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# Proceedings of the first ArCo Conference


## Art Collections 2020

Design and Museum Design,
Digital Heritage, Historical Research,
Posters

**Editors:**
Francesco Valerio Collotti,
Giorgio Verdiani,
Alessandro Brodini

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**1st ArCo – Art Collections**

Cultural Heritage, Safety and Innovation

International Conference

Original dates: May 28th-30th 2020

Effective dates: September 21st- 23rd 2020

Università degli Studi di Firenze, Italy

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# PROCEEDINGS SUMMARY

**1st ArCo – Art Collections**

Cultural Heritage, Safety and Innovation

International Conference – Sept. 21st-23rd 2020

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# Art Collections 2020

# Digital Heritage

# (ARCO 2020, DH)

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Art Collections 2020, Digital Heritage (ARCO 2020, DH)

# CH representation between Monge's projections and Augmented Reality

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**Abstract**

The representation of complex architectures presents a strong connection with the increasingly massive use of 3D acquisition systems and virtual representations. These tools have changed the relationship between researchers and Cultural Heritage artefacts, deeply affecting their analysis and representation. In this evolutive framework, may orthogonal projections still play an effective role in the study of buildings, or are they can be entirely replaced by 3D virtual models? May these firsts be compared with the communication powerful shown in the field of Augmented Reality? Starting from a critical review on the concepts of "representation" and "complexity", the article aims to provide a possible answer to these questions, through the description of some case studies characterized by a similar spatial and functional complexity.

 Peer-review under the responsibility of Giorgio Verdiani, Alessandro Brodini, Francesco Valerio Collotti *Keywords:* Complex architecture; Functional representation; Data communication; Drawings; Space interaction; Monge's projections; Virtual 3D model; Augmented Reality

## 1. Introduction

The representation issue of complex architectural shapes is a subject as much discussed as it is current and central within the path of knowledge and communication of Cultural Heritage. Over the last twenty years, the appearance and increasingly massive use of three-dimensional acquisition systems on the one hand and 3D modelling and virtual representation platforms on the other has made it possible to digitally translate complex architectural systems, suggesting increasingly realistic virtual representations. This latter leads to a double reality, traced along the path of representation, which tends to assume the virtual worlds as a "passage" and not the end of CH knowledge process. On the one hand the extended application of the double projections to represent architecture seems to be a prerequisite in many academic and non-academic contexts, showing an easy and understandable system accessible at different levels of users and cultures, thanks to its expressive potential combined with paper-based transmission. On the other hand, the visualization of 3D models through augmented reality defines a very interesting communication channel, an increasingly advanced tool for visualization and analysis that can bring back on paper some of the potential representative of the 3D model.
The consolidated use of projections for the representation of existing buildings or projects stuffs is mainly due to the easy generation of manual or digital drawings by anyone who owns and knows how to use the language of architectural representation, which define also the reading instrument of the final output. Alongside this undoubted advantage, orthogonal projections show the well-known limit of not being able to "solve" the visualization of complex distribution systems, unless proposing a very large number of drawings, a very time-consuming activity. This is one of the main bottlenecks of projective geometry applied to orthogonal projection, leading to a lack of 3D data and a strong limitation in spatial reading of articulated system.

Besides, augmented reality, in its different declinations and applications, allows a more immediate and complete experience, communicative and not necessarily mediated by a specific architectural vocabulary, then accessible to a wider audience. The possibility of preserving the potential of three-dimensional spatial representation allows to better understand the volumes, materials and interrelations between architecture and context. But the computer skills, needed to produce topologically correct 3D models for simulations at different levels, inevitably get away those who are responsible for creating and transmitting the digital content.

How these two expression instruments can coexist, if they are apparently at the antipodes from the historical and cultural point of view, as well as their process of construction and dissemination? Are they able to provide different useful information individually, contributing both to the knowledge of the Cultural Heritage, or do they remain antagonistic with a difficult coexistence?

The article tries to give an answer to this question through a critical comparison of different experiences conducted in recent years[1]. On the one hand, a particularly complex case study will be presented from a formal and distributive point of view, trying to suggest a possible solution that allows to go beyond the current limits of orthogonal projective geometry. On the other hand, two case studies of augmented reality applied to the visualization of Cultural Heritage will be discussed, showing their different potentialities and limits. At the end of the contribution, a critical conclusion on the role of these representation systems and their possible integration will be presented.

## 2. Complexity of representation

Are the consolidated methods of orthogonal projections, framed in the digital representation field, able to support at the same time the project and communication activities about Cultural Heritage? Besides, is it also necessary to use 3D models, providing more articulated and complete information for reading complex realities? In order to answer these questions, it may be appropriate to suggest some pro and cons of these representation methodologies after twenty years the introduction of the firsts digital survey systems, as suggested by Addison

[1] The article shows the results of case studies shared and discussed in recent years, while in the drafting of the article the attribution is as follows: M.R. wrote paragraphs 2-3-4-5, L.C. paragraphs 1-6.

and Gaiani (2000), after fifteen years of structured researches in the field of digital representation, reported in Bianchini (2003) for restoration application and in Fallavolita and Salvatore (2012) for modelling aspects, and 10 years after the descriptive geometry revolution, presented in Migliari (2009).

