The Modelization of Built Heritage. Comparing BIM Processes for Architectural Types

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Abstract

The study of an historical architecture and the heterogeneous set of information linked to has important repercussions in many areas: from documentation, to the planning of interventions, to the management of cultural heritage. The goal of total data integration is now pursued by the BIM processes; their application for the historical buildings involves methodological and technical implications both in the survey field and in the representation, linking the modeling operations to the massive data acquisition. These activities are very complex because of the use of libraries of standardized elements, in conflict with the uniqueness and complexity of the historical form. Two different case studies for eras and construction techniques are analyzed. For both the standardization process of the building process is evident, such as the presence of serial elements with easily recognizable geometries, handcrafted in the first case, industrially in the second. The parametric approach to the modeling describes, through creation of nidified elements with hierarchical structure, the logical process of decomposing the form.

Keywords: HBIM, architectural typo, standard, modeling, database.

Introduction

The evolution of digital technologies for the representation of architecture has allowed the achievement of objectives previously unthinkable for the survey, knowledge and communication of the built heritage. BIM processes –Building Information Modeling– promise new scenarios for storing and managing large amounts of information for the knowledge of Cultural Heritage [Messaoudia, Halin, De Luca 2018] by integrating 3D modeling and parametric tools.
This research aims to show the potentialities and the critical issues related to the introduction of BIM processes in the field of knowledge, transformation and management of the built heritage. These themes are closely related to the technological development of the last 20 years, which has brought an important change in acquisition and sharing knowledge. This is due to the almost exclusively digital methods used to build models as complete, heterogeneous, implementable and sharable databases. Furthermore, the increasing need for preventive and conservative interventions on existing artifacts imposes to have methods and tools to collect, store, compare, share and manage information on their past, present and future status. This is the context of the BIM (Building Information Modeling) and HBIM (Heritage Building Information Modeling) processes. The former, whose fundamental characteristic lies in the standardization of construction and architectural components, are now a fundamental reference for new buildings. However, it is still not completely adequate for for historical buildings, in which consist the majority of

our architectural heritage. Obviously, the construction of architecture requires the production of construction elements in favor of a greater economy and a simplification of processes and operations. BIM models for historical heritage, and therefore the parameterization of realities characterized by infinite possible variations, presents considerable degrees of complexity.
Furthermore, it's not always obvious the geometrical knowledge of space. The necessity to have systematic readings of historical buildings is closely linked to identifying an information system defined on the basis of macro-elements, to which data can be associated capable of documenting the specific material, historical and technological features. Therefore, it is necessary to keep in mind not only the link between the documentation of the history of the buildings and the changes that over time have undergone, but also the knowledge of the current state, inextricably linked to surveying and survey activities [Chiabrando, Sammartano, Spanò 2016; Costa, Madrazo 2015]. To fixed the model construction process, this research highlightis the issue on the themes of knowledge, modeling and interaction between heterogeneous data (3D/2D models, numerical models, mesh models, photographic images, information bibliographic etc.). This interaction arises from the overlap between parametric models and survey data, which must necessarily be referred to the study and analysis of existing buildings. This involves into the construction of 3D informative models starting from the massive acquisition of data and defined on the geometric and semantic level. First of all, the study and analysis of numerical models, allows to break down the historical artifacts into the elements that characterize them. Then, the parametric modeling, implements the metric and geometric characteristics with information that is constituted as a basis for the knowledge of the object analyzed. The overlap between the discrete model (numerical model) and the continuous model (parametric model) allows the reading of the discontinuities that linked with the degradation of the architectural elements, of the design intentions of space and shape management, and, through their comparison, the changes that architecture has undergone over time.
In the complex transition from a numerical model to a geometric one of the real elements, after the necessary preliminary reflections for a conscious approach to the

Fig. 1. Botany Institute at Sapienza University, Rome.

Fig. 2. Camuccini Palace in Cantalupo in Sabina, Rieti.

Fig. 3. Botany Institute, numerical model.

