

INTERDISCIPLINARY DATA FUSION FOR DIACHRONIC 3D RECONSTRUCTION OF HISTORIC SITES

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ABSTRACT:

In recent decades, 3D reconstruction has progressively become a tool to show archaeological and architectural monuments in their current state, presumed past aspect and to predict their future evolution. The 3D representations through time can be useful in order to study and preserve the memory of Cultural Heritage and to plan maintenance and promotion of the historical sites. This paper represents a case study, at architectural and urbanistic scale, based on methodological approach for CH time-varying representations proposed by JPI-CH European Project called Cultural Heritage Through Time (CHT2).

The work is focused on the area of Milan Roman circus, relatively to which was conducted both a thorough philological research based on several sources and a 3D survey campaign of still accessible remains, aiming at obtaining the monumental representation of the area in 3 different ages.

1. INTRODUCTION

This work is being carried out in the frame of the CHT² project (Cultural Heritage Through Time), supported by the JPI-CH action Heritage Plus, whose implementation consisted in involving several European groups with innovative proposals developing current issues of cultural heritage. The project's goal is to develop time-varying 3D products, from landscape to architectural scale, to envisage and analyze lost scenarios or visualize changes due to anthropic activities or intervention, pollution, wars, earthquakes or other natural hazards. The main aim of the CHT² project is to merge heterogeneous information and expertise to deliver enhanced four-dimensional (4D) digital products of heritage sites. CHT2 is working on the full integration of the temporal dimension, its management and visualization, for studying and analyzing Cultural Heritage structures and landscapes through time.

The proposed methodology for the whole project is described in the paper (Rodríguez-González et al., 2017), that suggest different ways to reconstruction of the diachronic life of an historical object, monument or landscape. It is based also on the integration of different contributions in the area started from the beginning of 2000 (Frischer, 2004; Guidi et al., 2008; Pletinckx et al., 2000).

The work here presented is the implementation of the proposed method for those cases in which the physical property is now disappeared entirely or almost entirely, leaving for example only some archaeological remains in different points of the territory. In these cases, the diachronic reconstruction will be based on surveyed data and philological analysis.

The search for historical sources, their proper analysis and interdisciplinary relationship between technological disciplines and the humanities are fundamental for obtaining reliable hypothetical reconstructions. Furthermore, is one of the most significant and difficult aspect of the work.

Given these premises, it must be underlined that there are cases in which the three-dimensional diachronic reconstruction is particularly complex. The reasons for this are several: (i) the

nearly total absence of remains to be surveyed; (ii) one or more periods of artefact's time life with historical documentation shortage; (iii) uncertainty of sources; (iv) difficulty to correlate documents and data to a three-dimensional representation.

2. CASE STUDY

2.1 Historical notes

The case study covers the south-west area of the city center of Milan that corresponds to the Roman Circus area. On this zone it's possible to see several traces of the different historical periods from ancient times until the densely urbanized structure of the present days. According to some archaeological finds, Milan was inhabited since the V century BC in the area corresponding to the current Via Meravigli, Via Valpetrosa, Piazza del Duomo. In this zone some protohistoric tracks converge, with traces of the following Roman roads still recognizable in the city plan. Such roads connected Milan with some towns and villages in its north-western neighborhoods belonging initially to the Golasecca culture, a prehistoric civilization who lived in the Ticino River area from the Bronze Age until the 1st century BC. The route towards Vercelli crosses the area studied within this research and corresponds to the current Corso Magenta.

In II-I centuries. B.C. excavation works and leveling have been made, in order to adapt the ground to the Roman urban model. At that time a first urban planning was conceived, probably maintaining the Golasecca road network. The entire settlement occupied an area 80 hectares, with a spatial organization influenced by differences in height, watercourses and by the existing routes. In the second half of the I century. B.C. the romanization of the territory was completed (Caporusso et al., 2014; Colombo, 1928).

With the arrival of the Romans and their culture, the investigated area was first dedicated to housing and productive activities.