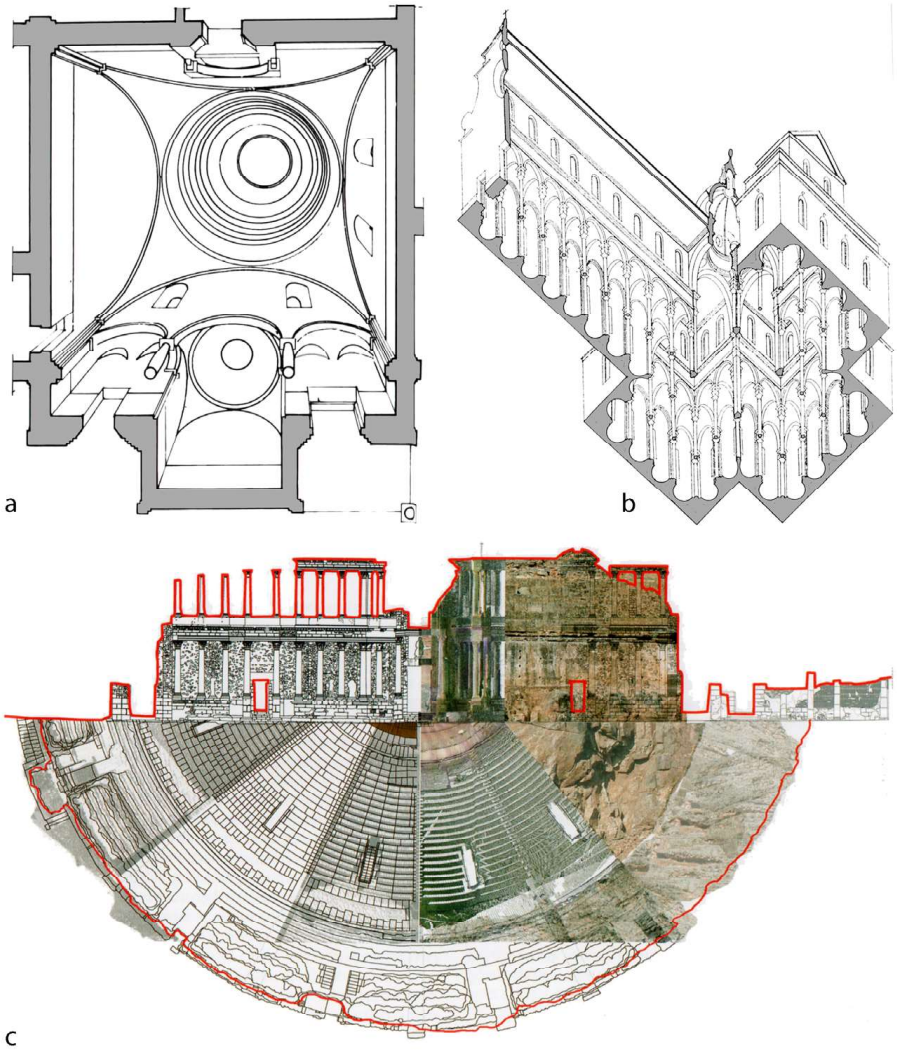


Fig. 1. Examples orthogonal projections with superimposed additional information: a) perspective plan of the Baptistery of Padua published in Battini (1989); b) Axonometry of the Holy Spirit published in Battini (1989); c) orthogonal views and integrated sections with clouds of coloured points or images of the Theatre of Merida, published in Bianchini (2013).

Monge's representations, framed within this critical-evolutionary process, support the entire process of CH knowledge, from its first cognitive step to the architecture restitution, from the system analysis to the project drawings. The initial knowledge is based on architectural survey, a system of complex operations with the precise aim to reach a dimensional, formal, material, structural, historical information on scientific bases about the artefact, carried out through the integration of different survey techniques and instruments.

This step allows to start a basic critical reading, analysis and interpretation for the enhancement, re-functionalization and restoration of existing building. In the CH field the communication must supply a precise documentation in order to transfer the multiple values of a monument in a unique and unequivocal manner. This knowledge path cannot be separated from a first important direct approach to the artefact, during which the operator is forced to observe it unmediated, grasping its spatiality, articulation, formal material and structural characteristics. They are translated into quick hand drawings drawn up mostly in orthogonal projections, creating the first graphic model useful for a correct representation and communication of reality. This graphic translation

obliges to a first level of selective simplification of the reality, defining a reciprocity relation between the real space and its relative representation.