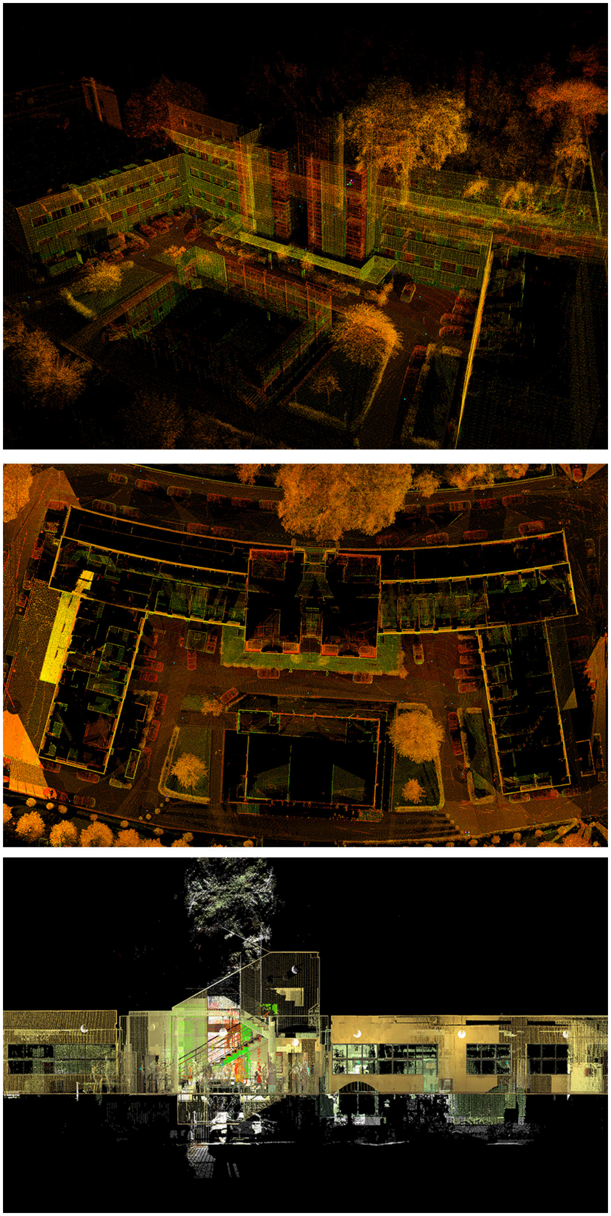


Fig. 4. Camuccini Palace, numerical model.

