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A Geomatic Approach to the Preservation and 3D Communication of Urban Cultural Heritage for the History of the City: The Journey of Napoleon in Venice

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Abstract: The use of historical maps in a digital environment can give considerable support to the study of the history of cities. It allows you to combine information from different sources, processed according to different geomatic techniques, to provide a reconstruction of urban configurations of the past and their comparison with iconographic and textual documentation of the same period. The aim of the research is to try to make the knowledge of a historical event easily accessible by converging within a simple model the various sources on which the reconstruction itself is based. This paper deals with the reconstruction of the ephemeral architecture created for Napoleon's visit to Venice through the generation of 3D virtual models. The reconstruction was approached through a rigorous method, inserting these models into the context for which they were conceived. The generation of the historical city model, taking advantage of the algorithms of structure from motion applied to photogrammetry, made it possible to compare it with what was shown by the old paintings depicting the event. Virtual models processed within the GIS environment have been uploaded online thanks to the use of WebGIS. We chose to share the research results on the internet to allow users to avail themselves of a space that no longer exists from within it, going beyond the pictorial images of the past, overcoming communication through rendering and videos. The simultaneous application of methods and techniques related to the various components of geomatics within the digital environment has enabled the operation of a faithful reconstruction of reality, bringing to light past urban scenarios that no longer exist and are only known through paintings.

Keywords: 3D building model; urban heritage documentation; 3D reconstruction; texturing of urban objects; virtual city model; GIS mapping; HGIS; historical cartography

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1. Introduction

The advent of the digital humanities has brought significant facilities for historical research, allowing large amounts of data to be managed in digital format; therefore, the processing and integration of information is greatly facilitated [1–3]. Over the past decades, efforts have been made to promote and enhance our heritage; in order to acquire tools close to people, instruments of knowledge must be understandable not only to specialists. The goal is to facilitate the access to culture to everyone, trying to increase the sharing of knowledge both in specialized and non-specialized environments. In this way, users who are increasingly accustomed to the use of new technologies have the possibility of accessing information that is not easy to transmit.

Archives are effective tools for preserving irreplaceable assets with immense educational value, and they play an important part in cultural heritage preservation. Digital technologies can make an innovative contribution to urban history, enabling processes ranging from research to training, and from dissemination to the fruition of cultural cartographic heritage. It is now possible to integrate traditional knowledge with alternative modes of communication that can foster new methods of research, e-learning, and other potential uses of information and communication technology (ICT) for cultural and educational purposes, thanks to technological innovation and the development of multimedia tools [4]. Cultural heritage digitization is fundamental for proper conservation, management, and improvement of the area's structures and landscapes. In recent years, the worlds of representation and semantic content have become increasingly entwined; in this regard, a GIS (geographic information system) has served as the first step in integrating geographical information associated with an object with semantics or data information [5].

The association between geomatic techniques and ICT allows, thanks to the generation of multimedia products, public access to cultural heritage while promoting conservation and enhancement (Figure 1). Drawings, plans, and cartography are not easily understandable by everyone. Special skills are required to "read" through a dimensional representation system, and 2D drawings, in particular, are difficult to interpret to non-specialists [6]. Historical research has taken on new dimensions thanks to digital humanities methodologies. Geomatic techniques applied to historical cartography, as demonstrated by some case studies such as the HistKI project in Dresden [7] and the Turin 1911 project of the Politecnico di Torino [8], appear to be extremely useful for studying and analyzing cartographic documents, as well as for exploring their contents in novel ways [9,10]. In order to recreate a new scenario of understanding, data can be spatialized and modeled in new ways, presenting all of the information recorded in written texts, historical cartography, and iconographic sources in spatial–temporal settings [3]. The work, which is based on a multidisciplinary approach that includes the history of architecture and the city, GIS, and 3D modeling, aims to highlight the significance of emerging technologies as tools capable of transmitting scientific knowledge in a straightforward and simply accessible manner [4,11].

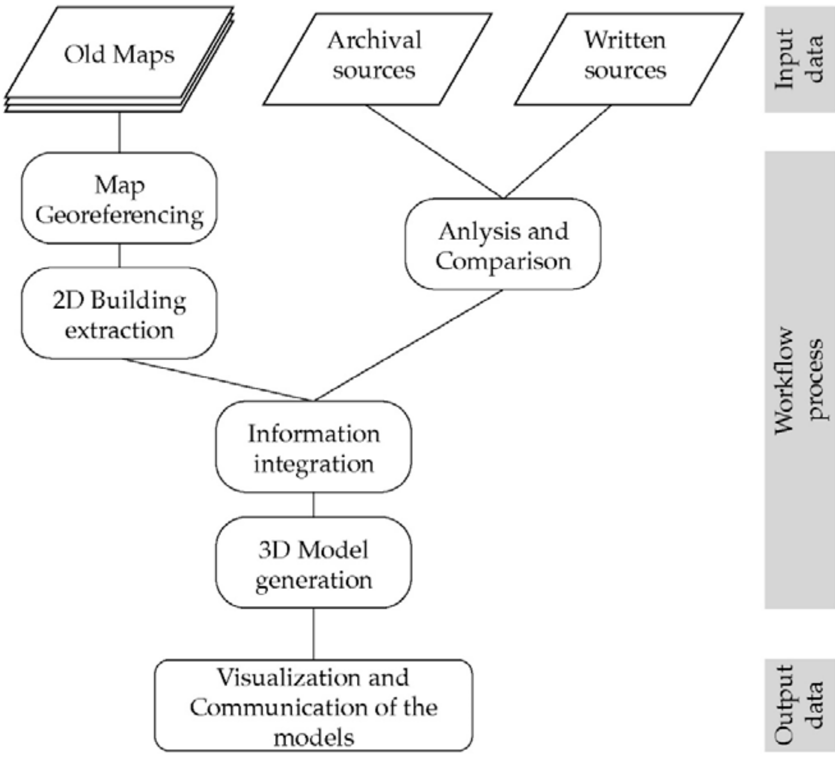


Figure 1. Methodology and workflow adopted to generate the historical city model integrating data from 2D historical maps and other sources.

Combining and comparing data from various sources necessitates a greater integration of highly diverse professional skills and the fields of scholarship to which they belong. Inter- and cross-disciplinary research is critical for achieving results and developing products that can express their cognitive and educational potential through interaction [4]. An essential part of this project is the comparison, integration, and homogenization of the information for the understanding of the studied area and event. The possibility of dealing with a model capable of containing the sources necessary for its generation as well as a synthesis of the information contained in them is of particular importance in the study of urban space, understood as a container of images, memories, traditions, and knowledge, for which the analysis of historical cartography is insufficient [9].

The use of information technology for the digitization, archiving, and visualization of cultural heritage is a broad field of research [8], with an increasing emphasis on the sharing of materials and online outcomes, allowing anyone to easily access information and fostering research and culture. Geomatic techniques and methodologies can play an important role in the creation of a three-dimensional (3D) model with the goal of documenting the past. Particularly in the cultural heritage domain, other analyses could benefit from a 3D model. It could be a good starting point for additional examinations, particularly in the cultural heritage domain, where highly detailed information linked to models and descriptive model data that provide a more general view of the studied object are required [12]. The generation of 3D data of heritage sites could help cultural heritage specialists in analyzing, interpreting, communicating, and valorizing the heritage itself and the historical information. The recreation of a changed historic settlement can provide a platform where people can learn more about the city and their history. Using digital technologies to collect and visualize various attributes of lost architectural heritage is critical for this purpose [13]. The available sources and the final level of detail that must be achieved determine which digital techniques and strategies should be used for virtual reconstruction. Finally, different objectives influence the results, but the use of 3D digital reconstruction is reported in various disciplines to support various analyses and considerations: hypothetical reconstruction giving life to never-realized projects from original drawings, means to support restoration in case of destruction, diachronic visualization of lost constructive phases of urban heritage, and repositories of historical photos of architectures connected to a 4D model [8].

The history of architecture is a process always based in a space and in a time. The organized information, by databases, has to link data to that space and that time. In the same way the city is composed of places and events that interest it, so studying the history means analyzing the context and the time in which the various buildings were built. As a repository of knowledge, traditions, memories, and images, urban space embodies levels of complexity that are difficult to fill with historical sources. A GIS in urban history opens up a world of possibilities for historical research analysis and communication. Furthermore, a GIS offers effective solutions for dealing with some of the issues and limitations associated with the incomplete and fragmentary nature of historical sources [9].

The work presented, interfacing with historical investigation according to this principle, seeks a way to convey its results that are easy to understand to the general public. Starting from the georeferencing in the GIS environment of the Napoleonic Cadastre of Venice, published between 1810 and 1811, and considering the geometric precision and descriptive details that characterize it, it was possible to analyze and highlight the evolution of the city over the last two centuries, distinguishing clearly the areas affected by significant transformations and relating them to the urban modernization process that started in the Napoleonic era [10,14]. The reconstruction of the city of Venice was based on the analysis of historical cartography [11,15], written sources, and other archival documents. It can be said that the reconstruction of some cultural assets that have undergone transformations or have been lost was carried out starting with other cultural assets. In fact, we must not forget that historical cartography is itself part of this enormous heritage that we have today. The digitization of historical documents is an operation that has been underway for a long time. Attention must now be turned to the critical reading of these sources through digital tools that allow queries typical of modern ones to be carried out on historical documents [16,17]. What made the integration of such heterogeneous information possible was the use of geomatic techniques [18]. In particular, the use of a GIS for the study of historical heritage has now become mandatory [1]. HGISs are thus configured as "interdisciplinary research projects that integrate the most advanced methods and tools of the geographic information sciences with the sources and questions of geo-historical and historical research, in order to emphasize the importance of contexts and spatial relationships for understanding historical dynamics" [16]. An HGIS must be seen as a complementary tool to traditional historical research [19–21], to which geomatics can provide support for various analyses. In fact, the GIS environment, by combining different types of data, is configured as a functional tool for studying the evolution of the city and rediscovering its history, both for research and dissemination purposes. The city's cartographic reconstruction was based on a variety of analyses, ranging from written sources to archival and contemporary cartographic and iconographic materials, as well as contemporary methodologies. The geomatic method and historical GIS provided the broadest foundation for the use of such heterogeneous information in relationship to the categories of space and time (historical data), from both a qualitative and a quantitative point of view. The GIS environment, by combining various types of data, becomes a useful tool for studying the evolution of the city and rediscovering its history, as well as for research and tourism promotion [17].