The graphic models, obtained through an iterative refinement process based on continuous validation with real and acquired data, are translated into architecture plans, sections and elevations. These are abstract models, referring to a dissociated representation of the building obtained by a perpendicular projected on different planes. Plans and sections are representations of a not visible reality, contained in imaginary secant planes that partially communicate the interior/exterior spaces. The content subdivision process that is carried on during the orthogonal projection drawing, with the elevation's exception, inevitably leads to a lack of information, which can be integrated only in part through the insertion of integrative data beyond the section plan (Fig. 1).

The "subjectivity" and "discretization" characteristics, typical of Monge's projections and strongly related to the designer's graphic sensitivity and cultural education, assume a key role in the correct definition of these representations. If, on the one hand, a degree of subjectivity exists, on the other hand these representations are standardised graphic models, transmitting univocally objective information related to the space complexity. That's the reason why 2D drawings are still the most used representation tool in the executive project phase, being a clear and uninterpretable communication tool.

Although each orthogonal projection is in perfect correlation with the others, the spatial understanding of the building through this type of representation leads to an important effort depending on the reader skills. In fact, these representations should be a synthetic and codified result of the designer's cognitive and critical path, so the communication is not so immediate for people who has not the same architectural and graphic vocabulary as well as the ability to relate abstract to real environment.

The orthogonal projections define the framework for the generation of 3D models, from which new orthogonal, axonometric or perspective projections can be extracted, according to the most varied expressive languages for communicative purposes. The mediation role assigned to the virtual 3D model between different 2D representations must be carefully considered respect to the model's purpose and the application context. In fact, the virtual model represents an interactive instrument for representing a simplified reality, whose construction requires a cognitive completeness of the whole analysed building. Therefore, once these data have been collected, the model can be reconstructed, extracting additional vertical or horizontal sections.

The automatic definition of these latter represents a useful instrument to integrate the model analysis in an interactive way, but it can lead to the construction of poor representations, not based on these critical awareness and graphic regulations necessary for a univocal reading, according to the scale of the representation. This last aspect requires a critical review also from the didactic point of view, in which it is more and more evident and verifiable an intellectual laziness that leads to generate first the 3D model, extracting from it the 2D drawings.

Observing the decreasing habit in manual geometric construction, amplified using digital representation systems, the automatic extraction of axonometric and perspective views from the 3D model is particularly useful, with a clear predominance of the latter for their similarity to the perceptual reality and their communicative impact. This ability certainly fills in and replaces a practice, traditionally consolidated in the process of CH analysis and representation, based on the definition of very elaborate manual drawings in axonometric or perspective projection, able to highlight the complexity of the analysed system.

The 3D model is the only information system able to merge in an organized way the complex set of hierarchical information contained in a real architecture (Fig. 2).

Besides, the lack of standardized processes about 3D construction and geometric representation, often related to the platform used and the experience of the individual designer, leads to a considerable complexity in the access, use and interaction of these models.

In the last five years the increase in the Augmented Reality (AR) applications has clearly simplified the interaction with virtual 3D models through direct human gestures, overcoming many of the fruition limits due to "standard" 3D interaction. The possibility to visualize some parts or the whole 3D models with simple devices greatly amplifies its communicative capacity and accessibility, as described in Sdegno (2018). There are still some bottlenecks related to the generation and interactive simulation of models in the AR world, highlighted

also in Russo (2019), but there are several experiments aimed at overcoming these limits, progressively refining a valuable tool for CH reading, use and understanding.