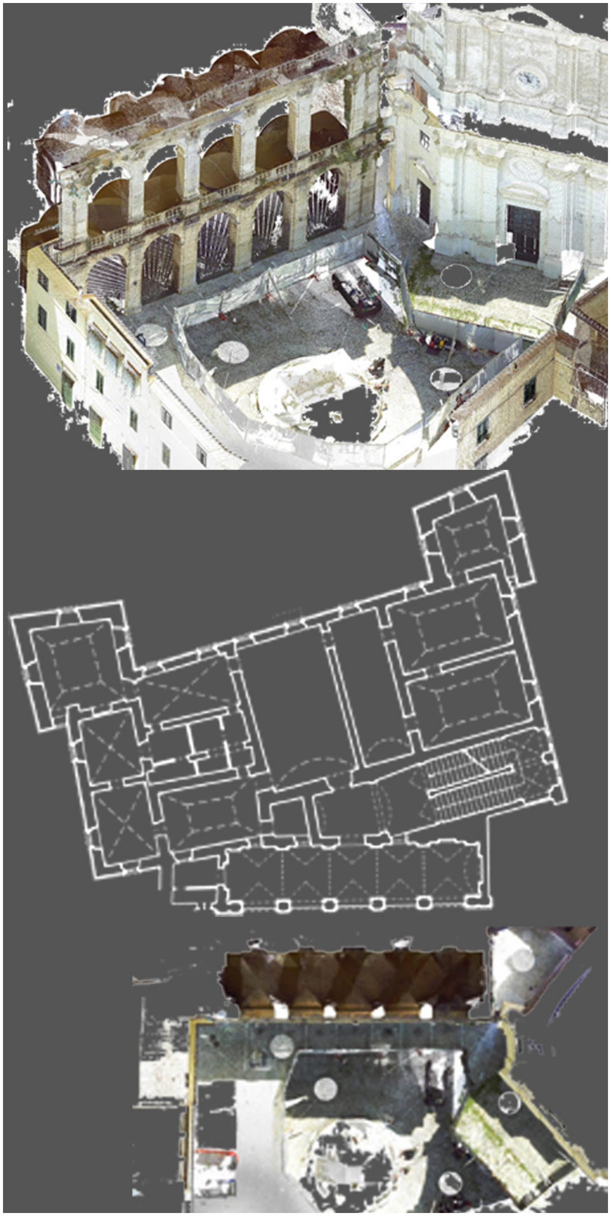
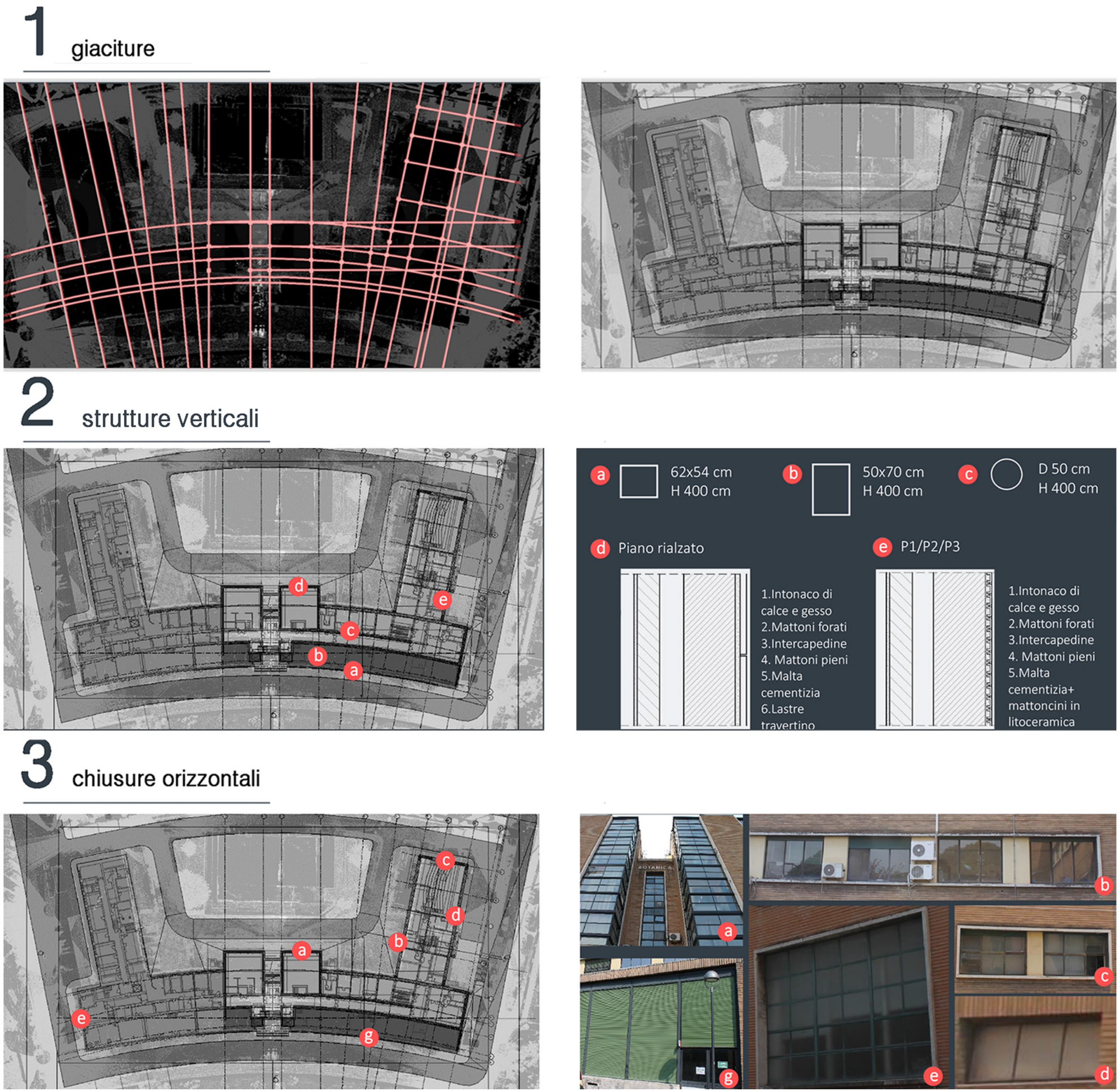


