systems, HMDs, and PCs. A game was created in which the player, in the role of a soldier, can explore the entire facility while completing various tasks and, by doing so, learn about its history and purpose in a pleasant way. Such tasks include fighting against infantry and ships, finding the elements spread across the fortress necessary to fire the cannon (a barrel of gunpowder, container with wads, rammer, fuse, linstock, bullets) or to light a fire that serves as a light source for the lighthouse (a hearth, basket of wood, kindling, fire torch).

[5] Lebiedź, Szwoch (2016), *Virtual Sightseeing in Immersive 3D Visualization Lab*; Pielak et al. (2018), *3D Model Making Patterns for Active Architectural Visualization – Guidelines for graphic designers cooperating with software developers*; Pielak et al.. (2018), *3D Model Preparing Patterns for Interactive Urban Visualization – Guidelines for graphic designers preparing 3D models for virtual reality applications*, pp. 1641-1645; Życzkowska, Urbanowicz (2019), *Architectural education and digital tools: the challenges and opportunities*, pp. 326-331.
[6] Widerski, Daliga (2018), *Accuracy analysis of 3D model obtained by photogrammetric method on the example of historic room from Wisłoujście Fortress*, pp. 1-5.

Matching the environment to the object

A bronze equestrian statue on a sandstone pedestal, designed by the Lviv sculptor Tadeusz Barącz and depicting the Polish King Jan III Sobieski, was erected at the garden square along the Wały Hetmańskie avenue, one of the most representational boulevards of Lviv, and officially unveiled in 1898. As a result of 1944's USSR takeover of the city, in 1950 the monument was transferred to Poland and placed in the park in Warsaw's Wilanów, and then in 1965 it was transported to Gdańsk, where it stands at the Wood Market square (Polish: Targ Drzewny) to this day. A few years ago, it was scanned by a team from the Polish-Japanese Academy of Information Technology, and the resulting model, along with spherical photos taken by a trainee from the Lviv Polytechnic National University, was used to prepare an application for the CAVE systems that allows 3D viewing of the monument in both the original (at present, occupied by the monument to Taras Shevchenko) and the current environment.

Virtual step back in time

The Seal Hunters' Settlement is another application available in the I3DVL where, by completing various tasks, the player can learn about the cultural heritage and urban design of the past era – this time, however, by stepping back in time and visiting a hand-modeled reconstruction of an early medieval port village in Eastern Pomerania that nowadays exists only virtually. During the game, the player talks to the settlers and receives tasks from them that require exploration of the village and adjacent areas. Such tasks are: collecting medicinal herbs, going out to sea and collecting fishing nets, cutting down trees and rebuilding a damaged palisade. Virtual reconstruction of objects and places that no longer exist is usually much cheaper, sometimes the only possible solution, and a great way to show and preserve valuable historical goods.

Virtual reconstruction – time machine

The sacristy of the St. Nicholas's Church in Gdańsk is a small room (compared to the church itself) that conceals a long history. It is part of a basilica that was probably built in 1185 and has been rebuilt several times, so it is an interesting historical building. The changes were so big that almost every part of the place was altered several times – from the floor, to the ceiling, which is the most interesting part. At one point it consisted of two rooms. A few years ago, in collaboration with architects from the Faculty of Architecture of the Gdańsk University of Technology, models were created showing the sacristy at different times – from its beginnings to the present day. The objects themselves were created using 'Rhino' software[7] and adapted for display in the laboratory.

[7] Kowalski et al. (2020), *Teaching architectural history through virtual reality*, pp. 197-202.

Fig. 13
Monument to the Polish King Jan III Sobieski in a changeable background rendered in the BigCAVE

Fig. 14
Virtual sacristy in St. Nicholas's church in Gdańsk in a specific historical era rendered in the BigCAVE

Fig. 15
Virtual Gierłowska Lizard at 100× magnification rendered in the BigCAVE

Virtual reconstruction of lost artefact

The Amber Room was a chamber decorated in amber, gold and mirrors. It was constructed at the beginning of the 18th Century by Gdańsk amber craftsmen on behalf of the King in Prussia. Shortly thereafter, it was presented to the Tsar of Russia, who placed it in Tsarskoye Selo near Saint Petersburg. Unfortunately, it disappeared during World War II. A few years ago, one of the students of the Faculty of Electronics, Telecommunications and Informatics at the Gdańsk University of Technology reconstructed it virtually from photos found on the Internet. Currently, it can be visited in the CAVE environments of the I3DVL[8].