In this work, 3D models play a fundamental role; they are in fact tools able to collect, organize, and show data from heterogeneous historical sources, allowing easy interaction between the user and model. The reconstruction was used to bring to light urban landscapes and monuments that had been altered or destroyed over time.

The primary purpose of a GIS is to evaluate reconstructions of the overall ancient scenario based on research data. After these steps are completed, the land and built heritage models become communicative and educational tools, which are typical functions of a virtual reconstruction of ancient environments [22].

The research was focused on the study of ephemeral architecture, but moreover to the urban context within which they were inserted, a scenario that differs from what is currently available to our eyes. It was precisely for the transformations that were initiated following the visit of Napoleon, as a consequence of the decisions taken in those days, the result of numerous inspections of the lagoon and the city. The emperor's stay in the city was in fact based on the idea of an economic and productive revival and of its homologation to the other cities of the domain.

Napoleon's visit to Venice is a historical event of fundamental importance, as well as difficult to read within the history of the city. The historiography is divided on the interpretation of the emperor's figure in relation to the process of homologation that begins in the lagoon city: consider it the killer of the Serenissima or the one who started Venice on the road to modernity; certain is that his arrival in the city marks an epochal passage, particularly in the urban events. Despite the importance of the event being studied, this is unknown to many. One factor that has certainly influenced the study of this event is the scarcity of materials received in this regard and the difficulty of becoming aware of it.

2. Materials and Methods

2.1. Representing the City's History through Historical Maps and Drawings

The perception of Venice that you have today as you walk through its streets is the result of design and transformation work done between the nineteenth and twentieth centuries. The nineteenth century, in particular, is remembered as a time of great transformations. Beginning with the Napoleonic period, a process of "urban normalization" began, with the goal of providing the lagoon city with all of the public facilities that a modern city requires while also encouraging pedestrian mobility [23,24].

Before the Napoleonic interventions, it was possible to move through the city only by boat, since the dense network of canals that separated the various islands and the insufficient number of bridges did not allow the configuration of a pedestrian road system. It was precisely in the years of the second French dominion, between 1806 and 1814, that the process of creating a road system that allowed people to cross the city on foot began. The realization of this project was made possible thanks to the burying of canals and the construction of numerous bridges. This process lasted well beyond the French years, reaching the present day [25]. The organization of the city's homologation process is based on a careful analysis of the urban structure of Venice, its characteristics, and needs, which results in a set of aggregative and disruptive actions of the institutional fabric [26].

During his visit to Venice, Napoleon met Giannantonio Selva [24], which was a turning point in the city's history. In fact, the architect presented the results of his city analysis (Figure 2) to the Sovereign, which became the basis for the drafting of decree n° 261 of 7 December 1807 [27]. The purpose of the provision, in line with what was proposed in the "Selva Plan", was to organize the city according to a functional configuration and urban development that was consistent with the existing city logic.

Figure 2. G. Selva, copy of the map made by L. Ughi in 1792 entitled iconographic representation of the inclusive city of Venice consecrated to the royal Venetian dominion. The paper shows the analyzes carried out by Selva on the city, 1807.

2.1.1. The Integration between Historical Maps and GISs

The use of a GIS in urban history offers great opportunities for the analysis and dissemination of historical research, providing effective solutions to overcome some problems and limitations linked to the incomplete and fragmentary nature of historical sources [9]. The work of reconstruction in the urban configuration of a part of the city of Venice at the beginning of the nineteenth century was made possible thanks to the study of a collection of cartographic and iconographic archival material.

Working with heterogeneous data from various sources necessitated the use of an information management tool that could link data together. A geographical information system (GIS) was used to manage metrical and geographical data as it evolved over time and space [19]. Geographic information system (GIS) technology is widely acknowledged as the best tool for bringing together and reporting data from the various disciplines involved in cultural heritage documentation processes [4].

Historical maps are a valuable source of information that cannot be found elsewhere, particularly the boundaries and physical characteristics of places that have changed over time [4,28,29]. The content of all of these documents is of immeasurable value for the study of city history, which is frequently hampered by analogue or physical medium wear and tear. To prevent deterioration of this limited heritage, the operations of identification and digitization of historical documents are critical for the safeguarding of the documents themselves, both in terms of content and support, allowing the use of the information provided without having direct contact with the source itself [30]. Ancient cartographic documents are part of the cultural heritage, which is a vast patrimony capable of providing content not found elsewhere. The integration of ICT and geomatics opens up new avenues for the use of cartographic data, enabling previously unattainable studies [10].

The acquisition, processing, and use of historical cartography in the digital environment is possible thanks to geomatics tools; GIS systems, in particular, allow one to enhance historical maps in a modern key, highlighting their utility. The maintenance of the metric properties of cartography in the digital environment is a fundamental requirement to be able to carry out research and applications specific to the IT environment; therefore, it is not feasible on the original analog documents [1,4,29]. In addition to data derived from textual sources, information obtained from historical cartography lends itself well to GIS analysis. In terms of textual sources, numerous data can be extracted from the maps, legends, and cartouches that accompany them, but the graphic element, above all, can be converted from analog to digital, imported into the GIS, and superimposed on the digital geographical base [31]. The information on the ancient map can be linked to various types of data in this environment. The overlapping allows us to first evaluate the calculation's quality and determine whether there are any areas of the paper that are more problematic in terms of geometric precision. Second, it allows you to notice differences in the ancient representation versus the modern one, indicating peculiarities in the design or evolution of the landscape; this allows you to objectively evaluate the contents of the card [30].

The research has interfaced with the study of historical cartography in order to infer spatial information referenced, analyzing it on the basis of the criteria of current cartography [32–35]. The most suitable media for managing this information based on historical data, therefore temporal as well as spatial, both qualitative and quantitative, are the HGISs or GISs applied to history. In defining the spatial configuration of a given urban context, it is of fundamental importance to base the research on the study of the cartography that represents it; in this case, the Napoleonic Cadastre of the city of Venice has been chosen, accessible through a WebGIS project created by the Cartography and GIS laboratory of the IUAV University of Venice in collaboration with the State Archives of Venice. The Napoleonic Cadastre of Venice consists of 29 sheets, two of which show the picture of union, that together constitute a complete map of the entire historic center on a scale of 1:1000 [15,36]. It was created beginning in the spring of 1807 and published between 1810 and 1811. The cadastral source has been used as a basis for the reconstruction of the area because, due to the particular structure that characterized it, it is prone to computer processing. Moreover, the return of the supplied territory is equipped with a set of characteristics that allow a historical study of the area that includes several factors beyond the physical one [19,37,38].

The use of an HGIS as a research environment necessitates the correlation of historical and contemporary cartography in order to allow for further analysis and consideration of possible spatial changes over time [39,40]. Georeferencing operations and the transformative model should be selected on an ongoing basis based on the quantity and quality of the information to be derived. These procedures are required because historical maps frequently lack geographical reference systems or are expressed in systems other than the current ones [41,42]. The process of georeferencing the historical map in a specific geodetic reference system returns to the acquired cartographic image the metric and geometric content initially possessed by the analog support, which was altered in the acquisition process.

2.1.2. The Analysis of Napoleonic Cadastre through an HGIS

The cadastral maps are designed to be an extremely useful tool for researching the city's history. In fact, they enable the search to accurately identify the characteristics of the various buildings constructed, thereby integrating them into the social fabric. All of these factors combine to make the historical cadastre the ideal cartography for studying the personalities and urban structures of the past. The land registers allow us to study the transformations of the individual areas of this structure, correlating them to their historical meanings. Furthermore, the identification of this system allows for the creation of precise historical documentation that can be compared to more recent data.

In order to analyze historical maps in the scientific way required in the geomatic field nowadays, georeferencing historical maps in relation to current cartography is required [11]. In this way, geodetic and projective aspects are known. The Napoleonic cadastre was georeferenced using the Esri ArcGIS Pro program and the city's technical map. The city of Venice's cartographic geodatabase has been adopted as a vector reference system, based on the Geodetic Datum Roma40. These cartographic data have a precision of 10 cm in the historic center, which is generally associated with a scale of 1:500. The numerical cartography that describes the city of Venice and its lagoon today consists of more than 70 levels. Within the research, only some layers have been considered, in particular those related to the buildings, canals, emerged lands, and all those elements necessary to define the current configuration of the urban territory and the lagoon, in order to compare them with data from historical cartography.

The georeferencing of a historical map in raster format consists of assigning cartographic coordinates to each pixel of the image so that this can be applied to the current cartography. The overlap is obtained by digital processes of geometric transformation and resampling, performed through the identification of points that remain unchanged over time, univocally recognizable in the historical map as well as in actual cartography or in the terrain, to be used as tie points [42]. The historical maps have therefore been used to look for buildings and urban elements that are still present, recognizable and identifiable with good approximation in the current reference cartography [2,4,43]. These points are called control points. The term "geometric transformation" means the process by which the grid of the original image is transformed into a new lattice with the use of appropriate polynomials. As a result of the transformation, all of the points on the cadastral map now have coordinates that are determined by proper interpolation functions from the known or given coordinates of the control points. There are two types of geometric transformation: global and local. A global transformation is so named because the best possible metric reference is assigned to the unreferenced map without changing the coordinates of the control points after the transformation. The transformation is based on parameters that are calculated prior to the transformation using the known coordinates of the control points; the parameters are valid for any point on the map; in other words, they concern the map globally; the larger the number of control points used for parameter computation, the better statistical solution is achieved; a statistical estimate of the transformation results is one of the process's outputs in terms of regular statistical quantities.

Local transformations, on the contrary, aim at deforming a part of the image. The parameters have local validity and are defined for each point of it. This process produces an exact transformation for the known points, or control points, while leaving the rest of the image nearly unchanged [2,11,32]. Resampling is the procedure that leads to the assignment of the radiometric values of the pixels relative to the new grid as a function of the values of the original pixels.