Fig. 5. Model of the Botany Institute. Scomposition and reconstruction of rationalist architecture: the constructive elements.



so-called HBIM, the discussion will focus on two case studies in the field of architectural heritage, representative of different historical periods and emblematic of interesting architectural types.
This theme is still at the center of experimentation by scholars of representation, historians, restorers, and figures involved in the field of cultural heritage. The research aim at outlining an operational protocol linked to the possibilities of managing the built architectural heritage, implementing the possibilities of HBIM in the consolidated integrated survey process [Simeone et al. 2014; Quattrini et al. 2017; Quattrini et al. 2015].
This study compares the process of HBIM by analyzing two case studies: the Institute of Botany at Sapienza university (Rome) and the Palazzo Camuccini in Cantalupo in Sabina (Rieti) (fig. 1, fig. 2). The first is a rationalist building, built between 1932 and 1935, which lends itself well to being studied through BIM processes for its typological, geometric-morphological characteristics, and for the presence of recurring and standardized elements. The second, built between 1566 and 1579, is an example of an intervention on a pre-existing structure: the originally military form of the entire complex was subsequently enriched by a graft on the façade, which is articulated on two levels with a portico and a loggia, designed to make it more suitable for a noble residence [Dal Mas 2015].
The choice of this architectures is not at all accidental. Modern architecture, of which the Institute of Botany is particularly representative, constitutes a substantial part of the set of public buildings in Italy. The orderly composition of regular geometries, the rigor of spatial solutions, the repetition of compositional elements and architectural details, make it particularly suitable for the application of knowledge and modeling methods that characterize HBIM processes. The loggia of Palazzo Camuccini, on the other hand, has its roots in Renaissance treatises, a collection of rules and geometric and proportional codes that express the intellectual activity of the architect of the sixteenth century, proposing typological solutions uprooted from any context.
On the basis of a typological representativeness in which unstable aspects coexist –linked to the uniqueness of the components– and stable aspects –linked to the recognition of the geometric matrix– it is possible to compare the modeling [1] of the elements within HBIM. The parametric approach to modeling for built heritage can be effective because, through the creation of nested elements with a hierarchical structure, it is possible to describe the logical process of decomposition of an architecture. The interaction between the discrete model (the point cloud) representative of the actual state (fig. 3, fig. 4), and the orderly logic of the operations for the construction of the parametric model, records the evolution of the form and the changes that the project originally suffered. The typological elements of the libraries are detailed through the parametric variations, obtained from the survey data, constituting a database of heterogeneous information, necessary for the archiving and transmission of architectural data of the past.

