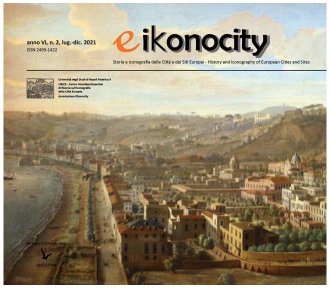

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Enrichment and sharing for historical architectures. A multidisciplinary HBIM approach

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Enrichment and sharing for historical architectures. A multidisciplinary HBIM approach

Giuseppe Antuono, Pierpaolo D'Agostino, Andrea Maglio Università degli Studi di Napoli Federico II

Abstract

This research work, relating to the emblematic Cultural Heritage case of Palazzo Cellamare in Naples (Italy), aims to verify, in a perspective of multidisciplinary interaction, some potentialities of the structuring of an HBIM system, usable through cloud-based sharing environments, useful both for managing extensive knowledge and for identifying possible uses of this system by different categories of users.

Integrazione e condivisione digitali delle architetture storiche. Un approccio multidisciplinare HBIM

Il presente lavoro di ricerca, relativo al caso emblematico di un Bene Culturale come Palazzo Cellamare a Napoli, mira a verificare, in una prospettiva di interazione multidisciplinare, le potenzialità della strutturazione di un sistema HBIM, fruibile attraverso ambienti di condivisione cloud-based, utile sia per la gestione di ampie conoscenze, sia per individuare possibili utilizzi di tale sistema da parte di diverse categorie di utenti.

Keywords: Cultural Heritage, BIM, Palazzo Cellamare.
Beni culturali, BIM, Palazzo Cellamare.

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1 | Introduction

In the current time of digital transition, during which the whole spectrum of the architectural topics focused on the definition of which are the most appropriate technologies to manage information referred to Cultural Heritage (CH), its digitization has long been the main question issue of an international debate about the ability in support its conservation, use and data management for the project intervention. So, several scientific domains are involved in the solution of how to face both the *digitization* and the *digitalization* of architectural artifacts [Garagnani 2019].

If digitizing is intended as the practice of convert something into a digital format – data or documents – speaking of digitalization is much referred to the trend by which a new paradigm states in a specific domain. A semantic difference that becomes significant when offered to topics like the historical and historiographical analysis of architectural artifacts, built up over the years and more often characterized by a morphological complexity, not easy to untangle, that consequently could benefit from new technologies as well as new mental habit. Moreover, we speak of a difference that is constantly driving towards the integration not only of new tools in the scientific investigation, but about the necessity of new methods able to adequately merge with traditional approaches and to enhance the interaction with the heritage.

In that way, the analytical phase of the work is also based on a careful historical research, with the aim of a complete knowledge of the artefact in question. A deep knowledge of the history of the building is an indispensable prerequisite for every action that must be taken and is the basis of the choices to be made regarding preservation and technological and infrastructural

Fig. 1: Framing of the study site. Palazzo Cellamare in its urban context (photo by authors).

adaptation. Today more and more the study of architectural history does not correspond only to a 'neutral' moment of knowledge but involves the recognition of values that can guide every future intervention. This is valid both on a more general level and for specific individual cases. In European cities, and especially in Italian ones, the centuries-old stratification makes this critical work of knowledge and recognition of hierarchies of values absolutely necessary. This analysis operation with the consequent critical judgment cannot fail to compare with the tools offered today for the knowledge of the artefact. Indeed, the conservation of historical architectural heritage today can make use of new tools, such as BIM modelling. With a view to interaction between different disciplinary areas, this study intends to verify some of the potential of Building Information Modeling (BIM) for actions aimed to the protection, the en-

Figs. 2-5: (From left to right) Some illustrative images that describe the architectural qualities of the external fronts: east elevation of Palazzo Cellamare (1); west elevation of the 17th century nucleus (2); east elevation of the 18th century courtyard (3); west view of the 17th century inner courtyard (photos by authors).

hancement and the conservation of the architectural heritage. It acts within the framework of its consolidated declination of Historic Building Information Modeling (HBIM), understood as an extension of BIM equally for the management of physical virtualization and knowledge applied to the architectural artifact. In this sense, BIM not only allows access to a virtual representation of a building in its components, but also can provide the associated information (all its metadata) just to be aware of the future life cycle.

Moreover, at the same time it is useful to establish as an informative container of the stratification, of which the building of historical and architectural value is characterized. It means that if the knowledge of the building conformation traditionally proceeds separately from that of its history, HBIM modelling offers the possibility of integrating these two phases of knowl-

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edge and making them interact. From a methodological point of view, for the architectural history studies this is an important opportunity, because it allows a reading, verification and comparison of the obtained results. By creating a catalogue of parametric elements, for example, it is possible to compare information on each individual architectural detail. This new possibility of dialogue between disciplines must not be seen as a distortion of a consolidated and recognized working methodology, but only as a further possibility to improve the management of information, making it available for a long series of possible applications.
In this context, the final goal of this work consists in the structuring of a system to manage both historical-artistic and historical-architectural information as well as of a morphological nature one and therefore to identify possible uses of this system by several categories of users. The traditional methodologies of investigation of the historical-architectural disciplines and of the representation area thus find an extremely useful field of comparison. The research on published and archival sources and the identification of problematic historical nodes are integrated with typical survey operations and with the analysis of the physical conformation of the object. Moreover, the new digital archiving methods offered by the object-oriented parametric modelling paradigm have shown the way to propose an organizational method that, critically conducted, allows an interaction on the enriched model for technical purposes and more.
The opportunity to define a paradigm of this information interaction mode is offered by the chosen case study, Palazzo Cellamare, which represents a monumental architectural episode of great symbolic value for the history of Naples and of great value in terms of architectural quality. Moreover, this complex artefact lives a contingent condition for which the building is subject to maintenance work and restoration. In this way, exploiting the potential of digital BIM simulation, a single structured and widespread database becomes useful to investigate, in a new light, interpretative questions still open for this building. Together with the interest in this building database, it is possible to compare some possible outcomes of this study with the methodologies of professional practice, verifying any immediate functionality.