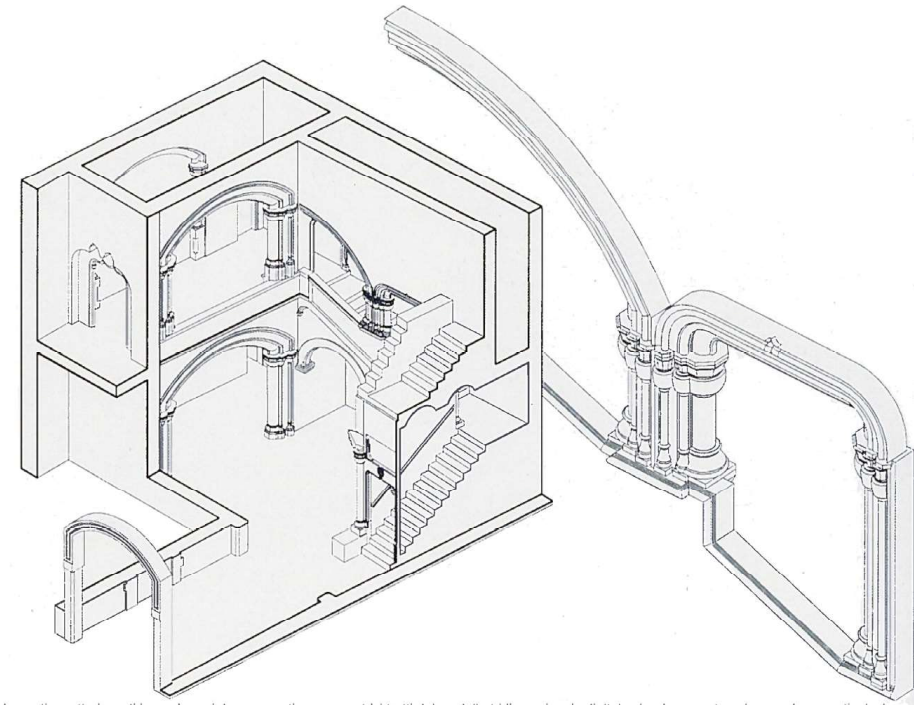

Fig. 2. In the image two axonometric splits taken from the three-dimensional model to show the complex spatial articulation of Palazzo Marzano in Carinola, 3D model and drawings by Francesca Tomassi, published in Cundari and Carnevali (2002).

## 3. Representation of complexity

A critical evaluation about instruments and methods for CH representation may appear too generic or not useful if the subjects analysed are not specifically expressed. For this, it's important to specify the meaning of "representation of complex Cultural Heritage" in this paper.

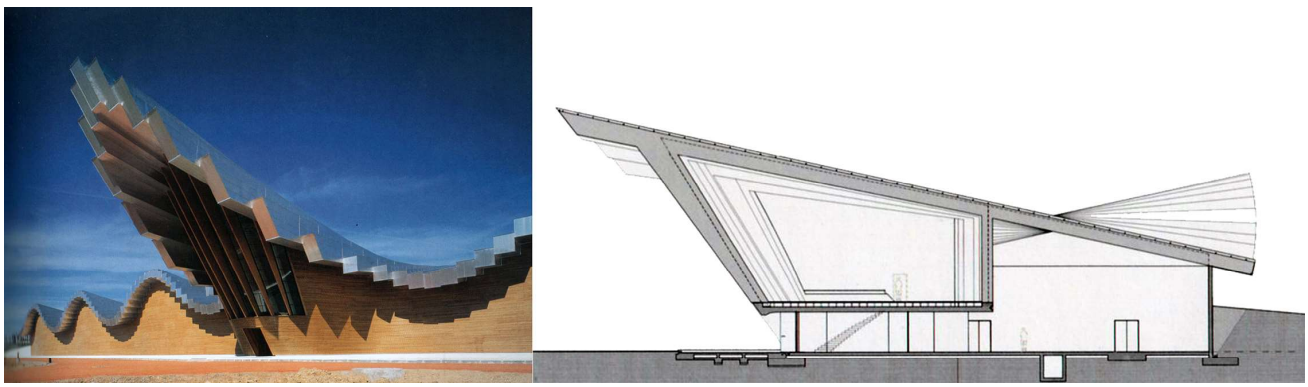

Fig. 3. In the example, the photograph is a section of Santiago Calatrava's Ysios Winery. The image shows how the section contains only the geometric information of a small portion of the real model that changes in space, published in Jodidio (2005).

The concept of complexity related to an architectural artefact generically may indicate a system decomposable into a set of indivisible portions which can present again complex characteristics, defining an articulated framework of reciprocal relations, not exclusively linear and static ones. This general definition does not consider the scale factor of an element, since it is well known that in the CH field a

small wall fragment may be considered equally complex as an urban context, depending on the component's identification and the scale of analysis.

In this research the CH complexity concerns with the network of spatial relations that can be expressed inside the monument, from the articulation of internal connections to the relationship between inside and outside spaces, up to the association between each space, the global building, and the system functionality. In this sense the attention is focused on some "families", well-aware about the presence of many singularities which cannot be assigned to precise typology. Moreover, dealing with a distributive-functional complexity, there is a close correlation between the scale factor and the level of complexity, affirming that a large size building often presents a higher level of distributive complexity.