Fig. 6. Model of the Botany Institute. Analysis of the compositional elements.

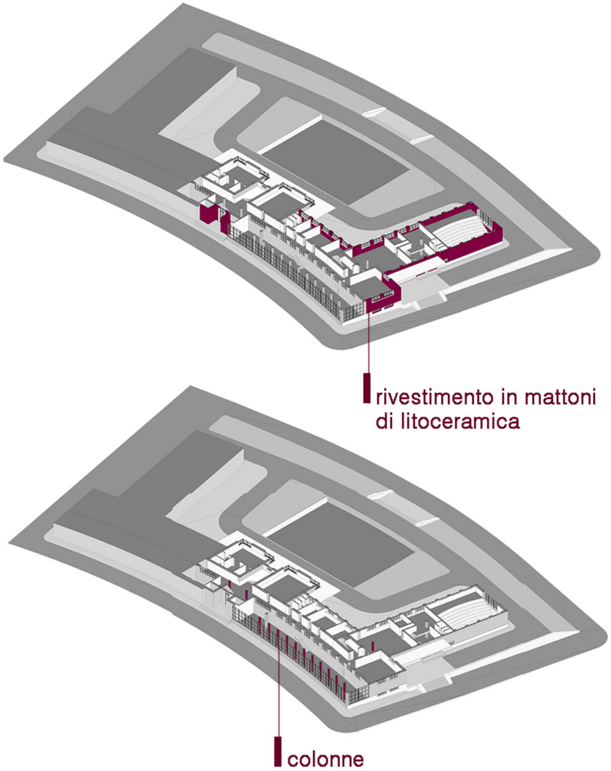
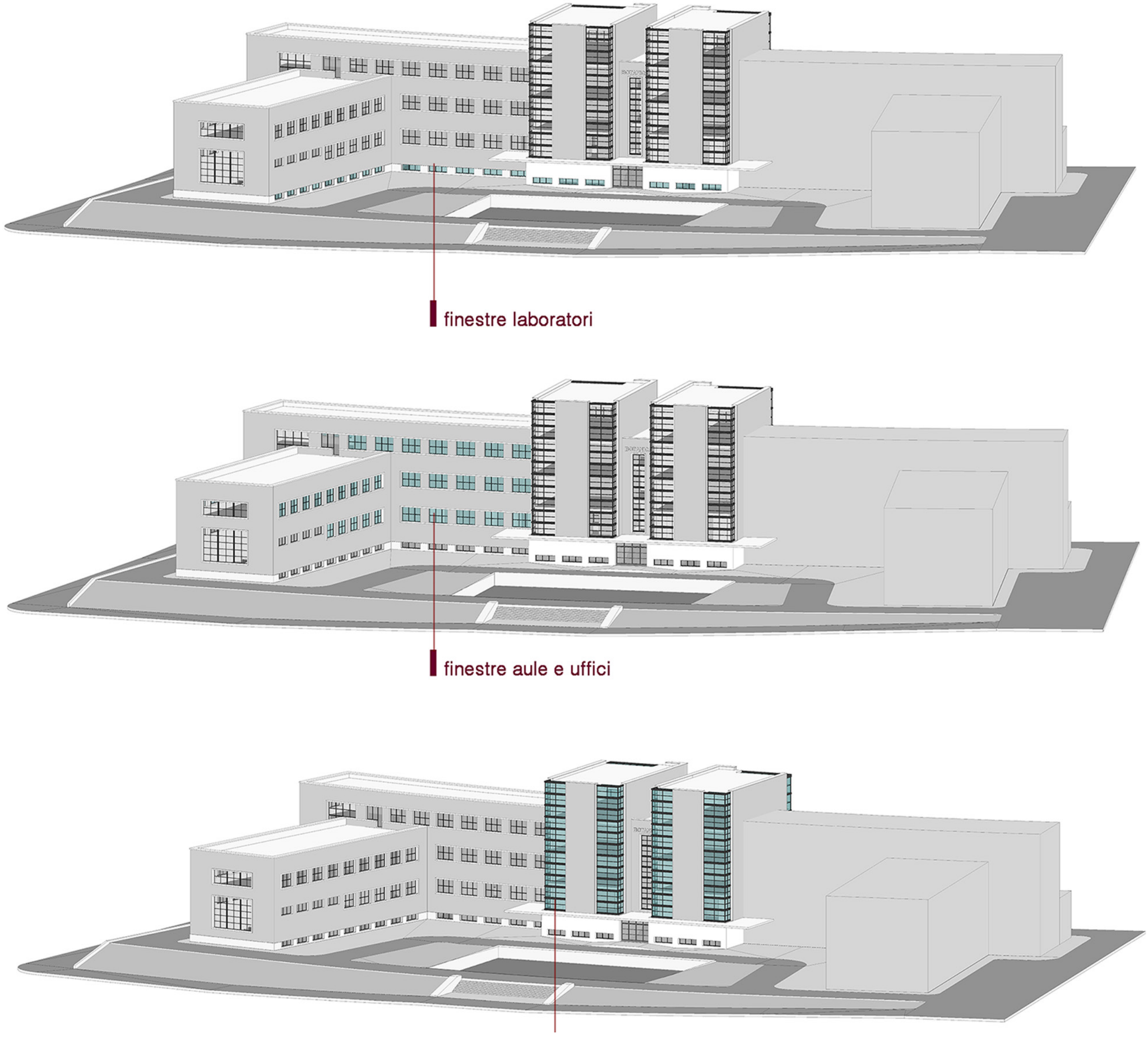