2 | Parametric modelling for Cultural Heritage. Topics and issues for a method proposed

In order to better outline and describe the operational framework, able to define a good practice about the data management referred to a architectural heritage as Palazzo Cellamare is, it looks appropriate to frame the issue of the parametric modelling in the current transitional period, even referred to a theoretical point of view that rises when technical outcomes needs coherent applications. In that way, during the first decade of the twenty-first century the paradigmatic turning point about the ability in sharing information in a digital domain occurred when there was a conclusive structurisation of satisfactory exchange formats, generally intended as designed to be used in the field of construction but widely used in several fields, such as the action on cultural architectural heritage. This paradigmatic shift represents the moment when technology became pervasive and invasive in the current debate, and in fact still affects most of the efforts of all operators involved in information interoperability, that represents the preferred evolution of BIM methodology.
Even if BIM methodology is nowadays fully eligible for fully collaborative interaction, the next operational philosophy envisages total data integration in a cloud-based environment, by exploiting web-based net applications. The potential provided from interfacing to information in shared environments accessible from the web requires verification not only of the instruments and methods linked to the construction of the so called digital twins of the buildings, but also

of the methods that can be used to maximise and optimise data enrichment of parametric instances on which to base object-oriented modelling.
The opportunity to work on a building with a remarkable architecture and emblematic history, such as the one described here, prompted not only a discussion regarding the most appropriate methods to not only integrate technology in the more traditional workflow of conservative restoration and final implementation, but also sparked a debate to try and understand how to influence the possible definition of an architecture to structure multidisciplinary data coupled with computer sharing architecture that goes beyond the more immediate technical and engineering requirements. On the one hand, establishing how to structure the information of the model when augmented and transversal fruition is envisaged must be evaluated against satisfactory strategies to manage and organise the computerised database. On the other, it also involves critical comparison with the technical scenario and tools that can be used to structure a system which non-technical users will hopefully be able to access. The problem of interoperability has induced increased interest in data enrichment and the determination to provide a structured solution to the intrinsic problem of semanticisation of the components of the model. With the exception of information exchanges, there has been a delay and shortage of protocols regarding how to categorise the 3D instance in the model and do justice to its relative computerised characterisation; this is effectively the main reason why extensive use of BIM is still blocked as regards complete information sharing. While it is possible to accept the lack of full enrichment in the design of new buildings – several authors [Zhang - El-Gohary 2014; Belsky - Sacks - Brilakis 2016; Sacks et al. 2017] have emphasised the lack of concepts in the formal schema characterising the most widespread open exchange formats (IFC *in primis*) required to express the code requirements needed by modelling in the field of architecture and construction – it is all the more important to emphasise that the lack of information is much greater for a BIM involving requalification and intervention on existing buildings. In fact, it's currently not unusual to use surrogate strategies and adapt digital instances developed for new designs which, albeit formally and in the geometric construction of digital artefacts, become inadequate in the structuring of non-geometric data.

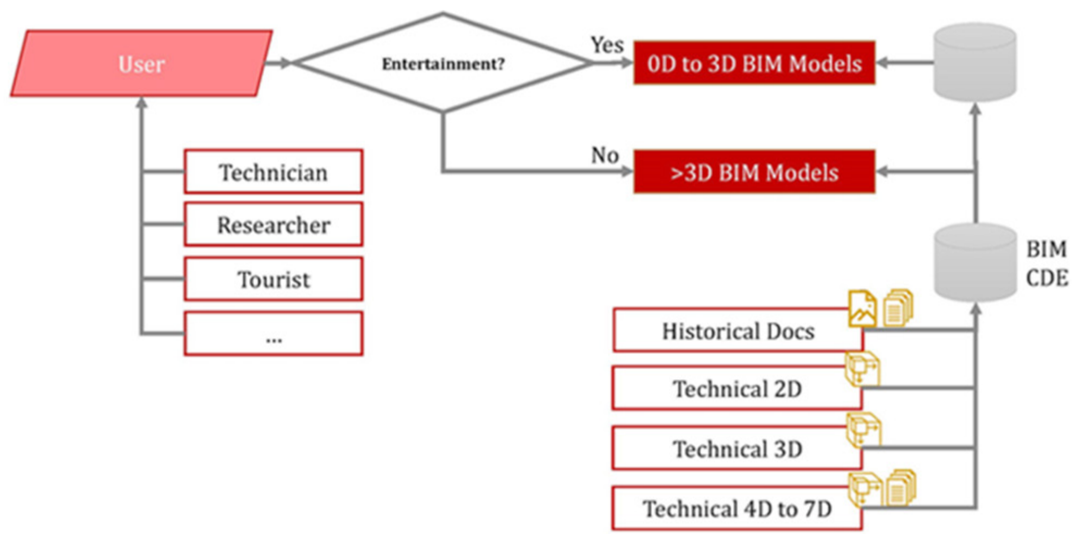

Fig. 6: A first schematic representation of the data access in the proposal (elaboration by P. D'Agostino).