For the choice of the mathematic model of transformation, the characteristics, in terms of accuracy, of the historical cartography adopted and the extent of the area under analysis have been taken into account [44,45]. It was therefore decided to adopt a transformation model present in the software ArcGIS Pro called "adjust", since it integrates global and local transformation. The use of both types of transformation is crucial, taking into account the deformations that the original medium has undergone and the possible alterations due to the digitization phase [40]. Since some areas of the city underwent important transformations between the beginning of the nineteenth and the end of the twentieth century, the reconstruction of the urban space was carried out using the retrogression method of three different historical cadastral maps of Venice. This method was necessary in order to correctly georeference some sheets of the Napoleonic cadastre on the basis of current cartography; in this way, it has been possible to recognise a sufficient number of control points between the various cartographs to proceed to georeferencing.

Georeferenced maps (Figure 3) are still digital images but contain geographical information related to the coordinate system used in the georeferencing process. In order to extract the information such as the building footprint, the map images have to be further processed and the data vectorialized.

Figure 3. The mosaic of the sheets composing the Napoleonic cadastre correctly georeferenced.

2.2. From Historical Maps to City Models

Since visual communication plays a fundamental role in the circulation of information, after this phase, the work was directed towards the creation of a city model. Under the constant evolutionary thrust of technology, city models constitute an extremely incisive and easy-to-understand element for the transmission of information and knowledge relating to the city [46], its history, and the events that interest or have involved it in the past [47,48]. Historical city models have assumed the role of tools for the knowledge and conservation of urban cultural heritage, configuring themselves as containers of histories that are usually written and difficult to analyze [6]. These new methods of transmitting knowledge make it possible to provide a large amount of information by integrating data from various sources and generating models that are easy to understand. In this work, the city model has been used to show the reconstruction of the city of Venice in 1807, and the models of the ephemeral architecture were made for the occasion.

The same techniques used for the creation of current city models cannot be adopted in the generation of a historical 3D city model. Most of the data must be derived from historical maps [49]. In fact, the survey techniques in use, such as photogrammetry and laser scanning, used for the digital twin creation of cities, can only be partially used for the reconstruction of areas that remained unchanged from the time of the reconstruction that is being carried out until today [50]. In addition to historical maps, the generation of historical 3D city models is based on the rigorous analysis of historical paintings and images.

Research has been conducted in recent years to develop methodologies for reconstructing historical 3D city models from historical maps in conjunction with other historical sources. In order to create a historical city model based on the historical cartographic data analyzed, it was first necessary to vectorize the information provided by the Napoleonic Cadastre in a GIS environment. Turning 2D drawings into 3D models is a task that cannot be automated because it requires intelligent data interpretation and organization in order to respect the true content of the sources [6]. The 3D city model should reveal the results of the original source analysis and the integration of the information required to complete the needed dataset.

Afterwards, the 3D model was developed. The height of the various buildings was obtained by integrating the information provided by the current cartography [4,29], as regards the buildings remaining unchanged, with what is inferred from the elevations of the Canal Grande made by A. Quadri and D. Moretti in 1831 (Figure 4) [4,6,11,29]. The digital copy of the various sheets has been scaled on the basis of the graphic scale in metres shown on them; the heights were therefore inferred by considering the water level as 0 altitude and comparing, where possible, with the data provided by the current numerical cartography, in order to have control over the reliability of the data [51]. This resulted in a 3D block model and a LoD1 3D city model (Figure 5), according to the CityGML [52] subdivision, of the area under analysis: the buildings overlooking the Canal Grande and the Marciano Basin, the Marcian area, and the arsenal. The models of the buildings near the ephemeral architecture created on the occasion of the visit of Napoleon, the Triumphal Apparatus in the Santa Lucia area, and the Grandstand for the Regatta in Volta di Canal, were further elaborated, reaching a LoD3. In fact, textures were applied and the roofs and facades of the buildings were modelled. Although the modelling in ArcGIS Pro software has greatly simplified the structures of the buildings, the ability to apply high-definition textures allows for suitable representations of the LoD3 [53].

Figure 4. A. Quadri, D. Moretti, Elevation of the Canal Grande of Venice, 1831, Drawing 6.

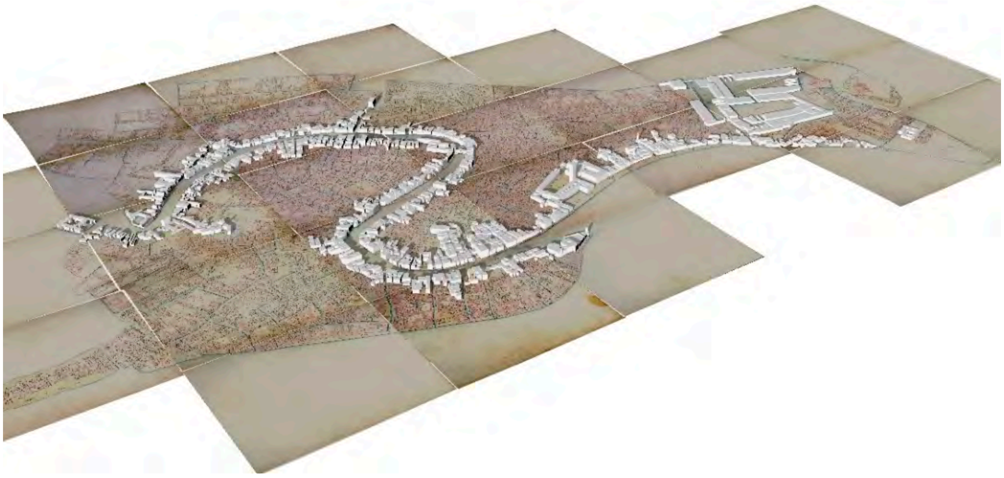


Figure 5. A bird's-eye view of the City Model.

As regards the area of Volta di Canal, which has remained almost unchanged, it was decided to apply to the fronts of the buildings previously modelled the images of the elevations engraved by Moretti, using these as textures [54]; later doors, windows, balconies, and access stairs were modelled (Figure 6). The choice to operate according to these modes was dictated by the precise desire to show an urban reality related to the past, combining the use of historical materials, elevations, and cartography with the potential offered today by digital tools.

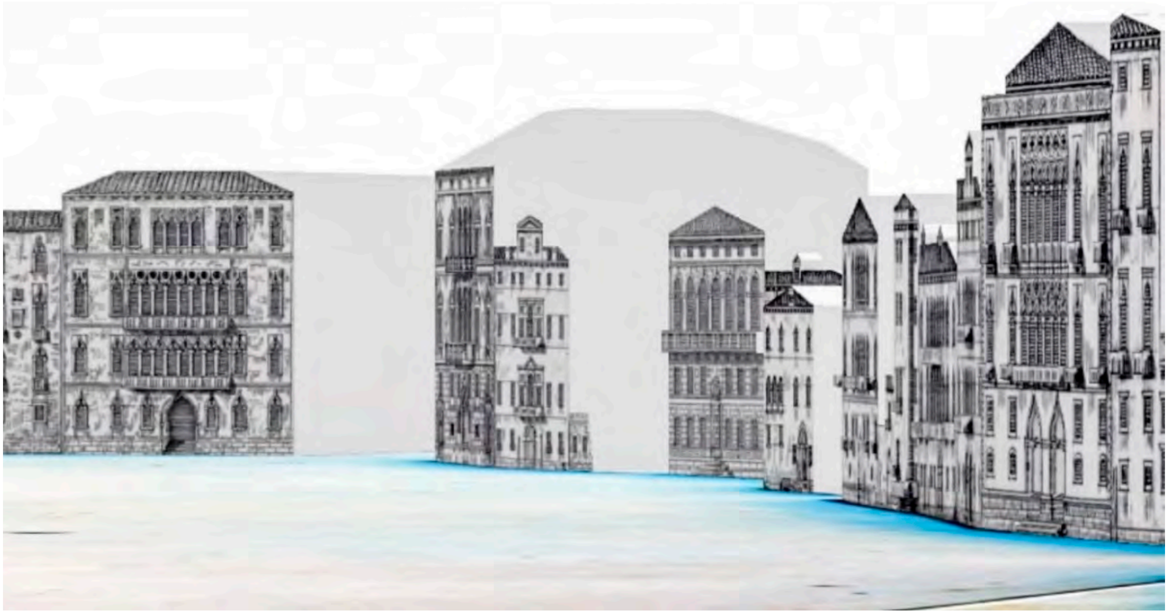


Figure 6. View of the LoD3 city model near Ca' Foscari.

Unlike the area of Volta di Canal, the area of Santa Lucia has undergone major transformations, linked to the construction of the railway station in the mid-nineteenth century. Considering this aspect, it was decided to model the fronts of the buildings in that area, integrating the information provided by the elevations described by Quadri with data from other iconographic archival sources (Figure 7).

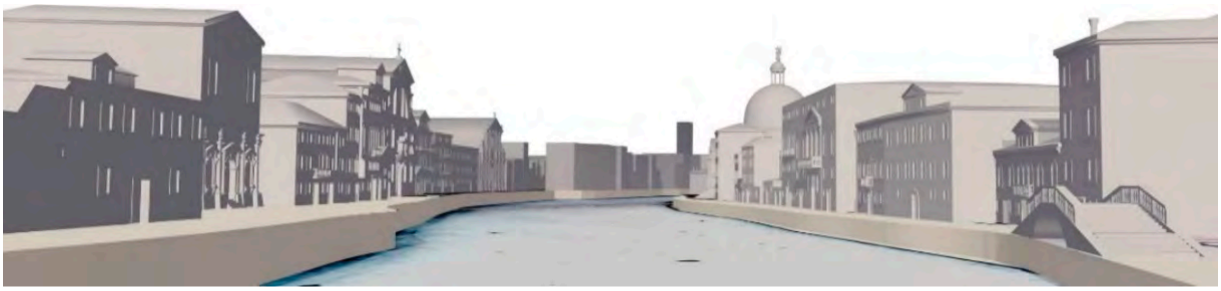


Figure 7. View of the LoD3 city model in the area of Santa Lucia.

The city model has proved to be an extremely versatile tool and adaptable to the communicative needs of the work [55], allowing parts characterised by a different level of detail to be combined within a single model, in order to facilitate the observer in the study of the areas of greatest interest for the purposes of the analysis reported [22]. This tool has enabled us to depict a past reality, generating a model for combining communicative tools from different eras in order to create more easily readable and usable historical documents through modern digital media.