Fig. 7. Model of the Botany Institute. The transparent vertical elements.



The parametrization of rationalist architecture

The modeling of the Botany Institute reach the representation of the constructive equipment, oriented according to the architectural components: structural elements (frames or masonry systems), infills, fixtures, finishes etc. A careful survey of the relevant data has allowed us to extract information on the geometrical and the spatial articulation of the building, identifying the positions, then the bearing elements and the relative structural axes, then the infill walls, the horizontal and vertical closures, openings and connecting elements, external finishing materials, interior cladding, and technological systems. The objective of modeling the different components according to a process that seeks the most complete knowledge has required the use of a methodology that does not proceed from the general to the particular (fig. 5). The issue is related to the knowledge and the recognize of the element not only from the geometrical-morphological point of view, but in its constitution in terms of dimensions, materials, typology and methods of use in the more general context of the project analyzed, highlighting the parallelism between the BIM processes and construction site practices. For these operations all the informative, textual, graphic and photographic material, provided by the Sapienza Technical Office found in the documentation phase, was fundamental, because it describes in detail also the position of plants and ducts, and painting.
The symmetrical structure of the building, its geometric recognizability and the repetition of the elements, represented the starting point in the approach followed. Grids, fixed wires and levels constitute the geometric rules for the elements, so bound by parametric relations. The structure of the model starting from these components therefore involves a discretization and an adjustment of the geometries that define the elements of the project, placing itself in a manner consistent with the state of affairs, documented by the survey. The seriality of the elements, found both on the facades and in the internal solutions, was managed inside the modeler both for the supporting structure, which alternates pillars with different geometries, and for the vertical, opaque and transparent closures, both for the bricks and the travertine slabs that make up the external facings (fig. 6). The starting point for modeling architectural elements is editing operations of the loadable families: walls, internal partitions, inter-floor and roof slabs were built with the aim of achieving the maximum level of detail. The cross-analysis between the survey data and the archive sources made it possible to define some parameters and starting attributes of the digital object, such as the thickness of the walls, the type of support layer, the type of external cladding in slabs of travertine or lithoceramic bricks, and the type of internal plaster coating. The elements with the most particular configuration, such as the wall with the base and the canopy of the raised floor, have been modeled starting from the definition of the profile, traced from the survey data, subsequently extruded. A separate discussion was made for the external cladding and for the transparent closures. The first was structured as a modification of the curtain wall, defined through geometric matrices that regulate the number of elements and the step between the axes that make up a grid. The glass windows of the towers were modeled as curtain walls, while the windows, of which five types were repeated several times within the project, were built through the modification of dimensional parameters of windows and doors associating them to a single type, greatly speeding up the modeling process (fig. 7).
The operations carried out allow to evaluate the process followed, highlighting some considerations. The first concerns the criterion used for the decomposition of the building and the choices made during the modeling phase that clearly reflect the rational logic that characterized the design of the building. The second concerns the actual correspondence between the real object, the numerical model and the parametric one. Although the starting point consists of a highly detailed relief, which highlights the peculiarities of the building in its general appearance and architectural details, the standardization of the elements has prevailed over the differences that can be found between different elements of the same category. The repetition of architectural components shows variations in the order of centimeters, so it was possible to make simplifications, considering these variations linked to the practical installation operations, which are never free from inaccuracies.

The protoparametrization of Renaissance architecture

The second part of this study aims to interpret and restore, in a digital parametric environment, the project logic underlying the Renaissance intervention of the double

Fig. 8. Palazzo Camuccini: from the analysis of the Renaissance treaty to the parametric model.