These considerations, which are true when the BIM paradigm is integrated into projects on existing conventional buildings, increase the degree of complexity and operational problems in more emblematic applications, i.e., in monumental buildings. Even when large data sets can be explicitly converted into three-dimensional digital primitives, current practice still requires that BIM modellers be operationally skilled in interpreting the information, given that we still lack an efficient automated process that can translate and render geometrically coherent the modelled object in relation to the real artefact which it virtually portrays. As a result, since we have to make the best of the 'digital transmutation' of an object, we tend to disrupt the semantic coherence in the non-geometric component which the whole model should instead maintain. So, it is not unusual for geometrically efficient models to ultimately lack a suitable identity code, relationships, and coherent alphanumerical data. This becomes even more important when the data structure – which strictly speaking should involve the virtualisation of the buildings in the digital domain in the aggregation of multidisciplinary data during the design phase – has to integrate information directed towards complete comprehension of each instance in relation to non-technical data.
As far as Italy is concerned, we should emphasise that the characteristics of the context (which are often encountered and, due to the scientific tradition used in the preservation of old built heritage, generate problems regarding approach) have assumed an unusual status when this issue is integrated into the BIM paradigm. In fact, considering the percentage of buildings to be protected compared to all the activities associated with the construction industry in Italy [CRESME 2020], a decision was taken to intervene on both a regulatory level and on the standardisation of the so called Levels of Development (LOD) [Pavan - Mirarchi 2019], acting in such a way as to introduce a level (the LOD G) specifically designed to protect the autonomy of the virtualisation of old built heritage even in digital BIM-oriented modelling. The scientific community has acted as pioneers in this field, trying to find efficient methods, especially as regards the construction of the geometric component of the parametric model. Solutions have primarily been found in solid conformation and the fact it can be achieved using digital survey data and interaction between geometric instances and survey output (points cloud) [Catuogno - di Luggo 2016; Scandurra et al. 2018; Giannattasio - Papa - D'Agostino 2019]. This has led to the consolidation of a method strategy which, in the specific of so-called Cloud-to-BIM, provides geometrically reliable models [Apollonio - Gaiani - Sun Zheng 2012; Paris - Wahbeh 2016; Bianchini - Nicastro 2018; Brusaporci - Maiezza - Tata 2018].
So, with regard to the virtualisation of existing heritage, the creation of a model characterised by the multiple processes of stratification inherent in a building, built fabric or territory must initially acquire data from all the specialists involved in the lifecycle of the building – client, manager, producer of materials and components – before any project can be initiated.
The knowledge-gathering and data acquisition phase regarding the state of the building is crucial before the process to create a model can deal with the problems associated with the interoperability of ICT tools and BIM sharing. Due to the difficulties inherent in accurately representing the variety of complex and irregular objects in old buildings, the HBIM methodologies that envisage the digitalisation of old buildings using data created by combining digital survey and manual acquisition techniques usually exploit existing BIM libraries of parametric objects which, however, need to be specifically recreated and codified [Murphy - McGovern - Pavia 2013]. The data or intelligent information in the model can vary from geometric and spatial to material, structural, environmental, cultural and economic.

In light of these considerations, one could ask what are the methods required to achieve a successful synthesis between the HBIM product and BIM sharing architecture. This involves understanding how to influence the weights to be structured, within each modelled instance, in order to achieve total comprehension of the modelled object, given the dual coordination of refinement and information integration at both geometric and informative level. This is important because international regulations and standards are significantly changing the way a BIM model is structured, affecting in particular the rationalisation of the information; the aim is to simplify the amount of data in the model which otherwise could contain information that is useless or ineffective vis-à-vis the desired goal. This is causing the LOD-based approach to be gradually abandoned in order to provide a different balance between geometrical features and documental ones.

This condition, albeit indirectly, is destined to be a key issue above all for public administrations and, in particular, to assist in regulating the formal documentation of subordination to a BIM-oriented bureaucratic process, hopefully also when the focus is on monumental and rare architecture. The objective was to avoid having to manage excess information compared to the amount of information needed to implement the design proposal or project, thus having a different effect on the need to balance the details of the geometric information (Level of Geometry, LOG) and alphanumerical and documentary information (Level of Information, LOI). In actual fact, considering the framework relative to the accomplishment of the requirements envisaged by a design action, it's clear that the levels of information detail integrate a state of information flow that will reduce the rigidity of the information sharing system. With regard to BIM applied to Cultural Heritage, it will affect the way the data is used even before its enrichment: in fact, as concerns the relationship between use and the need to satisfy the needs of multiple users, it would seem appropriate to try and provide another methodology for an operational architecture of cloud-based information sharing.

By borrowing the architecture characterising the structuring of the levels of information detail, the proposal currently being discussed directs the information organisation towards the construction and introduction of a Common Data Environment (CDE) which, as the driving force of the collaborative BIM system, allows to understand how it can also be used to interact with the part of the model that would drive to the information extrapolation by non-technical users who, for purely cultural purposes, may nevertheless find it important to interact with parts of the model or its data. Thus, opening the framework of knowledge to customs and functions beyond the boundaries of the world of purely technical applications helps us understand if and how qualitative data harvesting and the feedback from non-technical knowledge does in fact represent further input into the iterative system typical of BIM, even in those cases, such as the one discussed here, in which technical knowledge must be directly coupled with a sensitivity and attention to the context, something which digital tools, given their current rigid interpretation of data, find difficult to introduce into the well-structured process provided by national and international standards. If access to geometric or non-geometric data is to take place using different methods of access and authentication within the system, then it is necessary to study whether or not to aim for an extreme definition when detailing and achieving a certain LOG/LOI balance that impacts the confirmative and informative data in equal measure.