Digital twins of the urban layout

The Long Lane (Polish: ulica Długa) in Gdańsk is located in the downtown district, and its extension is Long Market (Polish: Długi Targ). The street and its extension form the Royal Route (Polish: Trakt Królewski), also known as the Royal Road (Polish: Droga Królewska). It is excluded from vehicular traffic and is a popular promenade. The Long Lane in Gdańsk is 320 m long. In 2023, the I3DVL received a scan (point cloud) from the Faculty of Architecture at the Gdańsk University of Technology of one of the parts of this street. The scan was converted into a 3D optimized model and created a visualization that can now be seen in the CAVEs of the I3DVL.

[8] Lebiedź et al. (2017), *Virtual designs and reconstructions of amber works. Amber craftsman simulator*, pp. 246-249.

Digital twins of the museum exhibit

The Gierłowska Lizard is one of the exhibits of the Gdańsk Amber Museum. With the help of a sophisticated tomographic scan made by the Faculty of Materials Science and Engineering at the Warsaw University of Technology[9], the I3DVL obtained a 3D model of the lizard imprinted in amber. Unfortunately, the resulting 3D model has no information about the texture or colors of this animal from 44 million years ago, so now we can only guess what kind of appearance and color this lizard had. Currently, the visualization of the 3D model of this exhibit can be visited in the CAVEs of the I3DVL.

Digital twins of the technical device

Two years ago, a research project was carried out by a student of the Faculty of Electronics, Telecommunications and Informatics at the Gdańsk University of Technology with the aim of investigating a possibility of using a Stewart platform in a virtual reality CAVE, before purchasing a physical device. For this purpose the student prepared a digital twin of a selected Stewart platform that consisted of a 3D graphical model, a multibody physics model and a driver software to control the simulated platform's motors. The digital twin was then connected to a lunar-martian rover simulator running on the CAVE and tested in various scenarios.

Scientific visualization

The protein molecule is a complex structure that is difficult to show on a small 2D screen. It is made up of hundreds and sometimes even thousands of amino acids linked together in different groups. The number of atoms in such a protein is so huge that trying to show it becomes very difficult. However, using huge screens and 3D technology, a visualisation of the protein haemoglobin was created. Interestingly – there is not a single atom in it, only the connections between them. A PDB (Protein Data Bank) file is loaded from which information on the position of each atom is read out. With the help of reverse engineering, it was possible to create a small algorithm that combines the atoms first into amino acids and then links them together to form long ribbons. Viewing it on such a huge scale against a black background shows how complex even such a small thing can be.

Virtual panoramas

The Scottish Tenement House in Lviv was built in the modern Gothic style in the early 20th Century. From 1909 to 1944, the building housed one of the city's most famous establishments, the Scottish Café. The walls were decorated with panels based on the works of Walter Scott, hence the name of the cafe. The Scottish Café became famous because in the 1930s it was often visited by mathematicians

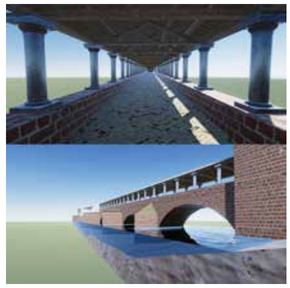

Fig. 16
Virtual walk around the interior of the I3DVL building rendered in the BigCAVE

Fig. 17
Virtual Amber Room rendered in the BigCAVE

Fig. 18
The bridge in Pavia reconstructed virtually by students to be rendered in the BigCAVE

[9] Kaczmarek et al. (2021), *3D Scanning of Semitransparent Amber with and without Inclusions*, pp. 145-154; Lebiedź (2020), *Virtual reconstruction of Gierłowska's Lizard*, pp. 94-97; Lebiedź et al. (2017), *Virtual designs and reconstructions of amber works. Amber craftsman simulator*, pp. 246-249.

from the Lviv School of Mathematics (Stefan Banach, Hugo Steinhaus, Stanisław Ulam, and others), where they collaboratively discussed research problems (written down in the notebook known as the Scottish Book), particularly in functional analysis and topology. In collaboration with the Lviv Polytechnic National University, a visualization of the interior of the Scottish Café was prepared for the CAVEs. It is based on panoramic photos of individual rooms of the cafe.