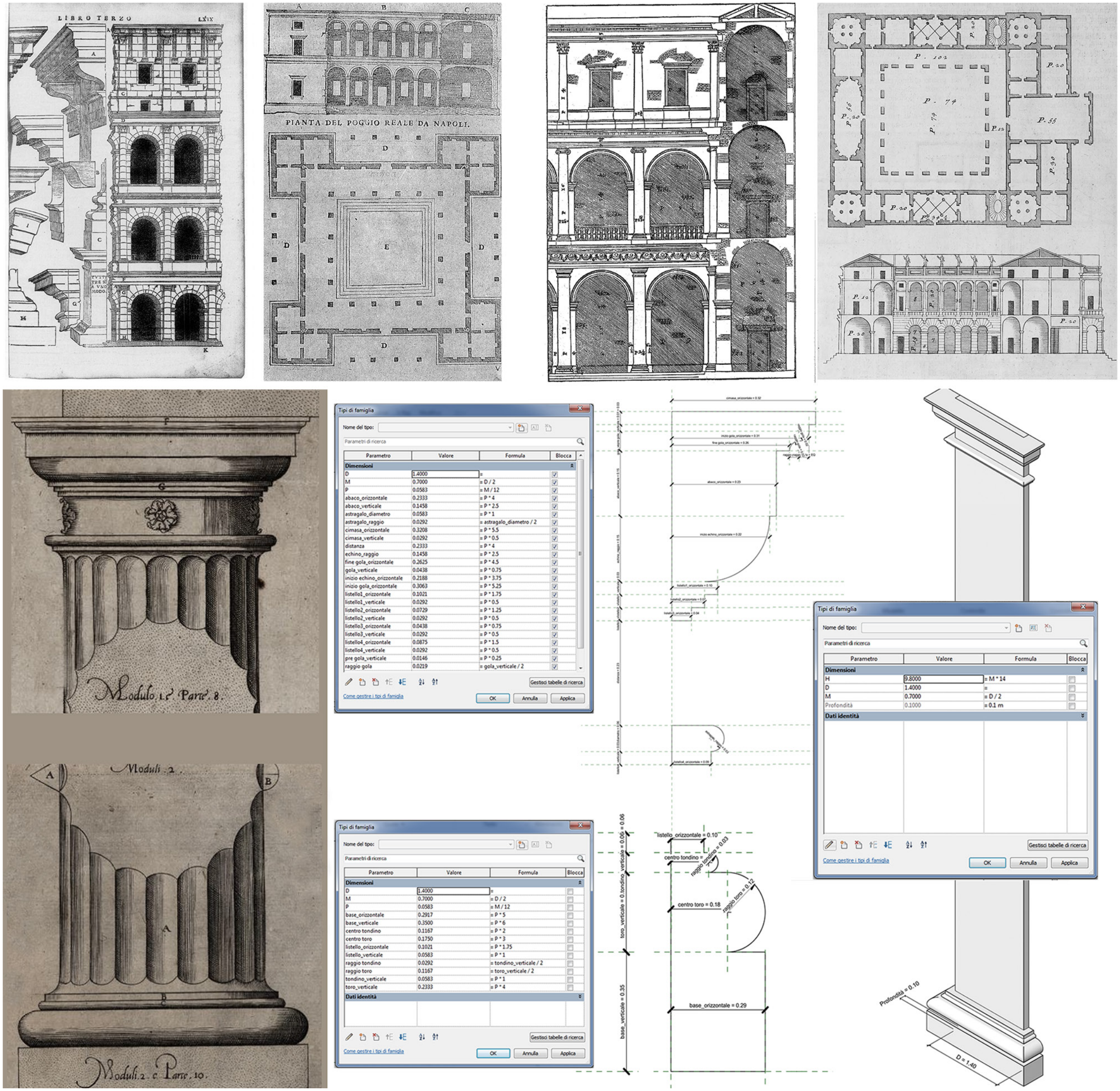
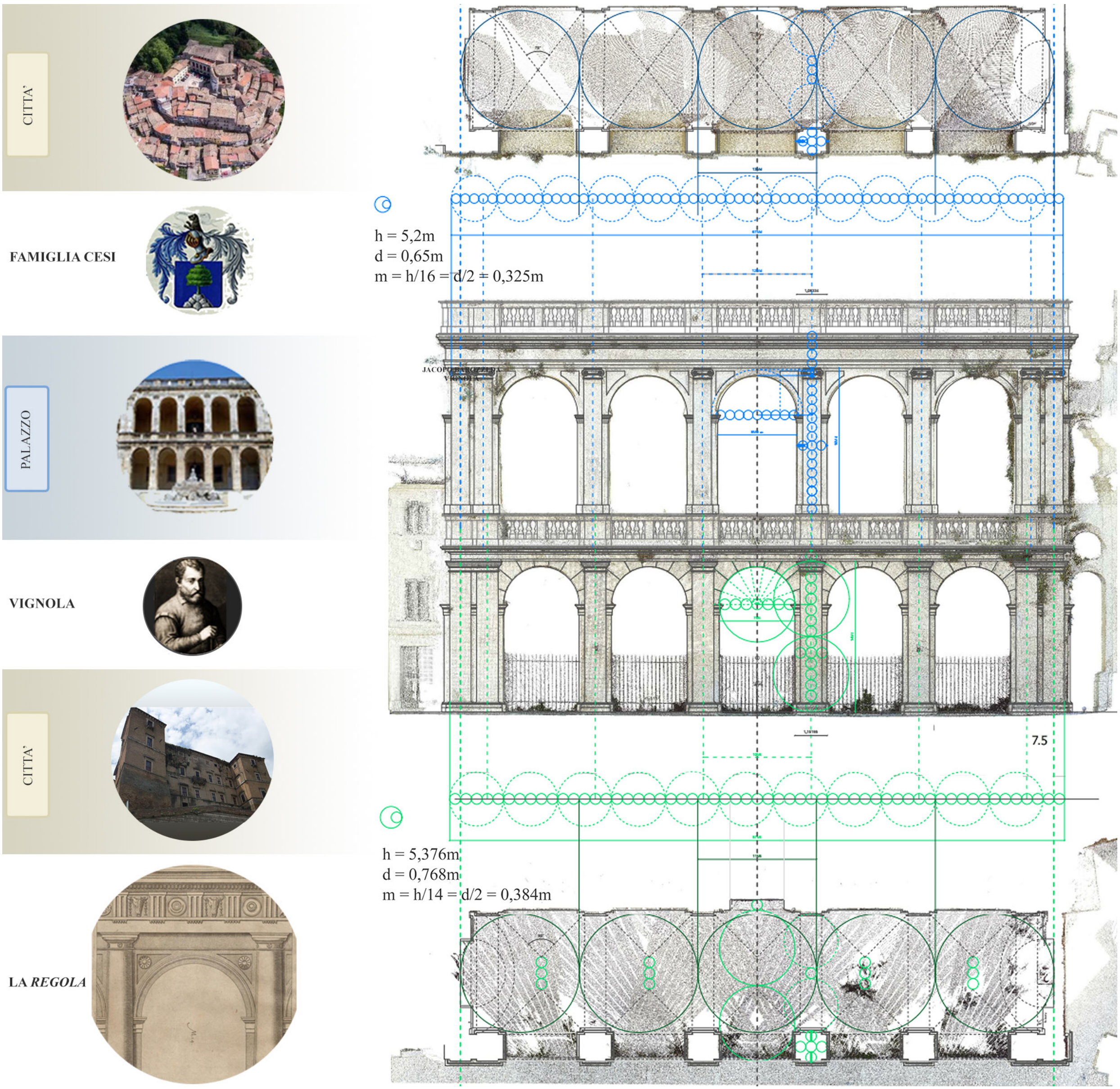