Recovering information, mediated by the differentiation of user type, requires a focus on how this information has to be organised, whether it has to be accessible in a duplicated form or if instead through the recovery of certain specific contents that deserve to maintain their own au-

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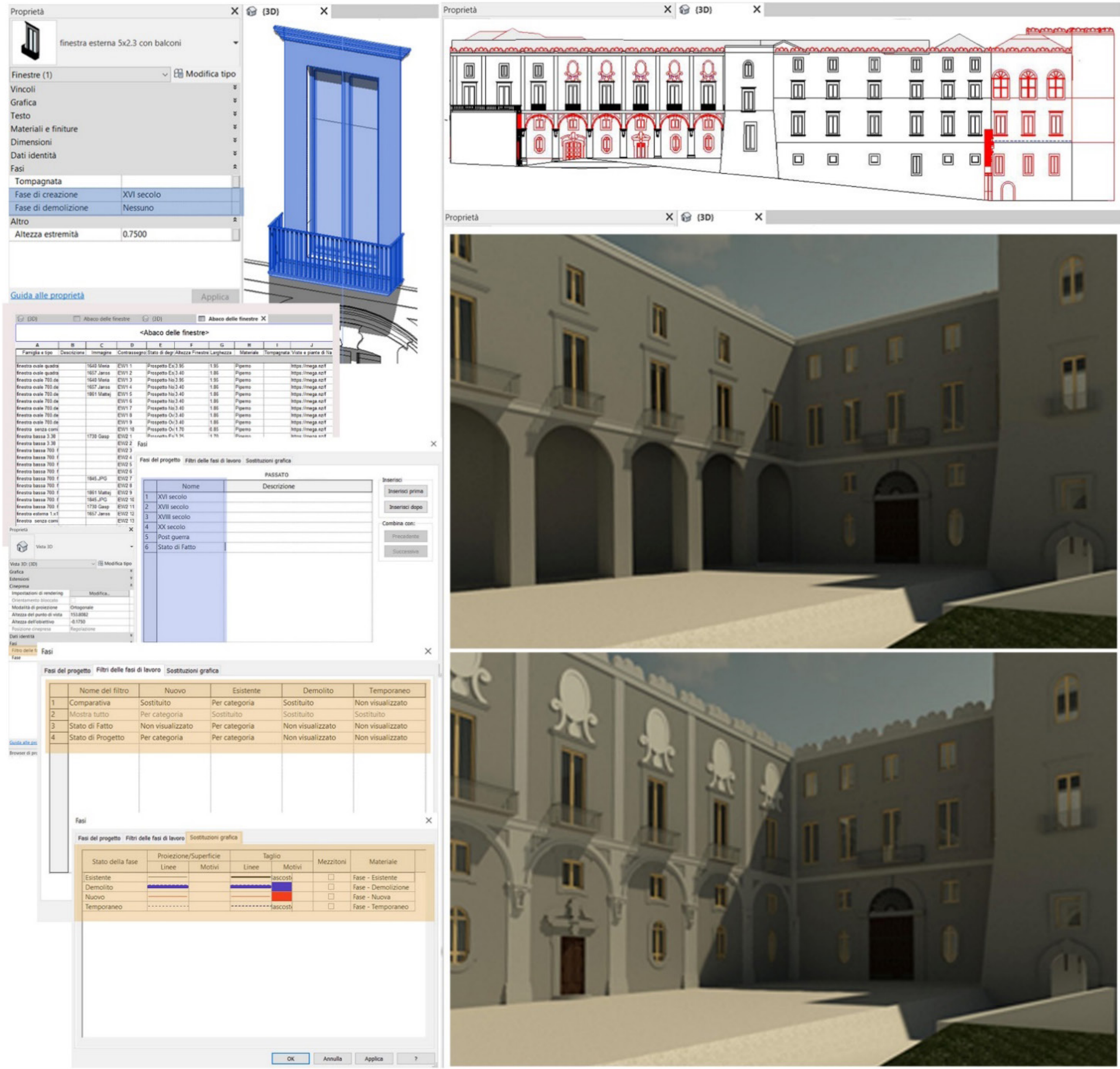
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Sostituzioni grafica
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XVI secolo
XVII secolo
XVIII secolo
XX secolo
Post guerra
Stato di Fatto
Inserisci prima
Inserisci dopo
Combina con:
Precedente
Successiva
Nome del filtro
Nuovo
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Demolito
Temporaneo
Comparativa
Sostituito
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Non visualizzato
Mostra tutto
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Stato di Fatto
Non visualizzato
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Stato di Progetto
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Motivi
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Fase - Nuova
Fase - Temporaneo
OK
Annulla
Applica
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Fig. 7: Parametric modelling and informative characterization of Palazzo Cellamare, aimed to the definition of the main historical phases: the first court in an XVI sec. simulation, on the top, compared to the XVIII intervention, on the bottom (previous page, elaboration by P. D'Agostino).

Fig. 8: Antoine Lafréry-Étienne Dupérac, Perspective plan of Naples, 1566, detail with Palazzo Cellamare (https://catalogo.beniculturali.it/detail/HistoricOrArtisticProperty/1500321432).