The term "virtual heritage" refers to the combination of virtual reality technology and traditional heritage. Through the use of interactive digital media, virtual heritage not only records physical appearances, but also cultural artifacts [47].

2.3. Reconstructing Ephemeral Architectures

Following the completion of the city model, attention was focused on the modeling of the ephemeral architectures created in honor of Napoleon's visit to Venice. To commemorate the emperor's entry into the city, a rich Triumphal Apparatus was built near the church of Santa Lucia, consisting of a single fornix and two rostrate columns on the sides. A tribune called the Macchina was also built in Volta di Canal to award the winners of the Regatta held to commemorate his coronation's third anniversary [56]. The only available source for reconstructing the lost architectural heritage is found in historical data. Historical images are frequently the only trace of our past's lost heritage [57]. As a result, it is fundamental to double-check the data provided by comparing data inferred from various sources, reporting them on the same scale as much as possible, and analyzing them looking for discrepancies [8,13].

By integrating the data coming from the figurative and descriptive sources, starting from the redesign, the ephemeral architectures have been modeled. Subsequently, the study of the paintings made by Borsato depicting the two events, was carried out in order to determine precisely the position of the architectures in relation to the urban context [6]. These 3D models were combined to provide a more complete description of the analyzed event [22].

2.3.1. The Triumphal Apparatus

Napoleon's visit to Venice is undoubtedly a watershed moment in the city's history; in fact, it marks the beginning of a transformational process triggered by the issuance of a provision, the first "special law" [25], during his stay. Napoleon's entry into the city was a notable event, not only because of the majesty and beauty of the Triumphal Apparatus built for the occasion (Figure 8), but also because of the location, at the north entrance of the Canal Grande, near the church of Santa Lucia, in an area of the city diametrically opposite to the Marciana area, which has always been the fulcrum of major events. The Sovereign arrived in Venice by land rather than sea, as the city's most illustrious visitors had done in the past. The purpose of the visit was not to spend some vacation days, but to become acquainted with the city. The entrance and location of the triumphal pump in this unusual position are part of this perspective of knowledge, as is the reversal of its interests, which are no longer solely aimed at the sea, but at the mainland and its links with it, foreshadowing the railway connection that the Austrian government would build half a century later. The intervention would have a significant impact on that area of the city, completely transforming it and upending the dynamics of movement flows that have been unchanged for centuries.

Figure 8. Anonymous, Napoleon's entry into Venice, watercolor etching, 1807, Palazzo Ducale, Venice.

Once the research and analysis of the graphic documentation were completed, we moved on to the comparison between the various sources. Engravings and paintings were compared to each other and to Morelli's description, which is the only written testimony we have. The information provided by the various sources has been integrated with each other on the basis of what Morelli describes. On this basis, it was decided to begin the redesign of the arch based on the engraving made by Selva in 1807 (Figure 9), depicting the plan and elevation of the architecture under consideration, integrating the data with those obtained from an anonymous engraving made in 1807 for the part relating to the bas-relief. The redesign of the two rostral columns placed on the sides of the arch was carried out based on this latter source. Since the ephemeral architectures are depicted with their main elevation parallel to the iconic plane of the image, it was possible to work on this engraving as a prospect.

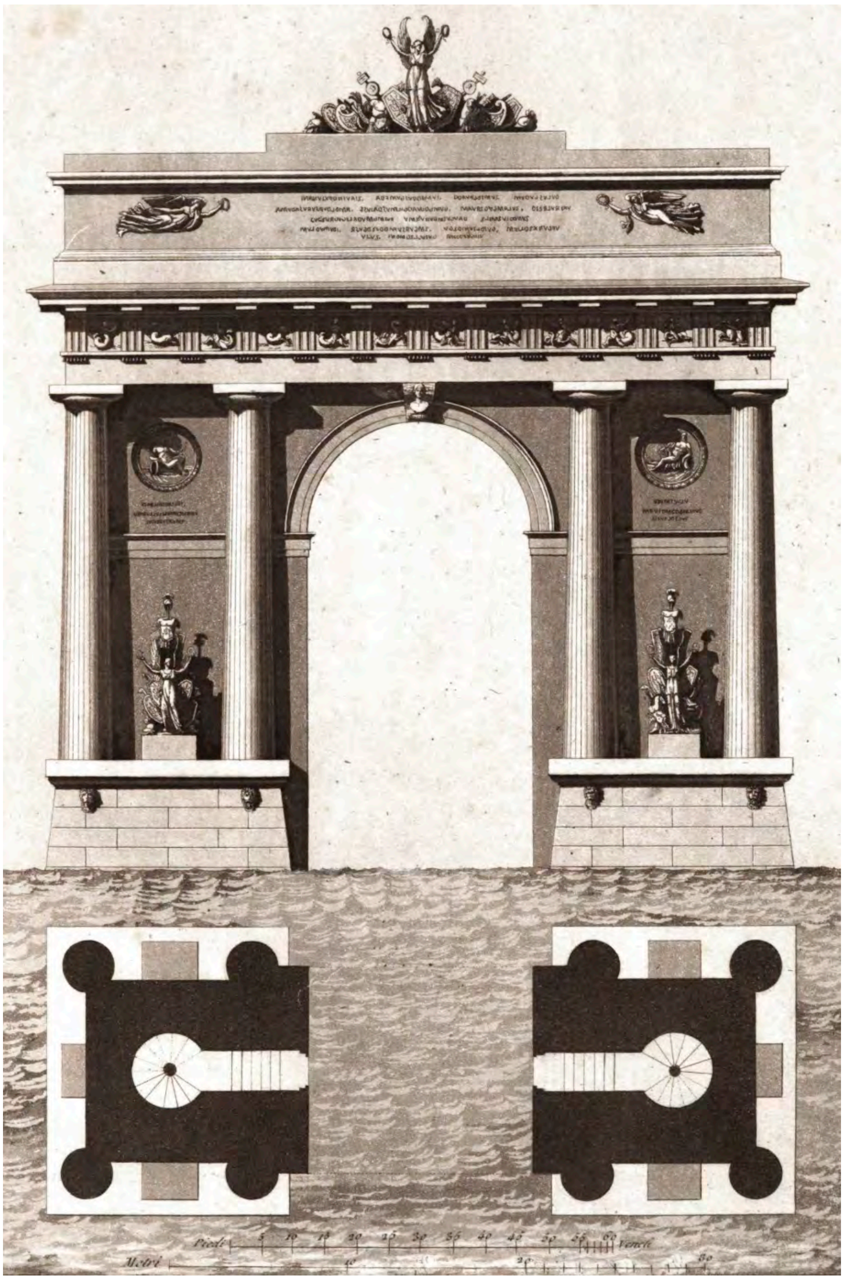


Figure 9. G. Selva, The Triumphal Arch built for Napoleon I's visit to Venice in 1807, engraving, 1807–1808, Museo Correr, Venezia.

The redesign and modeling of the ephemeral architectures were scaled using the two graphic scales, one in meters and the other in Venetian feet, located at the bottom of the sheet containing Selva's engraving from 1807. To have more control over the dimensions of the architectures, two copies of the same engraving were scaled, one in meters and one in Venetian feet. This was accomplished by converting Venetian feet into meters using a known ratio; in fact, one Venetian foot equals 0.3477 m. The comparison of the two dimensions revealed a minor difference of 0.018 m due to graphical error, which was acceptable given that the drawing was made for the 1:100 scale. The anonymous engraving was scaled to virtually replicate the bas-relief and rostral columns based on this dimensioning.

2.3.2. The Relationship between the Triumphal Apparatus and the City

Once the digital modeling of ephemeral architectures was completed, we moved on to a detailed study of the historic sources to determine the position occupied by the arch and the columns with respect to the city.

It is not possible to deduce precise information about the location of the Triumphal Apparatus from Jacopo Morelli's careful and detailed narration. Giuseppe Borsato's paintings "The Entrance of Napoleon I into Venice on 29 November 1807", dating from 1809 (Figure 10a) and 1847 (Figure 10b), were studied in particular. The results of this first phase of analysis did not lead to the precise location of the Triumphal Apparatus. Analyzing the urban context presented by the two images near the arch and columns, they are represented in both images near Santa Lucia's church. The analyses of the urban context depicted in the two paintings reveals that they do not correspond to reality. This is clearly noticeable in the 1809 painting, where the position of San Simeon Piccolo's church has clearly shifted to the east when compared to the location of Scalzi's church. Observing the 1847 painting, the context in which the ephemeral buildings are inserted appears to be the closest to the real scenario. However, when we carefully examine the urban front on which the church of San Simeon Piccolo stands, we notice that the position assumed by this structure has been shifted to the west. In both cases, these are pictorial tricks that allow the area of the city depicted to be more easily identified, drawing attention to the most recognizable buildings in addition to the Triumphal Apparatus, but making it impossible to pinpoint the exact location of the arch e columns. Furthermore, based on the width of the Canal Grande in the affected area as determined by georeferenced historical cartography, it appears that the canal has been widened in the paintings in order to emphasize Selva's architecture.

(**a**)

(**b**)

Figure 10. (**a**) G. Borsato, The Entrance of Napoleon I into Venice on 29 November 1807, 1809, Museo Mario Praz, Roma; (**b**) G. Borsato, The Entrance of Napoleon I into Venice on 29 November 1807, 1847, Veneranda biblioteca Ambrosiana, Milano.

2.3.3. The Inverse Method of Perspective

The inverse method of perspective applied to Giuseppe Borsato's 1809 painting "The Entrance of Napoleon I into Venice on 29 November 1807" was carried out to determine with precision and rigor the position assumed by the Arc de Triomphe and the two rostrate columns with respect to the city. The image depicts Napoleon's entry into Venice at the vault of Santa Lucia, with the majestic Triumphal Apparatus built for the occasion inside the Canal Grande. The scene, a perspective created using a vertical pictorial plane, places the arch and columns in an unintentional position with respect to the observer, emphasizing what is happening. The perspective construction of the painting enabled to apply the inverse method of perspective in order to obtain the planimetric position of the arch in the scene.

It was possible to determine the internal orientation of the perspective system from Borsato's painting by putting the metric and geometric data provided by the Mongian drawing into a system. Applying the inverse process to the overturning method and keeping the fundamental line level with the surface of the water, it was possible to determine the correct position of the observer and his distance from the pictorial plane. Painters commonly use this method to create images with a vertical perspective [58,59].