Fig. 9. Palazzo Camuccini: from the analysis of the Renaissance treaty to the parametric model.



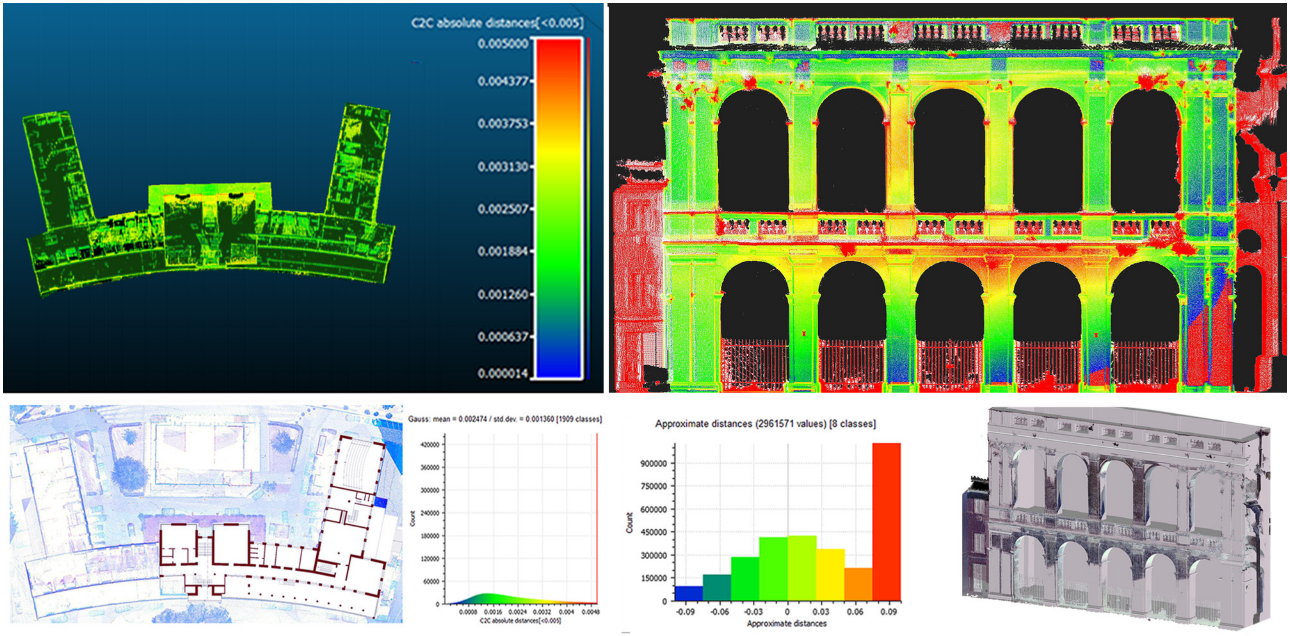
loggia on the pre-existing medieval fortress of Cantalupo in Sabina. The graft, carried out in compliance with the application of compositional rules shared at the time, is modulated according to a real space strongly conditioned by pre-existing buildings. The example considered is particularly representative of the cultural attitude that distinguishes the history of most architectural treatises of the time. Their huge widespread, also due to the invention of printing, began to remove the need for direct experience of architecture to exalt its virtual value, thanks to a great availability of two-dimensional models based on systems of rules. This makes the intellectual activity of the 16th century architect, expressed in terms of graphic models, geometric rules and proportional relationships between the parties, the proto-parametric reference for the construction of the digital model.
Palazzo Camuccini represents the union between the standards contained in the sixteenth century treatises and the specificity of particular solutions, adapting to the constraints imposed by the context and, therefore, separated by a purely typological study independent of the case in question. However, in order to define general and at the same time modular composition rules, it is necessary to follow a theoretical reference model (fig. 8).
The date of the intervention and the geographical position of the building, the wealth of similar examples in the same area, the client and the workers in service, brought together the theoretical model of the sixteenth-century double loggia of the building in question, with that described by Jacopo Barozzi from Vignola in the *Rule of Five Orders of Architecture* [Barozzi 1562]. The choice of Vignola's *Rule* as a theoretical reference in the construction of the parametric model of the loggia is determined in the first place by a 'geographical' reason, linked to the treatiser and the places he frequented in those years: as architect for the Farnese, the Vignola has a consistent following of workers in his employ. Secondly, from a 'temporal' reason linked to the treaty: the years of construction of the case study (1566-1579) are in fact immediately following the year of publication of the treaty (1562), which we can imagine as the expression of a know-how presumably already rooted in the local area.
Furthermore, this type of intervention is to be contextualised in a historical and cultural moment in which the concept of a city, large or small, is reinterpreted in an ancient key, understood as a place for social meeting, political organization and economic planning. This idea of civil life linked to the urban form is found in the will of the first citizens, bishops and nobles to renew the ancient splendor of medieval castles in favor of airy palaces.
Following the construction of the model based on the identified compositional, geometric and proportional rules, the overlap with the numerical model shows how the overall picture appears to be coherent with the Vignola's treatise only in part. By identifying both for the Doric order of the first level and for the ionic order of the second level, the module equal to the semidiameter of the column, it can be seen how, in the construction of the parametric model, the overall height of the building was forcibly reduced proportioning each order with respect to the order that precedes it in the rule (the Doric arcade is proportioned with the rules of the Tuscan order, the level of the Ionic order with those of the Doric order). Instead, the relations between the components of the sculptural apparatuses of the columns follow slavishly the treaty (fig. 9).
The model of Camuccini Palace, therefore, turns out to be representative of an ideal state, or rather of the design idea underlying the construction, and not of the current configuration. However, this model, when compared with the discrete model obtained from the survey operations, allows us to deduce further considerations. The difference between the two models, evaluated with respect to the deviation, in addition to giving information about the metric accuracy of the parametric model, offers the reading of the transformations that the building has undergone over the years (fig. 10).

Conclusions

This study is based on the search for a method based on a general procedure applied to particular cases. Following the recognition of serial and repeatable elements and their rules (geometric, dimensional etc.) it was possible to translate the relations between the parts into a digital parametric logic, valid both cases. The processes followed for the analyzed case studies contribute to the definition of ideal models; however, some substantial differences emerged during the modeling phase. In the case of the Botany Institute, the parameterization within the software used [2] allows the actual configuration of the real elements to be reproposed, designed according to a rational logic that involved mass production. The standardization of the

elements has prevailed over the differences that can be found between different elements of the same category. The repetition of architectural components shows variations about some centimeters, so it was possible to make simplifications considering these variations linked to the practical installation operations, often inaccuracies. This simplification, however, does not correspond to a metric and geometric approximation in the description of the forms, and makes the parametric model coincident with the 'as built'.
In the architectural orders that define the facade of Palazzo Camuccini, it is not possible to find the same concept of standardization that insists on the Botany Institute, starting from the project until its realization. Although it is possible to transfer to the digital model the design intention of the repetition of some architectural components (bases, capitals, moldings), it is necessary to consider that they consists of elements made by craftsmen, and their deformation and changing over time.
The construction of the model then follows the modulating design activity of the standard at the base of the structure of the Renaissance building, which involved repeating the elements while being aware of the peculiar characteristics of each of them. In the first case, therefore, the standardization of the components does not correspond to an approximation in their modeling, while in the second case the operations of geometric simplification were necessary for the construction of the ideal model.
The parametric modeling of architectural heritage components –and their possible variants– offered by a complex information system such as the HBIM, allows an acceleration in the construction of 3D models that must however take into account the architectural quality of each unique element of its kind.

Fig. 10. Botany Institute and Camuccini Palace. Comparison between the numerical model and the parametric model expressed through the standard deviation.



Notes

[1] Activity of construction of the digital model intended not as the sum of three-dimensional objects but as a cognitive process of creation of the forms that constitute it [Marotta, Lo Turco 2014. p. 55].

[2] Revit architecture 2017.

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