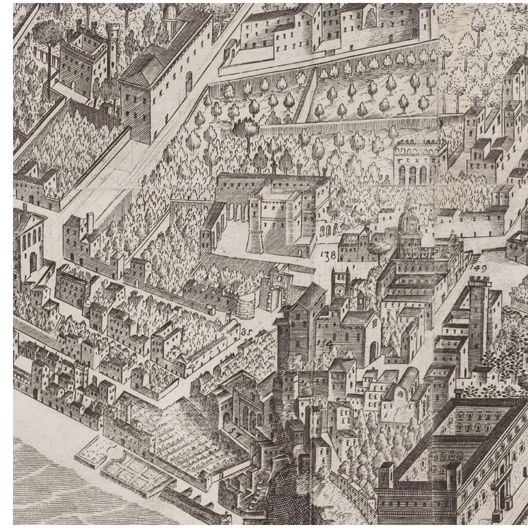

Fig. 9: Alessandro Baratta, View of Naples, 1629, detail with Palazzo Cellamare (http://www.ub.edu/enbach/img/mapas/napoles.jpg).

tonomy in the organisation of the information. A potential ambiguity and a non-unique access to the information would unhinge the philosophy of the dual structure of detail and lead to limited effectiveness in the dissemination of that part of the model on authoring platforms not specialised in object-oriented parametric modelling: a risk to avoid and susceptible to be solved. These considerations are illustrated in the operational description provided below but can still be improved upon and integrated in a research in progress.

3 | The Building History: Methodology and Sources

The object of this study represents a perfect example to experiment this new approach. Palazzo Cellamare (or Cellammare) is a monumental building of enormous importance, whose complex stratification makes the relationship between historical research and BIM modeling more interesting. The first nucleus of the building dates back to the first decade of the sixteenth century, but already in the Forties of the same century Luigi Carafa, second prince of Stigliano, decided to radically modify it, entrusting the task to the architect Ferdinando Manlio [Savarese 1996, 22]. An idea of the sixteenth-century appearance of the building can be given by the representation of the engraving by Étienne Dupérac, printed by Antoine Lafréry in 1566.

This one can be compared with Alessandro Baratta's view of 1629 which gives a more precise representation of the typology of the building, articulated as a fortress on an inner courtyard and with an external courtyard with arcades on two sides. The image of the building seems just a compromise between a palace and a fortress, thanks to the scarp walls and the dominant position. Actually, palazzo Cellamare is located on a hill overlooking via Chiaja, the access road to the city from the west, and thanks to the sixteenth-century works, what could be considered an extra-urban residence becomes a city palace. Not by coincidence, in the same years in which Manlio was engaged in the construction of the palace, together with Giovanni Benincasa he also took care of the restructuring of the fortress of Castel Capuano in order to adapt it to the seat of the court [*Castel Capuano* 2011].

Although some parts of the building, such as the internal courtyard, are still visible today, the current image of the building mostly dates back to the works carried out at the end of the sev-

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enteenth and at the beginning of the eighteenth century, after Antonio Giudice, Prince of Cellamare and Duke of Giovinazzo, came into possession of it. One of the most important transformations concerned the construction of the new grand staircase of honor, located in the eastern body, with access from the internal courtyard.
According to Benedetto Croce [Croce 1901, 50], this staircase overlapped a previous loggia, not visible in the Dupérac-Lafrery plan but certainly prior to the eighteenth-century works.
The grand staircase is probably due to the architect Giovan Battista Manni and is certainly affected by the cultural climate of that period. Its construction was in fact related to that of the staircase of the viceregal palace of Naples, built by Francesco Antonio Picchiatti 40 years earlier [Savarese 1996, 44]. The Prince of Cellamare took possession of the building in 1696 and relevant renovations were carried out in the following years, probably ending in 1700. In addition to the grand staircase, other parts of the building were affected by significant changes. The facades were modified with stucco works in imitation of brick and with decorations already suitable for the new eighteenth-century taste. The entrance portal to the grand staircase, in the internal courtyard, has been attributed to Ferdinando Sanfelice by analogy with several of his other works and must also be dated to the early eighteenth century [Savarese 1996, 46].
The last transformations of the building will be started in 1726 and will be entrusted to another important personality of the architecture of the time, namely Ferdinando Fuga. Born in Florence in 1699, Fuga had already established himself as a talented architect in Rome when he was called to move in Naples to work at Palazzo Cellamare. The affairs of the prince, who died in Seville in 1733, had prompted him to reside mostly in Madrid. Therefore, he commissioned his brother Nicola, cardinal, to supervise the work on the palace, and the latter turned to Fuga. Fuga will be among the main architects of the first phase of the Bourbon kingdom in Naples. Together with Luigi Vanvitelli, he will dominate the Neapolitan scene, creating monumental buildings of great urban impact, such as the Albergo dei poveri (since 1749) and the Granili (since 1779), and works of smaller size but of proven architectural quality such as, villa La Favorita (1768), the court theatre in Palazzo Reale (1768) and Palazzo d'Aquino di Caramanico (1775-1780).
In Palazzo Cellamare Fuga was commissioned to build the chapel, located on the northern arm of the external courtyard and completed in 1728. The chapel is arranged longitudinally to the body of the building and today are still visible the round arches of the old loggia, then walled up to build the chapel. Although its role is not clear from the sources, it is certain that Giovan Battista Nauclerio, one of the main architects of the Neapolitan Rococo, worked inside the chapel [Pisani 1996[1]; Savarese 1996, 69]. The chapel is undoubtedly one of the most valuable architectural and artistic episodes of the entire building.
For the first time Roberto Pane [Pane 1956, 8] had also attributed the paternity of the monumental entrance arch to Ferdinando Fuga only on the basis of a stylistic analysis. This authorship was then confirmed by further documentary researches [Savarese 1996, 70] which confirm the extent of Fuga's contribution in the last transformation of the building, after 1726. It is possible to get an idea of how the building should have looked during and after these works thanks to the famous view of the Flemish painter Gaspar van Wittel [Pisani 1992; Briganti 1996; Pisani 1996[2]], whose dating is somewhat controversial [Fig. 6a]: based on previous reflections by Leonardo Di Mauro and Nicola Spinosa [Di Mauro - Spinosa 1989, 189, cat. 32, tav. 12], Silvana Savarese [Savarese 1996, 44-46] hypothesized that the view may have been realized in the period between 1700 and 1701, while Massimo Pisani [Pisani 2003, 191-197] later dated it to 1729. This different dating is