The painting lacks facades parallel to the perspective plane, so a preliminary procedure for determining the reference was required.

The fundamental f resulting from the intersection of the vertical perspective plane π and the horizontal geometric plane α was made to coincide with the framework's base.

A pair of lines whose orthogonality in real physical space is known is required to define the position of the horizon line O, known as the height of the observer. A second pair of straight lines with the same properties but not parallel to the first is required to calculate the main distance d, the center of view V, and its projection on the perspective plane V_0. To establish the position of these points, we proceeded by making the inverse method of perspective of the upper base of the squares placed at the top of the two rostrate columns.

The geometry of these elements, which we know that are squares in reality, allows us to determine two pairs of straight lines orthogonal to each other and, respectively, rotated by 45°, taking into account that the diagonals of a square are further orthogonal to each other (Figure 11).

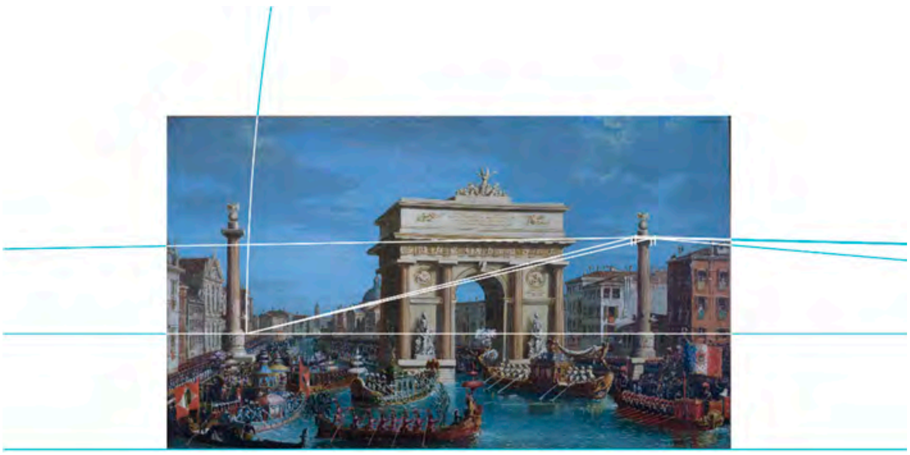


Figure 11. The construction of geometric system necessary to determine the internal orientation of Borsato's painting.

The main distance d is not equal to the radius of the diameter circumference $F'_aF'_b$ because the perspective of these squares is "accidental" and both pairs of opposite sides of the square are convergent. The point V*, or the overturning of the point V on the π plane, belongs not only to the aforementioned circumference, but also to the circumference of diameter $F'_{d1}F'_{d2}$, since even the straight lines belonging to the second pair are orthogonal to each other. Given these premises, the V* point is determined by the intersection of the two semicircles. The V_0 point's position was then determined by drawing a vertical line from the V* point that intersected the horizon line [58,59].

After determining the position of the center of view (Figure 12), we proceeded in applying the inverse method, which allow us to obtain the object's representation based on its Monge's projection. First, the Triumphal Apparatus' inclination with respect to the plane was defined. The plane π, on which the elevation of the arch and the columns lies, was determined by taking the height of the water at the base of the arch and the columns as 0. Finally, the arch's plan and height were returned (Figure 13).

It is possible to determine the position of the points on the perspective in true form by returning the edges of the geometry to f and O and knowing how the front of the arch is arranged in relation to the existing one. Starting from the projection of the point on the line f, the real shape straight line orthogonal to it has been drawn up to the ground line. The intersection of the ground line and the orthogonal, which passes through the point's projection, determines the real shape of the point. The position of the points in their real shape was also determined using the overturning homology method. The V* point is the center of homology, while the fundamental is the axis of homology. The point of intersection of the homology line of that point, that is, the line that passes through the point in perspective and through the center of the homology, and the line in true form on which that point lies, determines the real shape of the point in the homology method (Figure 14).

The position of the contact points between the foundations and the base of the columns and the edges of the buildings, lying on the same floor, was determined according to the homology method, because this method appears to be more expeditive. The data obtained were also checked using the other method. To determine the position of the arch in relation to the city, it was sufficient to return the position of an edge of two buildings using Euclid's first postulate, which states that "between any two points, only one straight line can be traced." Analyzing the points shown coplanar in the image and locating them in historical cartography reveals a strong inclination with respect to the axis orthogonal to the channel of the line that contains the two points.

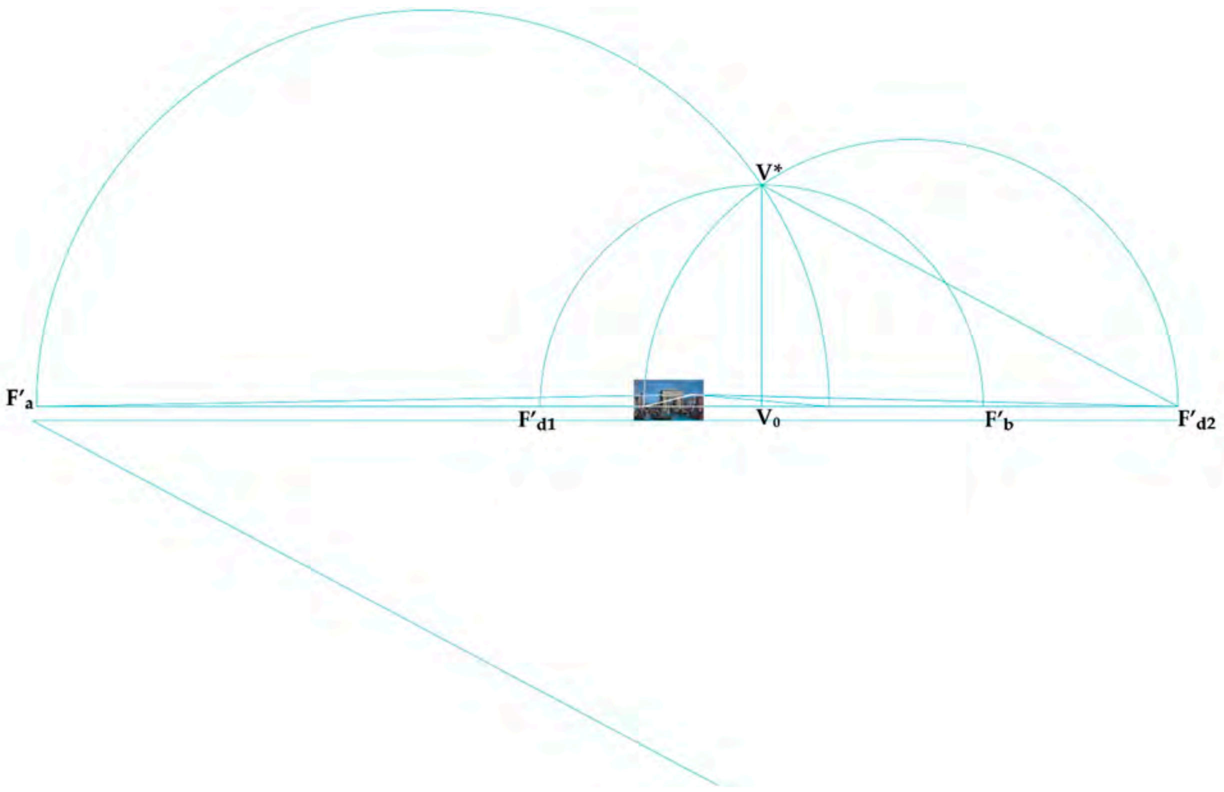


Figure 12. Determination of the position of the center of view.

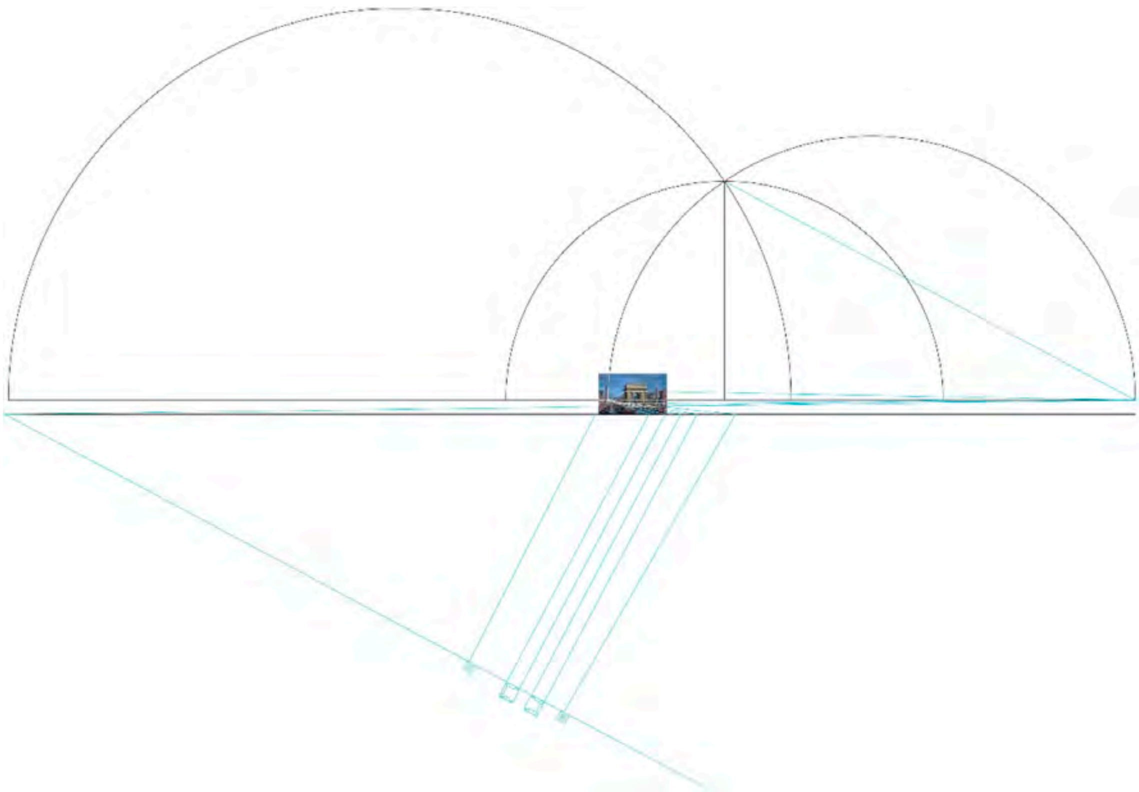


Figure 13. The determination of the position of the Triumphal Apparatus with respect to the city, based on the inverse method of perspective.