In the area, now occupied by the Archaeological Museum, recent excavations have revealed the presence of a *domus* belonging to various pre-imperial times. At the end of the I century BC, good

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quality residences and production activities should have been present, probably related to the metal extraction from the sediments of the Nirone river (then diverted to leave space to the Circus and city Walls), and the related processing. A subsequent domus must have been built in the I and II centuries AD, later transformed in a prestigious domus in the III century AD. For none of these buildings, unfortunately, a complete plan is known (Blockley et al., 2013).

In the 286 AD, with the tetrarchic subdivision, Milan became the capital of the Western Roman Empire, under the emperor Maximian. During the imperial period, up to 402 AD, the area has been modified by the construction of major buildings such as the imperial palace, the circus and the defensive walls (Mirabella Roberti, 1984; Sena Chiesa, 1990; Calderini, 1965; Caporusso, 1990).

The Circus was the open-air venue for chariot and horse races, or rather the place dedicated to the celebration of the Emperor's greatness and for this reason it was generally located near the Imperial Palace (Humphrey, 1986). The Milan's circus was also adjacent the defensive walls with which shared the western part

with it. This particular location has probably resulted in a number of peculiarities, such as the absence of the arc of Triumph on the apex of the curve. Although the circus of Milan was one of the most important of the empire, today only few traces are still visible: a tower of the city walls, a tower of the Carceres reused as a bell tower (formerly belonging to the Monastero Maggiore), and some sections of the walls or foundations in the private properties nearby, sometimes hidden in their interiors or in the basements (De Capitani D'arzagno, 1939; Blockley et al., 2012; Fedeli, 2015).

Historical sources report the existence of the circus until the Longbard's era. From that period, as happened to other monuments in Milan, the materials of the roman structures were used in other buildings construction. Archaeological studies were conducted mostly at the beginning of the '900 and after World War II, during the reconstruction of some private and public buildings, when it was possible to see the several archaeological remains. Many questions are still open about the building's elevation and its relation to the surrounding area: the imperial palace and the town fortification walls.

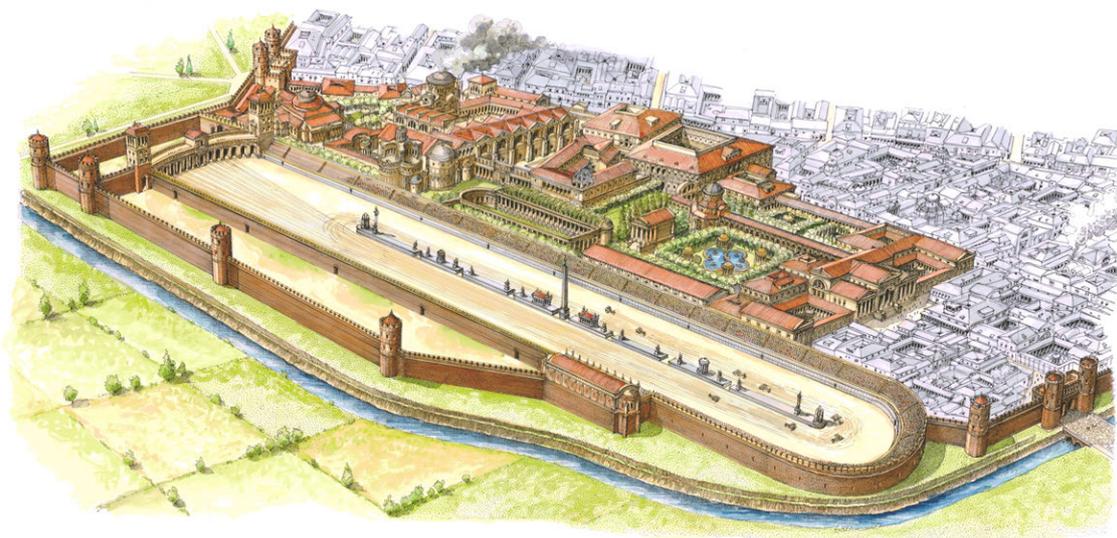


Figure 1. Reconstructive drawing of the Circus and the Imperial Palace (by F. Corni, courtesy of Civico Museo Archeologico di Milano)

The area of the circus includes the Church of San Maurizio, whose nucleus is of early Christian origin and was built in the form we know today at the beginning of '500. The church was connected to Monastero Maggiore in Milan, one of the most important female monastery of the Benedictine order, active since the Carolingian age.