Virtual exposition

Art and science seem to us to be at completely opposite poles. However, in the 21st Century, art is not only about brush and canvas, but also about using technology. In 2019, an art exhibition took place, the opening and closing of which were held in the I3DVL. The author of the work 'Implosion' is Elvin Flamingo, a well-known and respected Gdańsk artist. The model created by him was adapted to evoke as much emotion as possible and to show the whole as well as possible. It was shown in the BigCAVE on a scale of 1:1, even though the physical object was created one year later – it can be seen as an example of street furniture in Gdańsk. The event itself was quite popular – viewers marvelled not only at the work itself, but also at all the technology that was used to show it.

Virtual reality in architectural education

This year, an international conference called *PaviaDigiWeek* was organized by the Department of Civil Engineering and Architecture of the University of Pavia. The conference included workshops for students that aimed to deepen their knowledge by working in international, multidisciplinary groups. Each group of students was tasked with creating an interactive 3D application that presents a virtual reconstruction of a selected monument. The students were provided with a library of components prepared by I3DVL team, which implemented most of the required functionality, like moving around in the virtual world or creating text annotations that point to selected parts of the model. The provided library allowed the students to complete their work in just 2 days and the resulting applications were presented live on a seminar at the end of the week[10].

Virtual reality is widely used in various areas of human activity. In particular, it is used in the dissemination of cultural heritage and architectural and urban designing. This study outlines possible applications and describes those that have already been implemented in the authors' lab. With this study, the authors hope to establish new cooperation on topics that have not yet been launched. However, continuing ongoing topics is equally important, especially since the interest of architects and artists continues unabated.

[10] Galasso et al. (2024), *Virtual fruition of architectural drawings. 3D models and dynamic platforms for heritage knowledge.*

References

Dzierżko-Bukal I., Lebiedź J. 2018, *Urban prototyping in CAVE. Cooperation between the Academy of Fine Arts in Gdańsk and the Gdańsk University of Technology*, in *Proceedings of the 11th International Conference on Human System Interaction HSI*, Gdańsk.

Galasso F., La Placa S., Lebiedź J. 2024, *Virtual fruition of architectural drawings. 3D models and dynamic platforms for heritage knowledge*, in XXI *International Conference on Culture and Computer Science KUI 2024*.

Kaczmarek A. L., Lebiedź J., Jaroszewicz J., Święszkowski W. 2021, *3D Scanning of Semitransparent Amber with and without Inclusions*, in *29th International Conference on Computer Graphics, Visualization and Computer Vision WSCG 2021 - Proceedings, Computer Science Research Notes*, 3101, Plzeň, pp. 145-154.

Kowalski Sz., Samól P., Szczepański J., Dłubakowski W. 2020, *Teaching architectural history through virtual reality*, in *World Transactions on Engineering and Technology Education*, 18(2), Melbourne, pp. 197-202.

Lebiedź J. 2019, *Virtual reality support for the projects carried out in the AFA in Gdańsk*, in *The AFA's Art and Research Album: The Colours of Czarna Woda*, 1, Gdańsk, pp. 40-45.

Lebiedź J. 2020, *Virtual reconstruction of Gierłowska's Lizard*, in *The Amber Magazine*, 44, Gdańsk, pp. 94-97.

Lebiedź J. 2022, *Virtual immersive environments*, in *Intelligent interactive systems technologies*, Gdańsk, pp. 151-170 (Appendix: pp. 261-277).

Lebiedź J. 2023, *Virtual reality as a tool for development and simulation. Research projects and experience of the Gdańsk University of Technology*, in F. Picchio (ed) *Digital & Documentation. From Virtual space to Information database*, Pavia University Press, Pavia, pp. 1-6.

Lebiedź J., Mazikowski A. 2014, *Innovative Solutions for Immersive 3D Visualization Laboratory*, in *22nd International Conference on Computer Graphics, Visualization and Computer Vision WSCG 2014 - Communication Papers Proceedings*, Plzeň, pp. 315-319.

Lebiedź J., Redlarski J. 2016, *Applications of Immersive 3D Visualization Lab*, in *24th International Conference on Computer Graphics, Visualization and Computer Vision WSCG 2016 - Poster Papers Proceedings*, Plzeň, pp. 69-74.

Lebiedź J., Redlarski J., Rumiński J. 2017, *Virtual designs and reconstructions of amber works. Amber craftsman simulator*, in *Proceedings of the 10th International Conference on Human System Interactions HSI*, Ulsan, pp. 246-249.