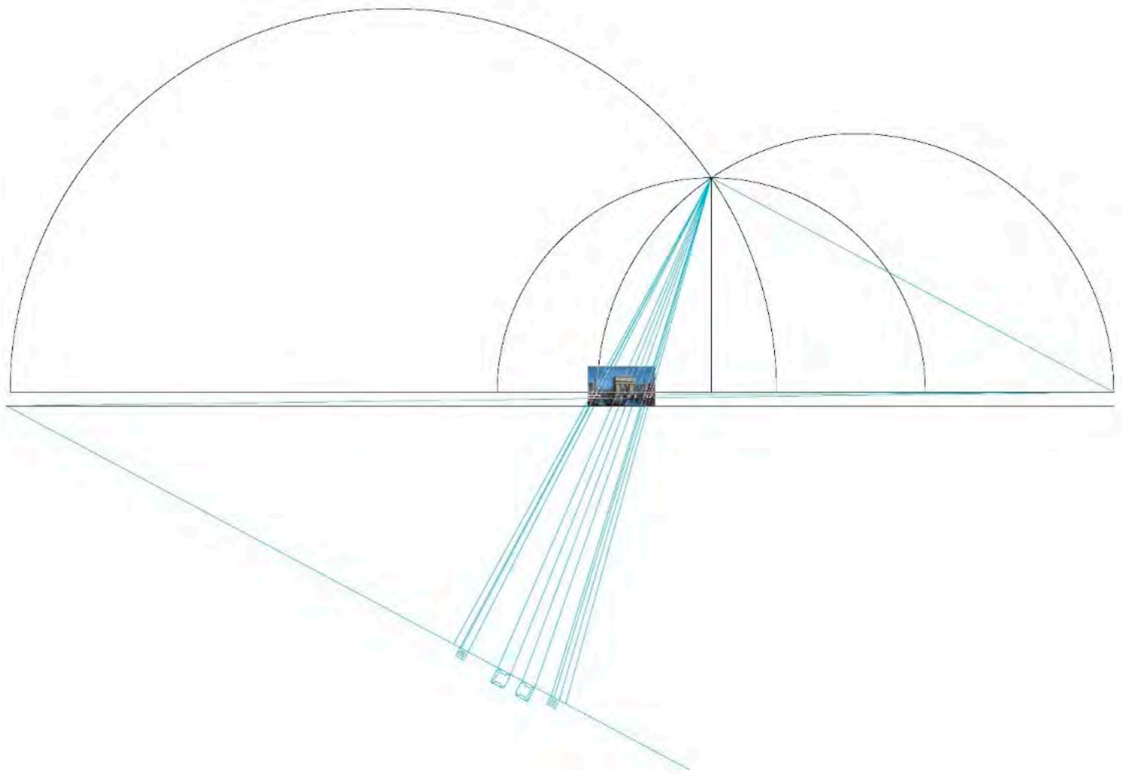


Figure 14. The determination of the position of the Triumphal Apparatus with respect to the city, based on the homology method.

After the restituting of the plan of the arch, the entire restitution was scaled on the basis of the real size of the building plan, derived from the redrawing. Once this operation was completed, it was possible to compare the width of the Canal Grande in the section concerned, derived from the historical cartography, with the width obtained through the perspective rendering. The comparison highlighted the significant widening of the canal operated by Borsato. This trick was made to give the right space and enhance the grandeur of the Triumphal Apparatus.

The first method was used to determine the height in the real shape of the arch, the foundations, and the buildings (Figure 15). The vanishing lines of the edges whose heights were to be known were extended, and a vertical line was drawn from the intersection of the joint of the lower point of the corner and the fundamental. The true height of the edge is determined by the intersection of this with the upper point's joint.

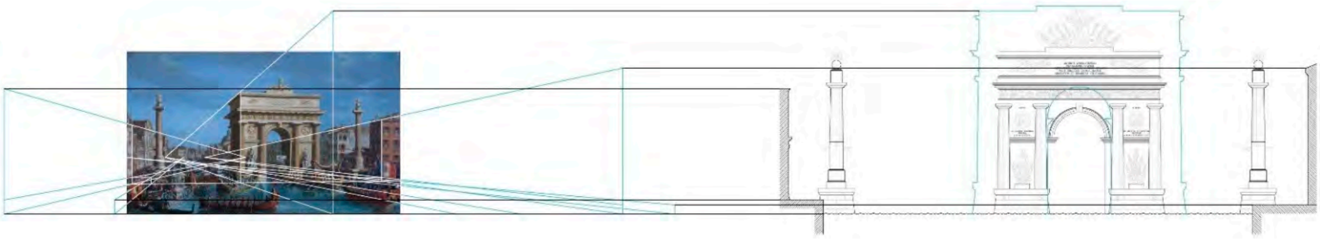


Figure 15. The restitution of the height of the arch, buildings, and foundations.

Comparing the height of the arch resulting from the redrawing with the height of the arch inferred from the inverse method of perspective, a discrepancy emerges. The arch shown in the picture is in fact larger than the height inferred from the elevation created by Selva. This divergence is justified by the painter's desire to give greater prominence to the Triumphal Apparatus, the subject of the painting.

2.3.4. Using Old Paintings to Recover the Geometric Parameters of the Perspective of the Image

After determining the position of the grip center of Borsato's painting in 1809 using the inverse method of perspective, it was decided to determine the same parameter using an alternative procedure in order to compare and verify the results obtained.

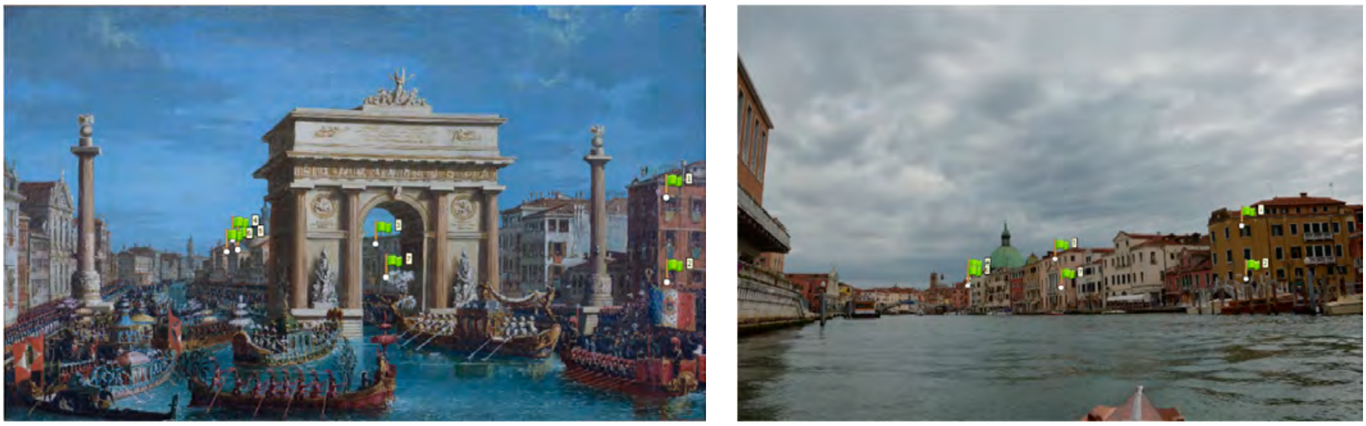
Historical paintings can help us understand what the architect had in mind when he designed the building. Indeed, by knowing the coordinates of some points in a specific coordinate system, the geometric parameters of the photographic image's central perspective can be recovered [6].

The orientation of the grip center was then determined using photogrammetric structure from motion algorithms. This was made possible by advances in photogrammetric methodology and the development of SfM-MVS algorithms in recent years [57].

The painting's grip center was estimated using the Agisoft Metashape software, which performs automatic photogrammetric processing of digital images and generates three-dimensional reconstructions of the objects in the frames using a set of automatic correlation algorithms derived from computer vision and are widely used in the photogrammetric field [60]. The structure from motion is determined by calculating the feature matching between the photos in the project. The points within the images are detected in relation to the variation of the point of view and lighting; thus, the software determines the correspondences between the images using an algorithm.

To determine the location of the frame's grip center, a photogrammetric model of the area was created. Because the reconstruction area insists on a part of the Canal Grande and the buildings that overlook it, the frames were taken by boat, departing from Piazzale Roma and heading towards the city. Individual images depict buildings on both sides and part of the canal in this manner; these images are also distinguished by a perspective construction similar to that depicted in the painting.

The photogrammetric set was imported into the Agisoft Metashape software. This software incorporates SfM-MVS algorithms that allow the three-dimensional geometry of a scene to be generated from multiple overlapping photographs. The software provides a structured workflow, with the main steps being bundle block adjustment, camera alignment optimization, and dense reconstruction of the scene geometry [61]. The first stage of image processing is handled by the software function Align Photos. It incorporates a bundle block adjustment procedure that estimates both intrinsic and extrinsic camera parameters. The position at which the photos were taken is reconstructed using the estimated external camera orientation parameters. Furthermore, the software detects analogous points on the images and converts them to tie points. The alignment process produced a 3D sparse point cloud, which was performed with the utmost precision [61]. The alignment produces a sparse point cloud that can be expressed in any reference system. As a result, a georeferencing strategy is required to perform a 7-parameter 3D Helmert transformation, which includes three translations, three rotations, and a scaling factor. This procedure is carried out in conjunction with the function optimize camera alignment. The markers in the various frames have been given coordinates taken from the city model. As a result, we can easily compare the results of the photogrammetric procedure with those of the inverse method of perspective. The dense cloud was obtained after the external orientation phase of the photogrammetric block was completed. In this manner, a more defined model of the area was obtained, within which the image was inserted, with the intention of having the software process this image as if it were another frame from the original photogrammetric set. To aid in the orientation of the painting, homologous points between the painting and the model have been identified in order to force the orientation of the painting (Figure 16a,b). In fact, the function of the support points is to optimize the alignment of the photos as well as to determine the coordinate system of the model.