The convent, among the largest and richest of the city, had its greatest extent in the '700, until it was abolished by decree of the Cisalpine Republic in 1798. After this event it was used for laic purposes (barracks, female school, military hospital).

During the '800 the main cloister and the buildings connected to the opening of two new roads (Via Luini and Via Anasperto) were shot down. Other serious damage occurred, moreover, following the bombings of august 1943, during the World War II. Nowadays, unfortunately, only small portions of the monument remain visible and a lot of historical documentation has been lost in a fire during World War II. In the '60s of last century the area of the complex was used as headquarters of the Archeological Museum of the Municipality of Milan (Civico Museo Archeologico di Milano) that still takes care to preserve the memory of the various eras represented in this part of town.

The rest of the area occupied by the ancient Roman Circus is instead almost entirely occupied by residential buildings (Capponi, 1998) and small remains of the circus are still visible in the basements of modern buildings in that area.

3. METHODOLOGY'S APPROACH AND INVESTIGATION

In some cases in the literature (Guidi and Russo, 2011; Micoli et al., 2013) diachronic reconstruction of a monumental complex starts by the three-dimensional survey of the current state of the monument and from 'reading the traces' of different ages at the restoration, along with a suitable philological research.

In this case, given the limited detectable findings, the work began with an in-depth philological research started from the research of historical data and archival. So this paper shows how all different kind of sources like texts, maps, drawings, archaeological reports, archaeological restrictions decrees and photographs has been integrated to hypothesize a reconstruction of the area, by referencing such documents to that specific location of the city.

3.1 Bibliographic resources

The first kind of source taken in to account are the bibliographic resources to document the history of the city and the monument of the area.

In particular, historical texts were considered, from which it is possible to infer useful information about life, state of the monument and reports of archaeological excavations past and contemporary.

Especially important for the study of the monument it was the text of the archaeologist De Capitani D'Arzago, that in the late

'30s of last century has thoroughly studied the Roman circus of Milan, confirming the existence, location and essential size of it thanks to discovery of the parallel walls, some portion of the foundations and a large part of the curve. In Figure 2 his plan reconstruction of the monument is shown.

The literature search was also conducted in relation to other examples of similar imperial-era monuments and pre-imperial-era domus; so it is possible reconstruct any missing information on the area under analysis with references to other analogous historical cases.