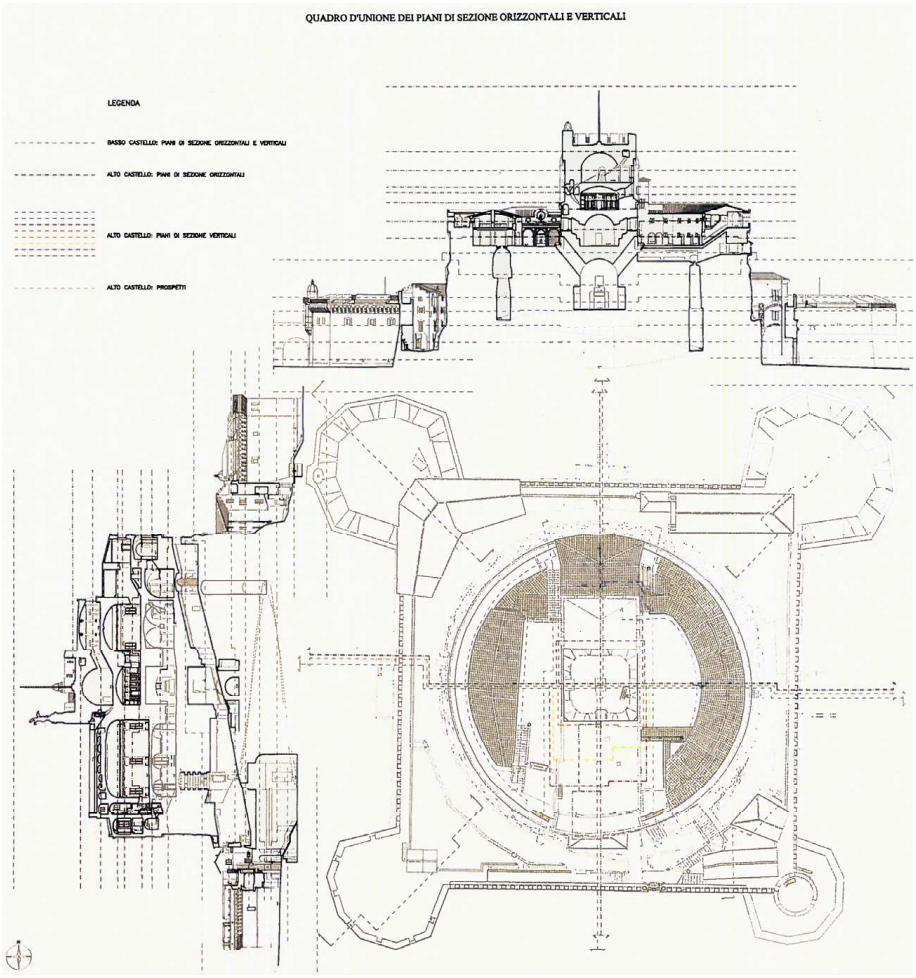


Fig. 4. Framework of union of the restitution project of Castel Sant'Angelo published in Cundari (2000).

The CH spatial complexity should not be confused with other complexities, such as geometric or material ones, more related to the characteristics of the artefact "skin". Besides, the boundary between these two different aspects may be very thin, since there's often a convergence of formal, spatial and functional complexity in Cultural Heritage examples. On the contrary, in modern and contemporary architecture the repetitiveness of technological-structural elements often leads to a conscious dissociation of these different features, proposing on the one hand geometrically simple but spatially complex systems rather than geometrically complex but spatially simple systems (Fig. 3).

A first critical consideration on the complex CH representation concerns the relationship between the actual survey methodologies and the process of graphic restitution.

The increasingly consolidated use of active and passive systems has certainly introduced a more in-depth level of knowledge of the architectural artefact, at the same time modifying both the relationship between the real object, the researcher and the restitution methods. If a precise and progressive knowledge of the direct survey is based on an "additive" data acquisition from the plane to the space, on the contrary a dense cloud of points already contains all the useful information for the restitution of the entire system, allowing to directly transformation to 3D model in space.

As far as the orthographic representation of complex distribution systems is concerned, it is necessary to achieve an important number of sections to allow an enough documentation and visualization of the building, using different scales of representation.

The discretization of a complex building description through a limited series of horizontal and vertical sections leads on the one hand to the hierarchical selection of significant elements, presenting in the meanwhile "information gaps" where reality is not represented. Besides, the production of many graphic representations is an activity that preserves the important process of cognitive, progressive and codified discretization, but it requires a great effort in terms of man/time compared to an unexpected communication result (Fig. 4).

This bottleneck in representation of complexity can be partially solved using 3D models, able to include and relate all the components of an architectural organism. The capability to be understood immediately, intuitively and interactively through human-vision representations, leads to be considered the most complete instrument in the representation of complex CH. The higher communicative impact respect to Monge's projections derives from the overcoming of an abstract and predetermined vision system. On the other hand, the construction and fruition of 3D models are still weak points, considering the required high level of specialization and the use of not easily accessible platforms for a wide audience. From the fruition point of view, the advent of AR has allowed a great step forward, democratising the use of 3D models through common and easier accessible platforms and systems. As follows some case studies are presented, quite similar from a spatial and functional point of views, on which different paths of representation have been experimented, in order to understand the advantages and limitations of each methodology according to its purpose.

## 4. Three case studies

The first case study, Delizia del Verginese, belongs to the suburban villa typology present in the Ferrara countryside, whose genesis is part of the complex system of suburban villas built by the Estensi Family during the Renaissance period, as reported in D'anna et al. (1984), Dosi (1998), Marchesi (2011). The origins of the building can be dated back to 1481, but it is only after 1533 when ownership is transferred to Alfonso I d'Este that the various architectural expansions begin, leading in the early 1600s to an admirable example of a building with a Renaissance garden. The main architectural transformations are commonly attributed to Girolamo da Carpi. Passing through some of the main noble Families of the time, the villa and the garden are preserved until 1932, when a decline start damaging both the building and the garden. Some important structural interventions in the 90s and the garden redevelopment in 2006 allow to recover the original Renaissance aspect (Fig. 5a).