Lebiedź J., Szwoch M. 2016, *Virtual Sightseeing in Immersive 3D Visualization Lab*, in M. Sikorski (ed) *Proceedings of the Federated Conference on Computer Science and Information Systems (4th Conference on Multimedia, Interaction, Design and Innovation MIDI'16)*, Gdańsk, pp. 1641-1645.

Pielak D., Kowalski M., Lebiedź J. 2018, *3D Model Making Patterns for Active Architectural Visualization - Guidelines for graphic designers cooperating with software developers*, in *Proceedings of the 23rd International ACM Conference on 3D Web Technology Web3D*, Poznań.

Widerski T., Daliga K. 2018, *Accuracy analysis of 3D model obtained by photogrammetric method on the example of historic room from Wisłoujście Fortress*, in *E3S Web of Conferences*, 63, Olsztyn, pp. 1-5.

Żrodowski C. 2015, *Application of Survey Simulator for Museums*, in *Condition.2015 - Conservation and digitalization Conference*, Gdańsk, pp. 147-152.

Życzkowska K., Urbanowicz K. 2019, *Architectural education and digital tools: the challenges and opportunities*, in *World Transactions on Engineering and Technology Education*, 17(3), Melbourne, pp. 326-331.

Credits

Research Project

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Perm National Research Polytechnic University - until 2022 (Russia)
Gdańsk University of Technology - since 2022 (Poland)
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Blesarq - since 2022 (Spain)
CTA srl - since 2022 (Poland)

Project Coordinators

Sandro Parrinello *(from January 2019 to May 2023)*
Francesca Picchio *(since May 2023)*

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A selection of the research outputs presented in this volume was developed through educational activities, including master and PhD thesis, academic courses, workshops, and international summer schools. These initiatives engaged students from the universities participating in the research programme and were conducted under the supervision and support of the project's researchers. The resulting materials, such as drawings, survey documents, and digital models, constitute an integral component of the scientific contributions published in this volume.

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Tutors: Marco Dell'Orto, Federico Modesti, Giacomo Tosini, Laura Galesio
Golden Gate, pp. 150–153, 274–275: Sabrina Bonanomi, Clizia Caroli, Giulia Venanti
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The Gdańsk fortress route. Survey and analysis for evaluation enhancement and management of european cultural heritage routes
(02–10 July 2023)
Scientific Responsible: Sandro Parrinello
Scientific Coordinators: Justyna Borucka, Francesca Picchio
Tutors: Anna Dell'Amico, Silvia La Placa, Hangjun Fu, Giulia Porcheddu, Alberto Pettineo, Andrea Bongini, Andrea Lumini, Anastasia Cottini, Joanna Badach, Szymon Kowalski
Participants: Martina Frazzica, Ghanem Yasmin, Clizia Caroli, Federico Bontempo, Aurora Aloi, Luca D'agostino, Gaia Di Lernia, Ahmed Assan, Eda Rusta, Michelina Strangio, Chiara Capirola, Valeria Maria Ranieri, Ilaria Enna, Sidorowicz Nicole, Mazurek Magdalena, Mulica Mateus, Kapczyński Adrian, Gochowski Miłosz, Dziąg Oliwia, Verbov Artemii, Komierzyńska Zuzanna, Zielińska Zuzanna, Uściłko Julia, Banaszczyk Julia, Bobyk Polina, Kupisz Jakub, Gołas Karol, Kwiecińska Alicja, Kopacz Maja, Sobczyk Julia, Benek Karolina, Sobiechowska Małgorzata, Rozwadowska Natasza, Shiroudi Kimiya, Dabruk Aliaksei, Hejnar Julia, Jackowski Szymon, Kreft Aleksandra, Mystek Zuzanna, Nowicka Magdalena, Pęcherska Julia, Raikowski Kacper, Romaniak Anna, Siemianowski Filip, Tomaszewska Edyta, AL.-Rfooh Anis, Mańkowski Szymon, Barbara Niedziela, Dominika Ochocińska, Fazel Fatama, Wiktor Dawid

3D Models and 3D printings
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Through the collaboration of lecturers, researchers and students from different disciplinary fields, the work proposed an integrated reading of historical and architectural heritage based on critical analysis, digital documentation, 3D modelling and information systems. PROMETHEUS addressed the complexities of applying BIM to heritage contexts, experimenting with digital and cognitive protocols for the representation, management and enhancement of a layered urban heritage within the European cultural framework.

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