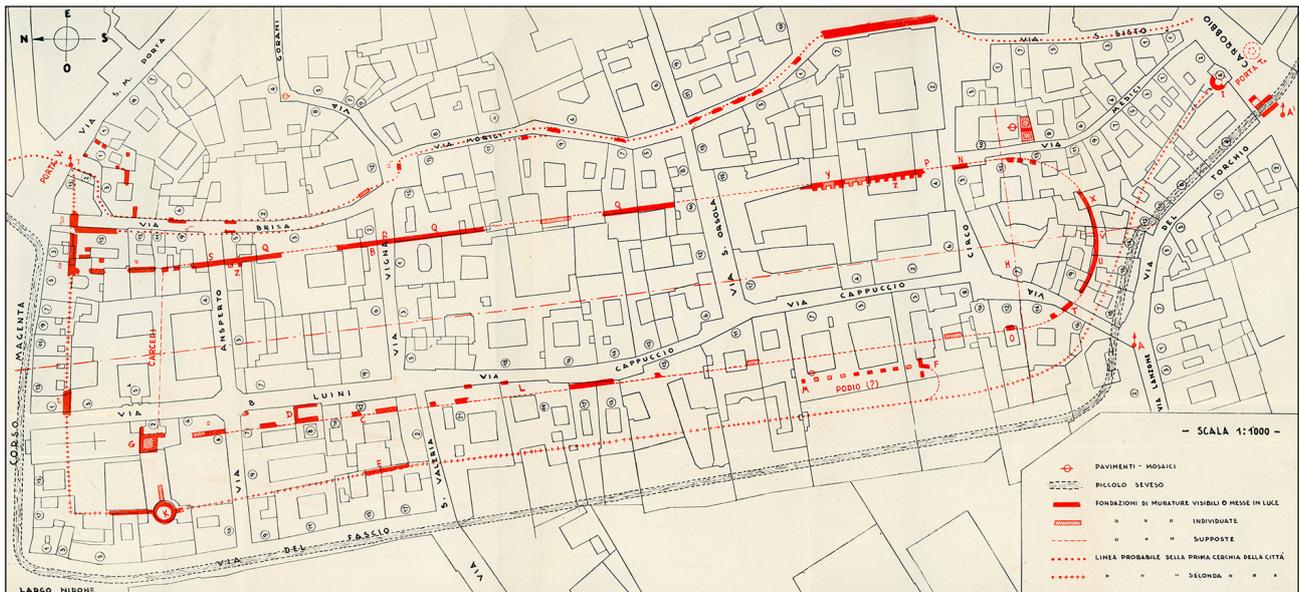


Figure 2. Plan of Milan Circus according to archaeological studies conducted by De Capitani D'Arzago (Capitani D'Arzago, 1939).

Legend: full red pattern: foundations of visible walls or put into light; obliquely red dashed line pattern: identified masonry foundations; red dashed lines pattern: supposed masonry foundations.

3.2 Historical representation

Another step of the work was a collection of maps, drawings and images concerning the various topics covered in the research. Drawings and historical paintings are fundamental to get information no longer available today. When possible, data for individual monuments are searched. If these are not available, as in the case of the studied area, historical representations of elements of the same typology and age are searched.

This kind of approach is useful to have typological indications and to validate the reconstructive hypotheses proposed by scholars.

In our case, for example, we have been researched sources regarding: (i) domus of pre-imperial era; (ii) Roman circuses built in the Empire in the same period; (iii) monasteries of the Benedictine order.

Unfortunately, in the case of Milan only poor graphical representations of the monuments involved were available, with reference to their active period.

With regard to more recent times, all the drawings of survey campaigns carried out in the area have been collected.

In the post war period, many buildings destroyed by bombing were rebuilt. In this phase the excavations for the foundations of modern buildings have, in some cases, revealed archaeological findings that sometimes were used as basement for the analyzed building itself. In other cases, like for example in correspondence of new roads or other unbuilt areas, such findings were simply

covered underground. In the latter cases the survey drawings made during excavations, like the example shown in figure 3, were fundamental to get information about archaeological remains today no longer accessible.

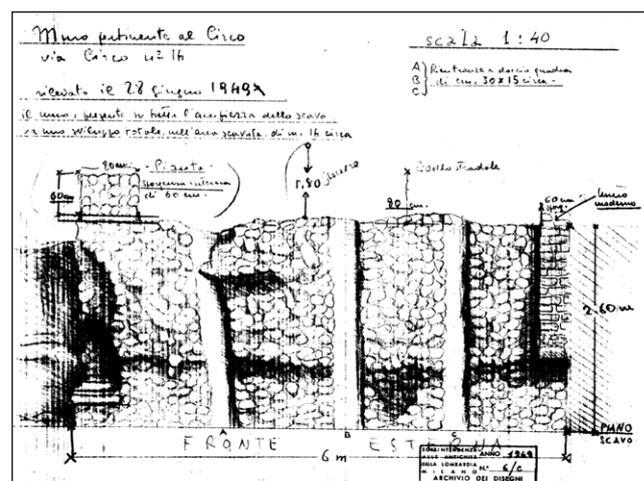


Figure 3. Drawing of an archaeological excavation carried out at Via Circo 14 in 1949 (Courtesy of Soprintendenza Archeologia della Provincia di Milano)

3.3 Historical maps

Then a deep iconographic research was carried out collecting also different maps from various periods that can highlight the urban structure of the area. About 60 city maps representing different historical periods from the Renaissance to the present days have been identified at the Civica Raccolta delle Stampe Achille Bertarelli and analyzed to study the evolution of the urban area.