The second case study, San Sebastiano Gate, is one of the main and best-preserved gates of Rome, located at the beginning of Via Appia. Its foundation date is estimated between 271 and 279 A.D. under the power of Emperor Aurelian. More details are in Giovenale (1931), Staccioli and Liverani (1970), Mancini (2001). The millenary history of the building can ideally be divided into seven periods, marked by relative external and internal transformations, as described by D'Ippolito (2017). The first three phases, concentrated in the first two hundred years, concern the transformation of the towers and their progressive raising, the closing of an archway, the construction of a counter-door with walls arranged in pincer form to increase controls and security at the entrance, the insertion of quadrangular ramparts as stiffening following some important seismic events, with the progressive replacement of the floors and the insertion of internal walls.

The fourth period embraces the medieval and modern age, with some reinforcement works, a raising of the two towers and several decorative enrichments. In the following fifth and sixth period, the gate does not present any evident external transformations, while important internal distributive changes are made due to the function changes, from the residence of people devoted to control entrance goods to the private residence of the Fascist

hierarch Ettore Muti, until to the Museum of the Walls. The last period, which arrives at its current state, begins following some works during the Jubilee, aimed at improving the accessibility of the Door. The Door is now in a controlled state of conservation, still housing the Museum of the Walls. From the outside it is possible to observe the monumentality of the work, which does not reflect the complex internal articulation (Fig. 5b).

The last case study is Palazzina Girevole, a building designed by Pier Luigi Nervi in the 1930s, which was never realized. Many information about the project and the historical context can be found in Nervi (1955), Milelli (1983), Nervi (2014), Antonucci (2014). The building, presented in a first version with a clear futuristic imprint and in a second version with a more conventional and rigorous structuralist approach, is defined by a cylindrical base and central core. The shape and dimensions of the house make it possible to create a double order of rooms, distribution and services, from which a design dynamism typical of the rotating architectural element can be seen. The structural scheme of the floors and elevations of the upper level consists of a series of reinforced concrete radial partitions connecting the two concentric cylinders. The internal one supports and connects the entire structure to the base, while the external one acts as a connection between the partitions and as a curtain wall. Looking at them frontally, the radial partitions are shaped like rectangular trapeziums with an oblique side corresponding to the intrados of the floor of the first level; the inclination of the floor characterizes the volume of the structure for the overhang of the continuous balcony (Fig. 5c).

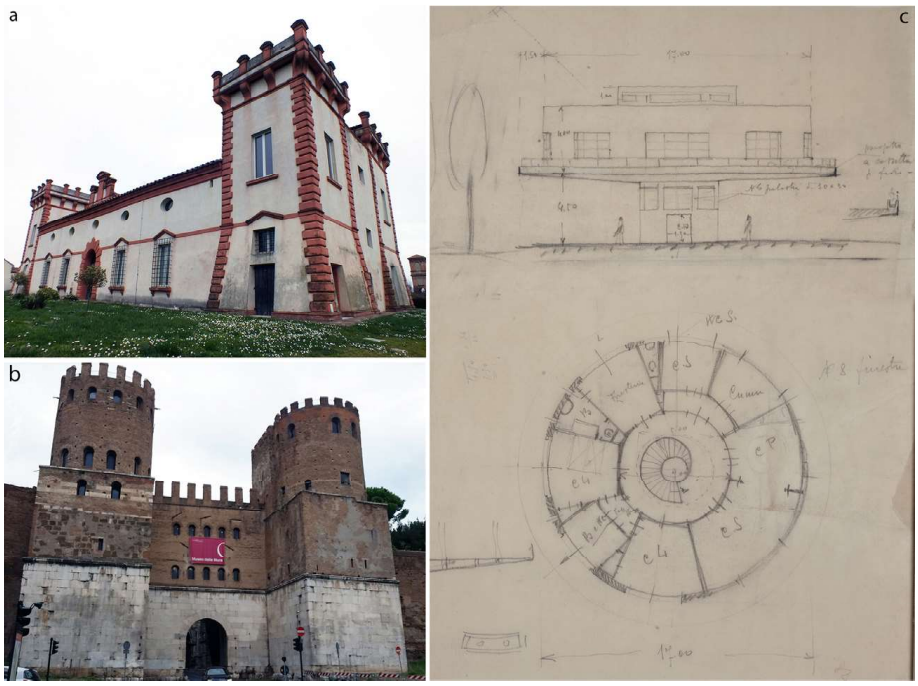


Fig. 5. Images related to the real three case studies: a) Palazzo del Verginese; b) San Sebastiano Gate; c) drawing of Palazzina Girevole.