(**a**) (**b**)

Figure 16. (**a**) The positioning of the markers in the picture, on the buildings of the Santa Croce district; (**b**) The positioning of the markers on a frame on the buildings of the Sestiere di Santa Croce.

Since the image shown by the painting does not coincide with reality, it was not possible to orient the painting by placing the markers on both sides of the canal. As a result, the painting was oriented in relation to two copies of the same model, each with a different homologous point. On the first model, the markers were placed on the buildings of the Santa Croce district (on the right side of the painting), and on the buildings of the Cannaregio district (on the left side of the painting). The position of the grip center in the two models was compared by following the orientation of the painting. The buildings in the Santa Croce district have remained virtually unchanged since the early nineteenth century. This enabled the identification of seven homologous points between the painting and the current frames, which were then distributed along the entire urban front. The painting was used to compare the orientation of the center of the picture obtained using this method. In fact, the Agisoft Metashape software allows you to align the model's point of view with the grip center of an oriented frame. This comparison, which presented similar urban perspectives, allowed us to consider the software's estimated grip center orientation.

Unlike the one just examined, the front to the left of the painting, which depicts the buildings of the Santa Croce district, has undergone significant changes. Many of the buildings depicted in the painting were demolished to make way for the train station in the mid-nineteenth century. Because of these significant changes, it was no longer possible to identify points of support along the entire urban front, but only in a specific area. In this case, five homologous points were found to be very close to each other between the cloud and the painting.

The obtained gripping center position turns out to be very different from that previously calculated, and thus incorrect (Figure 17). This consideration is confirmed by aligning the model's point of view with the grip center of the frame, which is thus oriented. The fact that such discordant results were obtained emphasizes the importance of the position of the support points in the orientation operations of the frames and the model in the chosen reference system.

Figure 17. Comparison between Borsato's painting depicted in 1809 and the view on the model obtained from the grip center calculated by SfM algorithms.

It was therefore decided to use the same procedure to determine the orientation of the grip center in Borsato's 1847 painting, which depicts a reverse shot of the same scene. A photogrammetric model of the Canal Grande was also created in this case, starting with a set of frames acquired by the boat in the opposite direction as those used to build the previous model. In this case, the procedure is the same as described above (Figure 18).

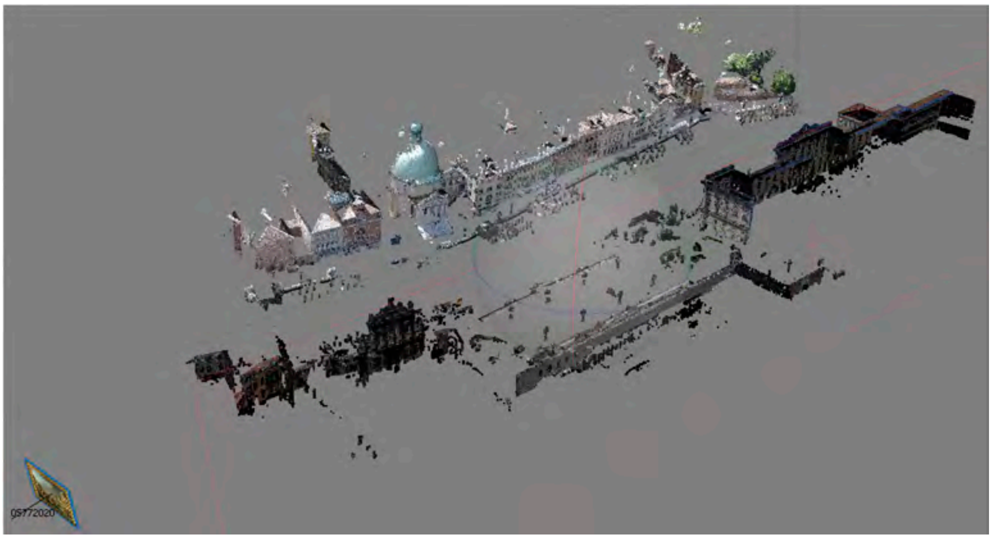


Figure 18. Orientation of the grip center of the painting related to a view on the dense cloud.

In this case, ten homologous points were identified between the frames and the painting, which were located on the churches of San Simeon Piccolo and the Scalzi.

The painting's grip center orientation turns out to be correct. In fact, the image you have of the model through this appears to be coherent when compared to what Borsato shows (Figure 19).

Figure 19. Comparison between Borsato's painting depicted in 1809 and the view on the model obtained from the grip center calculated by SfM algorithms.

2.3.5. The Relationship between the Real City and the City Shown by the Paintings

After precisely determining the reference points and their relationship to the Triumphal Apparatus, the arch and columns were inserted into the city's georeferenced model. As a result, it was confirmed that Borsato's perspective does not correspond to reality. It was decided to align the two urban fronts with the paintings and to incorporate ephemeral architectures. In addition to the city model created in a GIS environment, a second model was created by adapting the urban fronts to what is shown in the painting, so that the two different situations could be compared (Figure 20a,b).

(a) **(b)**

Figure 20. (**a**) The Triumphal Apparatus is positioned within the city, based on the references obtained from the inverse method of perspective; (**b**) The Triumphal Apparatus is positioned within the city shown by Borsato's painting, based on the references obtained from the inverse method of perspective.

It was possible to position the cameras in correspondence with the grip center of the painting in the second model generated using the photogrammetric process and inverse method of perspective. It was thus possible to observe the model calculated using the two methods from this point. As a result, it was possible to confirm that, despite some differences, the results are comparable. The same comparison was made with regard to the painting that was examined using the two methodologies.

The difficulty encountered in inserting the arch and column models within the urban context has highlighted the importance of reconstructing ephemeral architectures by working within a georeferenced model at urban scale. Because of the precision with which the urban context and ephemeral architectures were recreated, it was possible to define with certainty some of the perspective measures used by the painter to emphasize the majesty of the Triumphal Apparatus, built on the occasion of Napoleon's visit, and the context in which it was inserted.

2.3.6. The Grandstand for the Regatta

The Regatta has always been a very important event for the city of Venice, having been held annually since the time of the Serenissima and continuing to this day.

Only one long period of suspension occurred in the history of this important tradition, coinciding with the years of the first Austrian dominance (1798–1806) and belonging to the Napoleonic Kingdom of Italy (1806–1815). During the reigns of the two foreign dominions, only one Regatta was held, on 2 December 1807, during Napoleon's visit to Venice to celebrate the third anniversary of his coronation as Emperor of the French. This event's planning can be interpreted as an attempt to reconcile the foreign government with local tradition. As a fusion of the French custom of bestowing honor on the Emperor and his achievements and the Venetian custom of doing so through water parties and regattas.

The finish line of the regattas is traditionally located at Volta di Canal, a bend of the Canal Grande in front of Ca 'Foscari, where a floating Grandstand called a "Macchina" is built at the point where the Rio de Ca' Foscari enters the Canal Grande.

On the occasion of the Napoleonic Regatta, a grandiose "Macchina" designed by Giuseppe Borsato was built to award the winners [25].

Napoleon watched the event from the terrace of Palazzo Balbi, where a lavish loggia had been constructed [56]. The palace was chosen because its location in Volta di Canal allows you to fully enjoy the Regatta spectacle by focusing on both strips of the Canal.

After finishing the research and analysis of the graphic documentation, we moved on to the comparison of the various sources. Engravings and paintings were compared to each other and to Morelli's description. Based on these analyses, it was discovered that images and relationships are coherent; in particular, the work's rich decorative apparatus does not contain discordant elements between the various representations.

We then moved on to the phase of redesigning the architecture based on the 1807 engraving by Borsato (Figure 21), which was presented as a panel in Jacopo Morelli's book. This image was chosen because the work's plan and elevation are presented precisely. Furthermore, there are two graphic scales at the bottom of the sheet, one in meters and one in Venetian feet. To scale the image before redrawing and verifying the data obtained, the same procedure was used as with the sizing of Selva's arch. The plan and elevation of the Grandstand were thus sized based on the presence of both scales, reporting them in meters. In this case, too, the difference that emerged between the two dimensions, 0.019 m, was found to be compatible with the graphical error given that the drawing was made for the 1:100 scale.

Figure 21. G. Borsato, The Grandstand for the Regatta, engraving, 1807, Museo Correr, Venezia.

2.3.7. The Relationship between the Grandstand and the City

We focused on the relationships that ephemeral architecture has with the context in which it is inserted by analyzing Borsato's paintings depicting the Macchina and the Regatta. The Macchina's proximity to the Canal Grande and the noble palaces that overlook it leads us to believe that it is one of these. The machine is thus designed as a temporary urban front, occupying the space between Palazzo Balbi and Ca 'Foscari, where the Rio di Ca' Foscari flows into the Canal Grande. Considering the ephemeral architecture as an urban front, it was decided to treat its representation using the methods used to create the city model in a GIS environment, texturizing the surfaces with historical images. The machine model was then georeferenced, locating it within the city model, referring to the architecture's position in relation to the city in the painting (Figure 22).

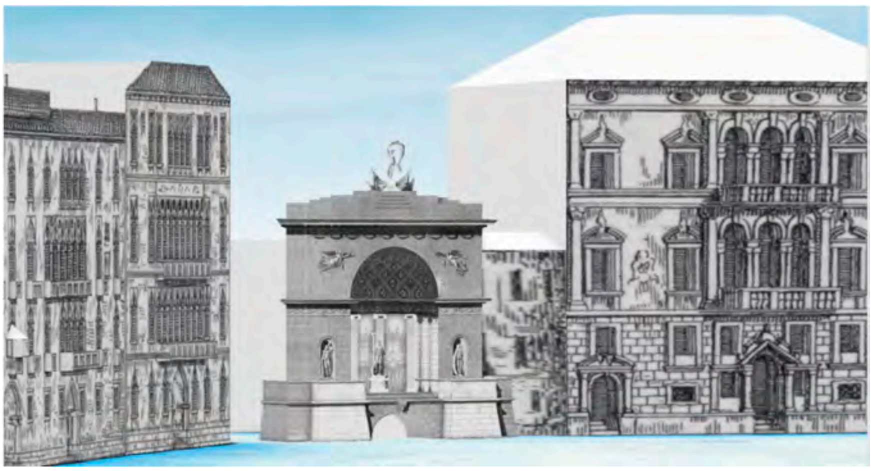


Figure 22. A view of the Grandstand inside the city model.