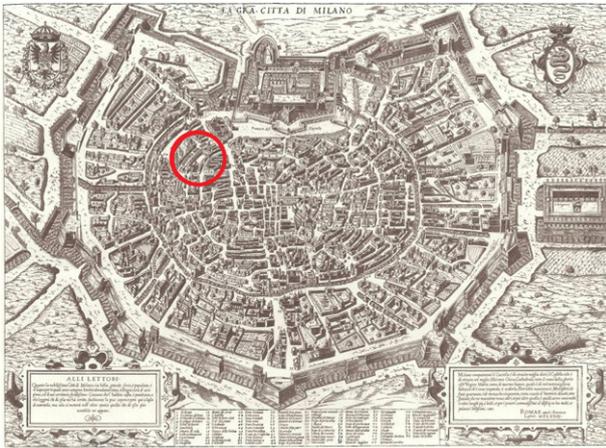


Figure 4. Milan perspective map - 1573 Antoine du Pérac Lafrery, preserved at the Civica Raccolta Stampe A. Bertarelli. Surrounded in red the study area

3.4 Photographic images

Another type of data taken into account are the photographs taken mainly during the after-WW2 excavations. Images of artifacts and structures inside the urban area, taken from different points of view and sometimes referred to two or more different periods of their life, are a valuable support for the three-dimensional reconstruction process.

Specifically, a research in the photographic archive at the Superintendence's office was made with regard to the area of interest. About one thousand images were found and about 100 of them have been selected. This selection regards artefacts visible during construction projects (e.g. the metro, new skyscrapers) or inspections of the superintendent. These images are a valuable documentary heritage because many artefacts are no longer visible, embedded in the foundations of modern buildings.



Figure 5. Elevated View of the remains of the three pillars of the Circus foundations, Via Circo – 1959 (Courtesy of Soprintendenza Archeologia della Provincia di Milano)

3.5 Archaeological restrictions decrees

Starting from a detailed map of the circus made in the late '30 of the last century, the work is verifying the accurate position of all the remains of the circus walls and its connected structures. This part of the work deals also with a capillary search, in connection with the inspectors of the Superintendence of Milan, of all the street numbers of the actual buildings in which basements are still visible the remains. During this search, it was also stated that all the cadastral units interested by archaeological findings are under restrictions but, given the period in which these restrictions were defined, most of them are brief and unclear. Hence, it was difficult to identify the single structures, their position and their extension, and this required a huge archival work.

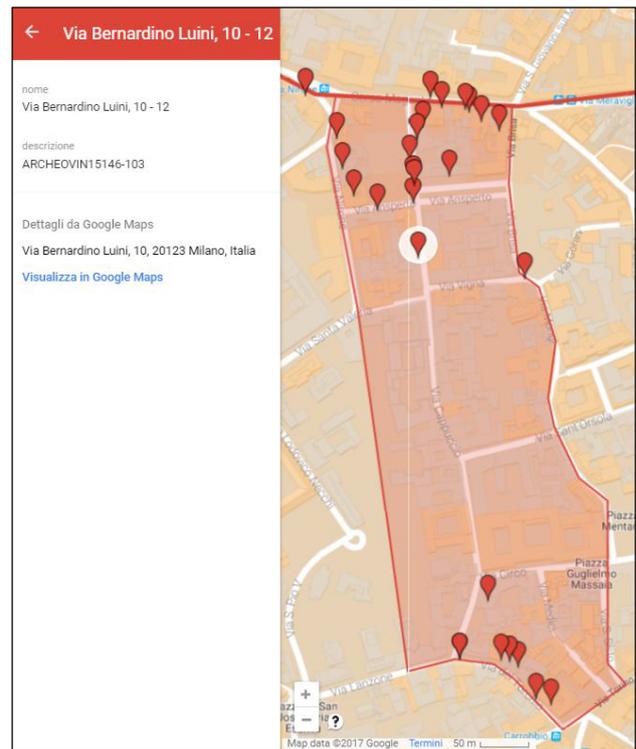


Figure 6. Mapping of areas subject to archaeological restrictions decrees (red points on the map)