## 5. Data acquisition and elaboration

The Delizia del Verginese was studied in 2018 through an extensive multi-scale survey campaign, planning a cognitive and interpretative analysis of both the building and the garden based on the geometric information acquired on a territorial and architectural scale. The integration of active and passive methods from the ground for the architectural survey with passive methods with RPAS at a territorial scale has allowed to acquire a complete geometric information of the entire Villa. More details on the complete survey and analysis process are reported in Russo (2018).

The data collected allowed to represent plans, elevations and sections of the building, through a process of analysis and reading in relation to its transformation over time, highlighting the relationship between the external and internal spaces. The orthogonal sections and facades drawings have allowed to create a virtual

3D reconstruction, suppling a usable model to promote the CH communication, showing this architectural asset off the main tourist routes (Fig. 6a). To achieve this last goal, a process of transformation of the existing parametric model into a digital data suitable for AR visualization has been carried on, facing different bottlenecks referred to 3D surface construction and transformation, as described in Russo et al. (2019). The result obtained can relate, through a simple fruition, the 2D information of the building and the context with the 3D model (Fig. 7a).

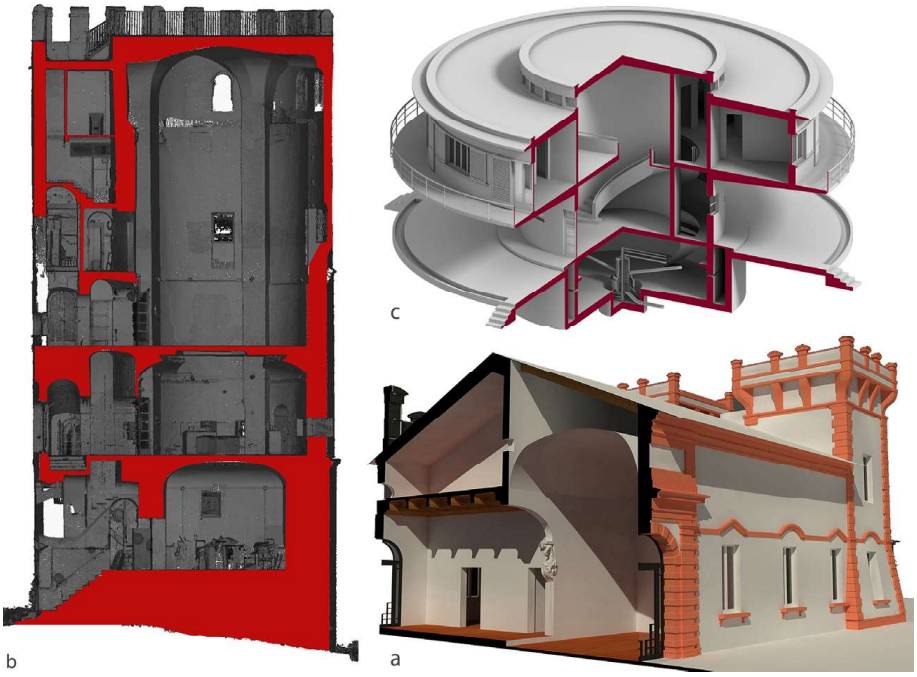


Fig. 6. a) Vertical prospective section of Palazzo del Verginese 3D model; b) Range-based point cloud and superimposed vertical section of San Sebastiano Gate; c) Double vertical section in axonometric view of Palazzina Girevole 3D model (rendering by S. Menconero).

The San Sebastiano Gate was the subject of an extended survey in 2019 by a 3D laser scanning campaign, described in Carnevali et al. (2020). The survey allowed the geometric acquisition of all the exterior and interior parts of the building. In this case the survey was planned to answer the concrete need of the Capitoline Superintendence to have some plans and sections passing through specific points of the monument, in order to produce a supporting documentation for a design intervention. This request defines one of the most interesting aspects of the case study analysis, because the complexity and articulation of the spaces made it extremely difficult to use traditional direct survey methods for the study of volumes and the production of detailed sections. The complex and dense cloud of points generated by more than 300 scans served as starting basis for the extraction of specific orthogonal sections passing through the most complex points, characterized by vertical connections (Fig. 6b). The effort in representing such an articulated system through a limited sequence of vertical and horizontal sections has showed on the one hand the complexity in defining the correct number of planes useful for the description of the monument, on the other hand the evident impossibility to communicate clearly and immediately through this kind of representation method the complex articulation of the vertical connections (Fig. 7b).