Fig. 10: General view with Palazzo Cellamare by Gaspar van Wittel, *Il borgo di Chiaia da Pizzofalcone*, 1729 ca. (*La collezione d'arte del Sanpaolo Banco di Napoli*, edited by A. Coliva, Milano, Silvana Editoriale 2004).

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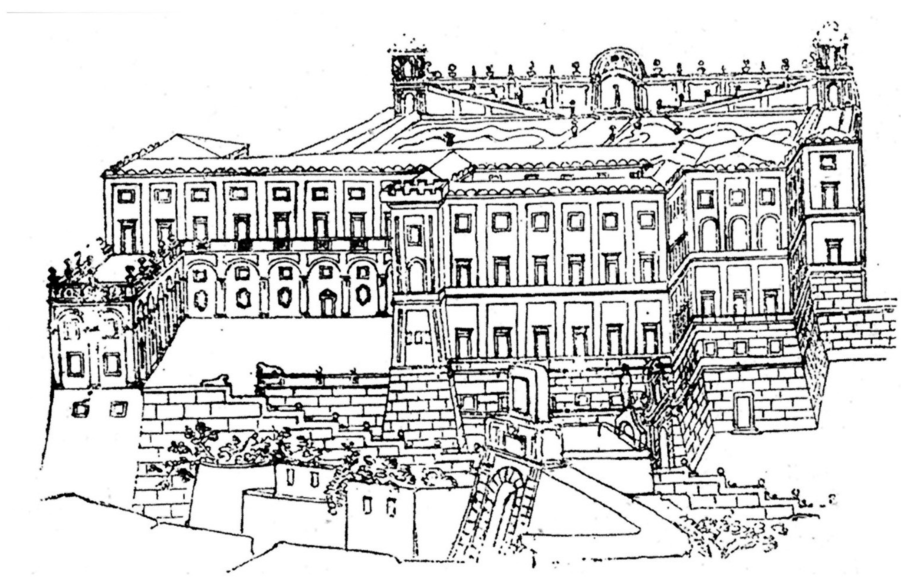

also based on the presence, in the painting, of the entrance portal on the ramp made by Fuga. It is also possible that the oil painting on canvas was executed later, in Rome, on the basis of drawings previously made in Naples, as some inaccuracies would seem to confirm [Confalone 2004, 148], to some extent surprising in the precise and accurate work that characterizes the Flemish school. The view is entitled *Il borgo di Chiaia da Pizzofalcone* and shows the Chiaia district, nestled between the Vomero hill and the sea, seen from the east. The palace is clearly visible on the right of the painting and its imposing size dominates the entire area. Not a little prominence is also attributed to the vast gardens of the palace, which then covered the entire Mortelle hill and today are considerably reduced due to the construction of new buildings on the upper part of the hill.
The vegetable gardens to the west of the palace are also clearly visible and will disappear only at the end of Nineteeenth century when Via Filangieri will be traced.
Then also the external ramp, with the monumental portal, can be observed, as well as, in the external courtyard, the open arches that will be closed just to build the chapel. Evidently, at the time van Wittel portrayed the scene, the chapel's work had not yet been completed.
More than two centuries after the intervention of Fuga, a further transformation concerns the external access ramp to the building: between 1948 and 1950 a vast movie-theater was built inside the enormous tuff caves located under the Cellamare palace [Maglio 2007, 2019]. In order to gain access from the street to the new cinema house, the architect Stefania Filo Speziale demolished the initial part of the ramp, building a side access that leads to the monumental portal of Fuga. In this way the axiality between via Chiaia, the ramp and the portal is lost, even if the bulk of the portal continues to constitute a perspective backdrop for those coming from the royal palace along via Chiaia.
As seen, the history of the Cellamare palace is complex, as its current form is the result of interventions and modifications carried out over the centuries. Moreover, despite various researches on archival documents, there are still unclear points in its architectural history, so that the research has to be carried on. This architectural stratification, which involves some of the most important figures of the Neapolitan context from sixteenth to eighteenth centuries, is not an exception in the monumental architecture of the city.
The use of procedures on the one hand capable of managing the information obtained thanks to in-depth historical research and on the other hand of evaluating them in a systematic manner therefore appears extremely useful. The work presented in these notes demonstrates how even the visualization of the acquired data and the comparison between the architectural elements in a sort of abacus also become useful tools for a possible progression of the research.