3.6 3D survey

Another stage of the work regards the 3D survey with reality-based techniques of all the remains still visible in order to have a starting point for the reconstruction.

Currently, the survey works of the visible portions of the monument have been performed only inside the archaeological museum in Milan. The results, shown in figure 3, consist of the 3D digitization of one of the towers of the “carceres” of the circus, nowadays used as bell tower of the church dedicated to San Maurizio, and the so-called “polygonal tower”, belonging to the city walls when the circus was in activity.

Subsequently will be screened, along with the superintendent, all areas subjected to archaeological restrictions represented in Figure 6, in order to assess the actual presence of remains, their state of conservation and the opportunity to perform a three-dimensional survey. If, according to the archaeologists, the identified remains will be deemed relevant to the Circus and useful to its digital reconstruction, their survey will proceed. Depending on the conditions of operation, such 3D digitization will be made with both SFM photogrammetry or laser

triangulation depending on the available conditions about lighting, working space, etc.

The monument portions detected, suitably georeferenced, will serve to validate the archaeological excavations of the past and will give the main constraints over which create the three-dimensional reconstruction.

In addition to the validation of historical plans, the three-dimensional portions are fundamental as elements of proportion, in relation to the examples of the same type of monument highlighted by other sources, to define the trend elevation of the building, typically the most critical parameter in the reconstruction of any ancient building not existing anymore.

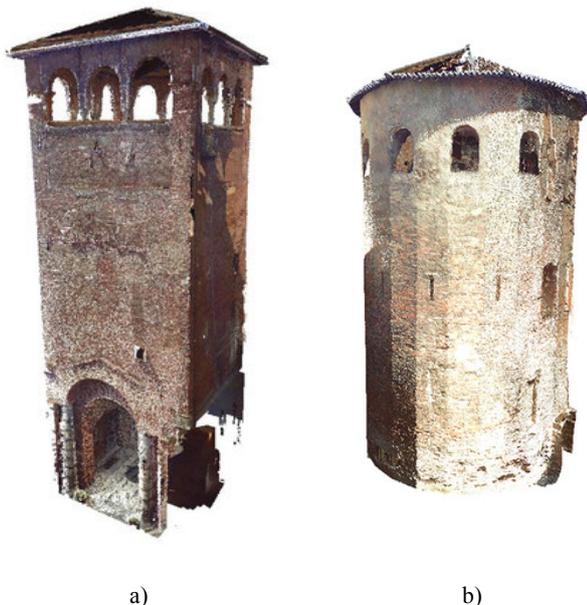


Figure 7. 3D Point Clouds: a) tower of Carceres, b) polygonal tower of city walls adjacent to the circus, still visible in the garden of the Civico Museo Archeologico di Milano

4. CRITICAL ANALYSIS AND 3D/4D RECONSTRUCTION

The so-called 4D reconstruction is usually intended as the process for obtaining the shape of real objects and its changes along a temporal dimension. This is based on a methodology (Rodríguez-González et al., 2017) for integrating the different sources of non-uniform data. On the one hand the surveys described above, georeferenced to the topographic network of the city, will help to identify the accurate positioning of the building and to obtaining precise measurements of the shape and length of the structures. By merging such data related with the current state on the monument with the vast archival material collected until now, a rearrangement of the historical representations will be made, like for example the normalization of historical plans in a uniform scale. From such integrated base of information, a 4D reconstruction will be carried out together with the archaeologists, in order to better identify the proper reconstruction of the ancient building and all the changes that affected the area from the late roman period until the present time.

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