In the case of Palazzina Girevole the topic of existing drawing interpretation was addressed, aimed at the construction of a hypothetical 3D model. Starting from a first graphic fragmentation of 2D drawings, as described in Barlozzini et al. (2018), the different systems that contribute to the definition of the architectural building have been analysed individually, reconstructing homogeneous project representations. Then the 3D model was created through parametric modelling, filling in critically those "information gaps" in the drawing representations. Finally, the 3D model was used both as a tool for the representation of the project, through the generation of predetermined views and its AR communication.

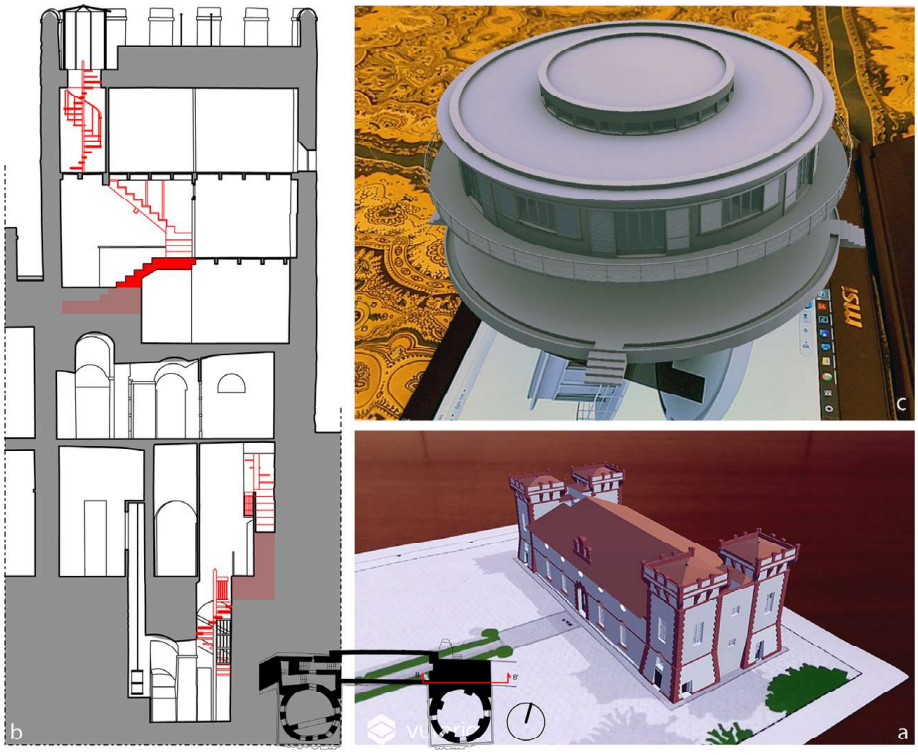


Fig. 7. a) AR visualization of Palazzo del Verginese 3D model; b) Vertical section of San Sebastiano Gate with red vertical connection and transparent red colour for the hidden elements; c) AR visualization of Palazzina Girevole 3D model.

Being a project never realized, renderings have assumed an important role in understanding the spatial relationships and the compositional issues (Fig. 6c). Experimentation through AR, on the other hand, made it possible to easily show the 3D virtual reconstruction building, introducing the functional aspect through the rotation of the artefact (Fig. 7c). The integration between 2D and 3D representations have highlighted the complex relationships existing between the load-bearing structure, the mechanical rotation system of the building, the technical systems, and the architectural details, acting as a powerful tool for project communication.

## 6. Conclusions

In the recent decades, the methods for CH representation have considerably changed, due to the presence of different instruments for digital acquisition and modelling, introducing a new cognitive approach to the architectural artefact and its relative restitution.

In this panorama, representations in orthogonal Monge's projections still have a fundamental role both for those who create and read them. For the firsts they represent an exercise of understanding and synthesis of the building organism, for the second they are an example of clear and uninterpretable communication of architecture. Their principal limits lye in being abstract and incomplete representations, requiring the ability to read the drawing and relate it to reality.

While these representation methods support the whole path of CH analysis, the 3D modelling is referred only to the last step, for the necessary global knowledge of the physical object combined with a high specialization of its creator. The 3D virtual model thus becomes the result of a convergence of external skills and CH knowledge, which are consistent and organized within a virtual hierarchical system, which in turn allows to generate endless new representations to support the artefact understanding. The current lack of rules that regulate 3D representation combined with the complexity of their use, often mediated by specialized digital platforms, leads to a preference for orthogonal projections in the representation of executive drawings, which can present a data limitation but clearer and immediately readable representation.

Through the case studies shown in the article, 3D models mixed with AR represent the only chance to describe and communicate an artefact in its complexity, going beyond the limits generated by the distributive-functional complexity of spaces.

The possibility to easily use these contents and linking them to the context can boost the use of 3D models in the process of CH representation and analysis. Currently, both the methods of representation based on orthographic projections and 3D models through AR are not alternatives, since each one has its own potential and limits. Their balanced use within the whole process of CH representation allows to face the problems given by the complexity of the system, providing the best answers for the understanding of the architectural element.

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