4 | Designing and sharing an infographic system

The unique characteristics and extraordinary importance of the complex building known as Palazzo di Cellamare are due to the building techniques, materials and decorations that have transformed it over a period of five centuries. These are the premises behind the testing of a H-Bim prototype developed to optimise data sharing in a cloud environment. Compared to traditional local storage systems, the prototype satisfies the demand for transmission and iteration of interdisciplinary information structured according to different paths/interpretation levels, thereby providing more effective management and dissemination of its tangible and intangible heritage.
The workflow used to generate the parametric *As-Is* model of Palazzo di Cellammare involved integrating the CAD to BIM approach (useful in predefining the geometry and parametric components of the object-oriented 3D models based on technical, historical and archival documen-

Figs. 11-12: Ferdinando Fuga, Chapel of Palazzo Cellamare, dedicated to the Vergine del Carmelo, after 1726 (Savarese 1996, 60); F. Venconi, Palazzo Cellamare after the renovation, 1729 (Savarese 1996, 67).

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tation), with the Capture to BIM approach [Barki et al. 2015] required to update the metric data obtained by using a consolidated digital photogrammetric survey method and integrated representation [Remondino 2011, 1104-1138].
The digital photogrammetric survey was performed on two sets of digital images for the internal fronts of the sixteenth-century courtyard and for the external fronts of the building, with a Reflex Nikon D7000 camera (with 16-85mm f/3.5-5.6G ED VR lens), Consequently, a discreet model in points cloud from photos reconstructed in Zephyr Aerial, geo-referenced and scaled correctly thanks to the use of the GCP, was useful to evaluate the quality of the BIM model created both from a topological and metric point of view on the CAD drawings. Comparison between the model and the unconstructed dataset, which shows a distribution of most points within a maximum range of 0.15m with a standard deviation value of 0.10m, resulted in the updating of the BIM-objects adapted to the geometry based on the detected reality [Garagnani - Manferdini 2013, 87-92; Ozdemir - Remondino 2018, 135-142] to be included in an LOA-30 to validate the representation of the detailed elements of the artifact, as well as the implementation of those gaps in detail.
The metric and geometric analysis of different parts of the complex revealed certain distinctive architectural features typical of old built heritage. The features, attributable to changes made in the seventeenth/eighteenth century, could not be easily turned into elements governed by serial geometric-proportional rules and codices. It therefore required the implementation of parametric libraries with specific families of architectural components created in compliance with the rules codified in contemporary treatises [Brusaporci et al. 2018].
Therefore, each element is described not only by the general family parameters, but also by specific instance parameters in order to contain in the actual state that information inherent to historical, geometric-dimensional, morphological-figurative characteristics relating to the type in question [Quattrini et al. 2016] also described through hypertext links. In particular, the information that has been integrated into the architectural information system are: alphanumeric data on characteristics, properties and constitution (i.e. location, type of use, conservation, etc.); alphanumeric historical documents (cards, transcriptions, etc.); raster historical documents (maps, iconography, various types of images, etc.); alphanumeric data survey (quantities, materials, construction techniques, deterioration, etc.); survey of georeferenced vector data; raster data survey (photography, orthophotography, etc.); raster and vector documentation useful for describing the evolution of the building or its state of conservation; alphanumeric diagnostic data regarding the types of degradation and the frequent ones, starting from the characterization of the surfaces through textures deduced from photoplanes obtained from the photogrammetric survey, and to the control and intervention times. In particular, the Level of Development of the level of information (LOI) of the digital objects tends towards a LOD G, given that the level of geometry (LOG) refers to a LOD C, maintaining the level of detail related to the restitution scale of the urban investigation (1:1000) and architectural investigation (1:100/1:50) with an information characterization and a topological breakdown of the elements which makes it possible to virtually follow the construction phases of the building [Bianchini et al. 2016, 10.1-10.9], tending towards the as-built conditions of the building (1:20/1:10).
The result is a multi-series infographic reference system for the different types of operators, who will exploit this resource for work purposes or for an interest dictated by curiosity and thirst for knowledge, which in the easy tracking of the elements requires a coding of each type. Through a mark elaborated ah hoc to easily visualize the communion of some historical-artistic characteristics, in addition to the geometric characteristics and positioning or height of the element. For example,