The georeferenced model was then textured using the Esri ArcGIS Pro software. The image of that part was then applied to the individual components of the model, using the same engraving that was used to redesign the work. Particular attention was paid to the points of contact between surfaces belonging to different planes, to ensure that the texture was coherent and lacked obvious discontinuities.

3. Results: The Use of Online Portals for Urban Cultural Heritage Knowledge and Conservation

The historical research phase has revealed how, in the study of the history of architecture and the city, paintings and project drawings, combined with the reading of historical documentary sources, frequently do not allow a simple and complete understanding of the subject under consideration. The materials are often scarce and difficult to interpret. Furthermore, the time it takes to obtain reproductions of these in high definition, so that they can be studied more in depth, is very long. Another aspect that negatively affects the knowledge of some historical events is linked to the lack of concrete elements, usually architecture or monuments, present in the area today that testify to them, as they were built to last only the time of the event or were demolished.

The concept of ephemeral is linked to the relationship between form and time, which is inherent in the concept of transformation, or rather the passage from an initial to a secondary state. The concept of ephemeral thus identifies not only the architectures built for Napoleon's visit and then demolished, but also the urban relationships that these came to weave with the context in which they were inserted, which is thus configured as a system in mutation, subject to changes over time. These considerations give rise to the desire to seek a way to communicate the history of places that have changed today in a way that is easily accessible to a large number of users and easy to read, in order to promote knowledge not only of historical events but also of the urban reality that characterized Venice in the early nineteenth century, in addition to sources and historical cartography.

The use of online platforms that integrate sources and information and allow access and query by all users is an ideal solution for communicating work results [43]. When considering the educational role of the information to be transmitted, the communicative aspect is critical [2]. Virtual models that are accessible online have been created using the possibilities provided by ICT (information and communication technology). These models would allow you to enjoy a no longer-existent physical space, allowing you to perceive a space from within it, going beyond the pictorial or engraved images of the past and also overcoming the communication that is now made by digital reconstructions through rendering and video.

The desire to generate an alternative reality to the museum, a product that can be of assistance to it, allowing you to see through a monitor something that in reality cannot be used, guided the realization of these works. Certainly, the function of a virtual model lacks the emotional aspects typical of a real visit to a place, but its dissemination via the web allows a large number of users to enjoy it for free. The ability to interact with virtual models online is particularly relevant to the spread of knowledge [8]. These outcomes are available to everyone, everywhere; all you need is an internet-connected device. This type of solution is especially useful when dealing with documents or archives that are inaccessible.

The user's interaction with the online model is not limited to the ability to move within a space; it is also possible to insert information on the work and reproductions of historical sources, which can be accessed by clicking or pointing to specific areas of the model. This is a crucial fact because it enables the consolidation of sources and materials that would otherwise be kept in separate archives and museums. In terms of dissemination, various systems have been used, with different methods and tools used to reconstruct the digital models of the two ephemeral architectures and the urban context in which they were inserted.

The study demonstrated how ICT-enhanced geomatics tools can provide the applications required to integrate data from disparate sources into a coherent set. Establishing and organizing structures, resources, and stable networks that promote knowledge are all part of the process of valuing a good. As a result of the work, the city model was loaded onto a WebGIS platform, and a virtual tour of the model was generated based on the painting depicting Napoleon's entry into Venice.

3.1. The Virtual Tour

The virtual tour gives you the ability to shift between spherical images at different viewing points and allows you to make a real virtual visit, exploring the environments reproduced in their entirety, thanks to this immersive digital tool, which was created by interconnecting a series of spherical images obtained from the digital model [62]. This virtual space, which can be accessed via an internet connection, allows you to incorporate other multimedia elements into the spherical images, as well as gather information about the sources used to create them and the objects represented.

The virtual tour is a cutting-edge communication tool that allows you to create interactive image paths.

It is created by combining a number of panoramic images in order to achieve a reliable representation of the space you want to make accessible. These images, which are displayed in a spherical projection on the platform, have their own coordinate system. Through the angles θ and φ (Figure 23), it is possible to place a button (known as hotspots) in coordinates and associate it with multi-source and multidisciplinary information in a specific position of a panorama [62].

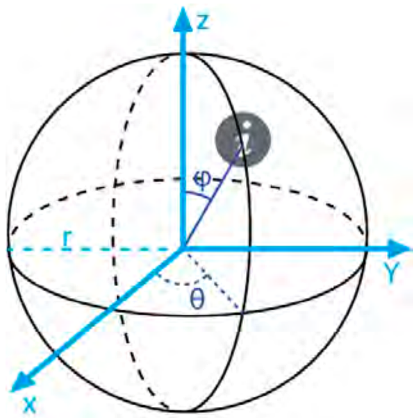


Figure 23. Positioning of the information in the panoramas.

This tool provides an addicting e-experience that can be accessed via computer, tablet, or smartphone. The virtual tour allows other multimedia elements to be integrated into the spherical images, resulting in a product that contains more information than spherical images alone and with which the user can easily interact. The next step is to create an immersive virtual scene, which allows you to evaluate the spaces you want to present on the Web with precision and immediacy.

As a result, this tool was chosen to convey the urban reality of the Santa Lucia area in the early nineteenth century, which had been drastically altered by the construction of the railway station. The virtual tour can be thought of as an interactive photograph that allows us to visit locations as if we were actually there. The final product offered to the end user is an interactive virtual scene generated by the union of several spherical images, which can be photographs or renderings generated from a virtual model, as in this case.

To create the virtual tour, we first created a 360° rendering of the model, then used open source Marzipano software to export a virtual tour created from a series of panoramas as a web application. After processing the scene, you can create a virtual tour application that can be hosted on numerous websites.

The difficulty of coherently integrating data from various sources and fields, as well as the selection of information to display on the platform, are the challenges to overcome when creating a virtual tour [62]. Virtual tours are fascinating tools because they provide users with numerous options (Figure 24).

Figure 24. Views of the virtual tour.

3.2. The WebGIS

WebGIS allows researchers to combine geographic data from various fields of study into a single information platform, resulting in a variety of applications and ideal solutions for the dissemination of projects aimed at preserving a place's memory and history. These tools have altered how geospatial data are transmitted, shared, and displayed; the Web extension of GIS programmes allow you to process and analyse georeferenced data from anywhere you have an internet connection, reaching a large audience of specialised users and operators [9], and encouraging a multidisciplinary approach to urban historical studies. The neologism WebGIS refers to web-based geographic information systems (GIS); it is thus an extension of the web of applications created and developed to manage numerical cartography, with specific communication and information sharing goals with other users. Information systems are defined geographically when they are designed to operate with data related to the geographical space. They arise from the need to collect, process, manage, and make available a large amount of data and information about the territory. The software for managing geographic data, which must have specific characteristics and requirements, distinguishes a GIS from a WebGIS. WebGIS is not just an add-on to a desktop GIS program, it is also a piece of Web-based software. Spreading geographic information through websites entails allowing users to process and analyze georeferenced data from anywhere on the globe through a connection, as well as reaching a large audience of users, including non-specialized users. A WebGIS is an application that allows you to navigate and query a map using only a standard internet browser. A WebGIS enables researchers to combine geographic data from various fields of study into a single information platform. It also includes a number of applications and ideal solutions for memory dissemination and conservation projects. Setting up and organizing stable structures, resources, and networks that favor knowledge are all part of improving an asset. The connections between the GIS and the data archiving systems inherent to cultural heritage have been made possible by the integration of various technologies and solutions available today in IT systems. The Esri ArcGIS Online software, a Web extension of the ArcGIS Pro software used for cartographic data processing and the generation of the city model, was used to create the WebGIS presented here. Interactive maps can be created with ArcGIS Online to easily explain data to users. The software interface is extremely immediate and user-friendly, allowing the user to explore and interact with the model, as well as visualize and analyze the data it contains, using intuitive analysis tools that help even non-specialized users understand data.

WebGIS was chosen because it allows you to share three-dimensional maps and scenes, allowing any user to explore and comprehend data within a system that provides spatially referenced data. The ability to share the work's results online allows them to be used by other researchers, such as historians, who are often not particularly skilled in the use of GIS and modeling tools, favoring the development of scientific and historical research for the enhancement and conservation of the city's history (Figure 25). Furthermore, because these are simple models that integrate various sources and the data derived from them, they endorse the approach to the topics analyzed by a wider audience of users, providing them with a wealth of information and simple communication tools.

Figure 25. Views of the WebGIS.

4. Conclusions

Cultural heritage has four stages in its global life cycle: knowledge, use, communication, and management. All information is available to stakeholders in the case of the WebGIS platform used in this project, which allows for the storage and management of data in various formats and from various sources.

Starting with the analysis of historical maps, the research examined some aspects of the city's history, identifying the case study in an event as significant as it is unknown. The topic was investigated from two perspectives: one based on the rigor of the technical–scientific method, and the other on the dissemination and promotion of acquired knowledge. The work is presented not only as an example of the potential offered by geomatic techniques applied to the reconstruction of a past urban scenario, but also as a way to heighten interest in a historical event that has left no visible trace within the city. The experience has highlighted the significance that geomatic techniques, particularly GISs, have assumed in the knowledge and dissemination of historical events, particularly those related to the history of architecture and the city. The method used allowed for the integration of humanistic knowledge and technical skills into a single model. The sources were investigated with the rigor typical of scientific research, in order to obtain products capable of communicating the story of the event narrated, not only with a view to an easy understanding of the events of the past, but also providing correct metric and spatial information, inferred from research conducted using objective methods.

The application of technology to an interdisciplinary project provides a powerful and adaptable tool for analyzing a significant cultural and sociopolitical phenomenon. Experimentation demonstrates that geomatic techniques can broaden research opportunities in a broad and modern multidisciplinary context, demonstrating that the digital environment can be very valuable not only for conservation, but also for modern analysis of historical cartographic heritage.

As a matter of fact, geomatics presents itself as a tool for knowledge and cultural heritage protection, providing the tools required to ensure knowledge, conservation, and fruition of the patrimony.

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