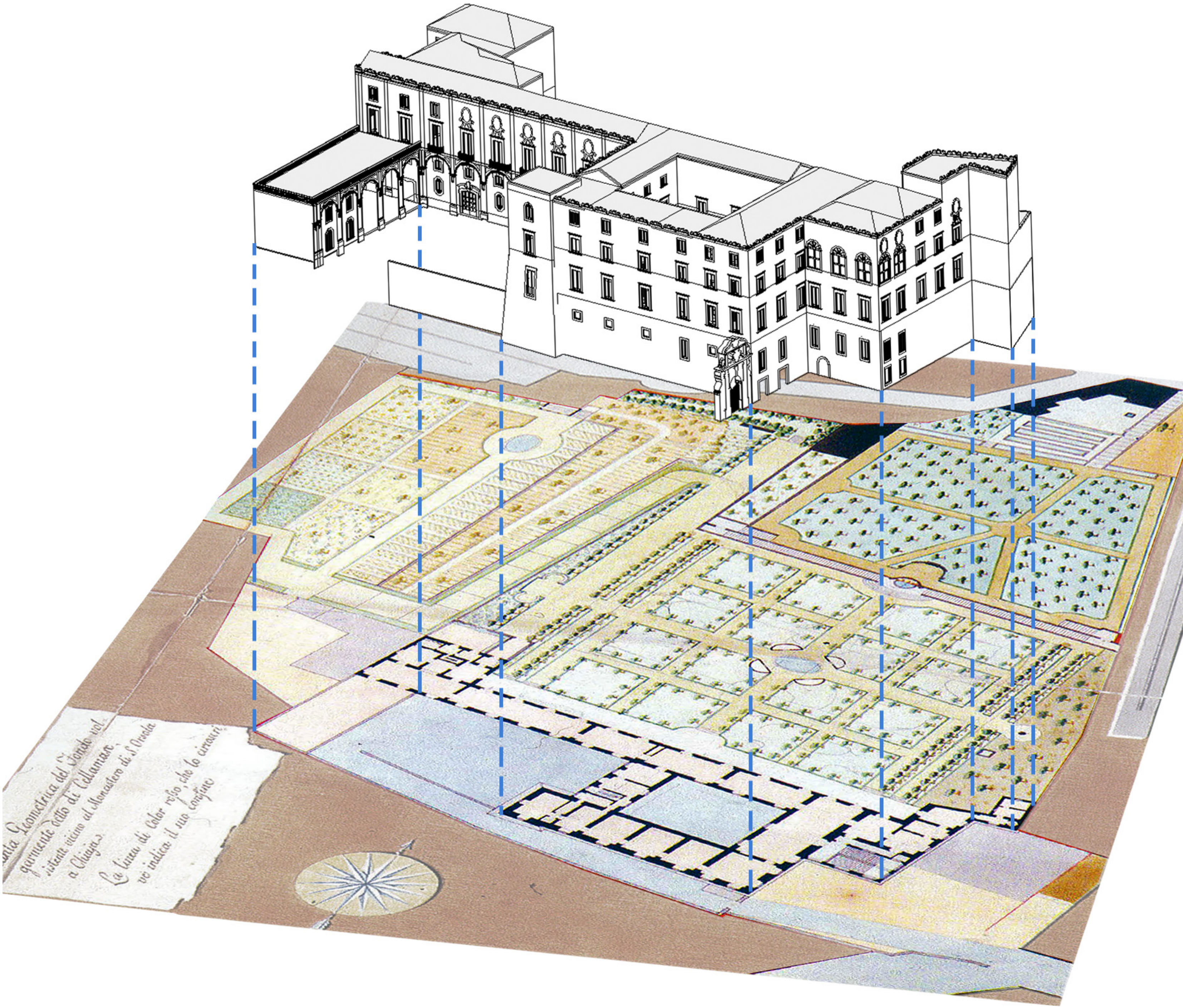
the mouldings around the windows and the external surfaces of the complex were the first nucleus of an ontological type for the building in question. These elements are not only volumes but 'smart' or 'semantic' parametric objects [Pocobelli et al. 2018, 909–916] with a formal, technological and functional identity established using a classification system created *ad hoc* and then coded (e.g., in Fig. 8) depending on the type of element (window=W), its planimetric and altimetric position (the sixth window of the third order on the elevation of the outer courtyard E-6-3), and the number of the same type of elements with the same historical period (n=9).

Thus, the descriptive properties and a time parameter were added to the model, creating a 4D-HBIM representation, i.e., a dynamic temporal simulation of the building phases and work performed. The latter can be consulted to also view the survey of the damages associated with the anthropic activities before and afterwards. Each element of the complex fits in with its surroundings, creating spatial and constructive relationships which, however, often underpin historical-cultural (and sometimes social) issues that are difficult to appreciate by simply interpreting the building and the elements added over a period of time. A graphic solution was therefore required to obtain visual feedback of the demolition and restructuring of the building since its construction and thus obtain a better understanding of the forms as well as the alterations that each of its components has undergone through the years.

This was achieved by analysing the graphic and historical-digital component linked to the typological system via the URL parameter with the views and maps of Naples from the sixteenth to nineteenth century. Using the «filter phase function» function, work continued on the diachronic definition of the volumes and elements from five main historical periods (sixteenth, seventeenth, eighteenth, nineteenth and twentieth century) in order to identify, quantify and account for the building projects [Osello - Ugliotti 2017, 69], as well as develop alternative scenarios that can be interpreted by superimposing the scenarios on the current state of the site. To establish the changes made to the south elevation, the outline of the architectural object as well as different kinds of lines (dotted, continuous, dash-dot, etc.), colours and hatching were used to identify the graphic replacements associated with the «new», «demolished» and «existing» phases. One alteration involved plugging the arches of the outer courtyard to make way for the construction of the Chapel of the Vergine del Carmelo designed in the eighteenth century and commissioned by the Prince of Cellamare.

Another alteration, in the second half of the eighteenth century, required plugging the windows of the fourth order on the same façade; this variation was requested by the Prince of Francavilla so that the rooms on the *piano nobile* could be upgraded and frescoed (the windows were hidden behind ornamental Baroque stucco motifs). However, when the dates of the volumes and surfaces are unknown – for example the loggia projecting out towards via Chiaia built between the sixteenth and eighteenth century [Savarese 1996, 39] – then the items in question were graphically drawn differently and the code contains the word «uncertain».

This methodological approach was adopted in order to formally and coherently file, relate and represent the heterogeneous descriptive data of the building; it was an opportunity to satisfy the increasingly insistent demand by different groups of users for accessible data (also on the web) regarding the management and distribution of existing buildings. Therefore, the research studied the approaches required to develop an open-web database for data management and processing that exploits semantic user-friendly systems for architecture and its contents. No solution was found in the potential provided by 'relational databases management systems' (RDBMS) which as plug-in open BIM do not allow 'links' between tabular information concerning the docu-


Geometrica del Fondo vol
garmente detto di Cellamare
sistente vicino al Monastero di S. Orsola
a Chiaja
La linea di Color rosso, che lo circon
vi indica il suo confine

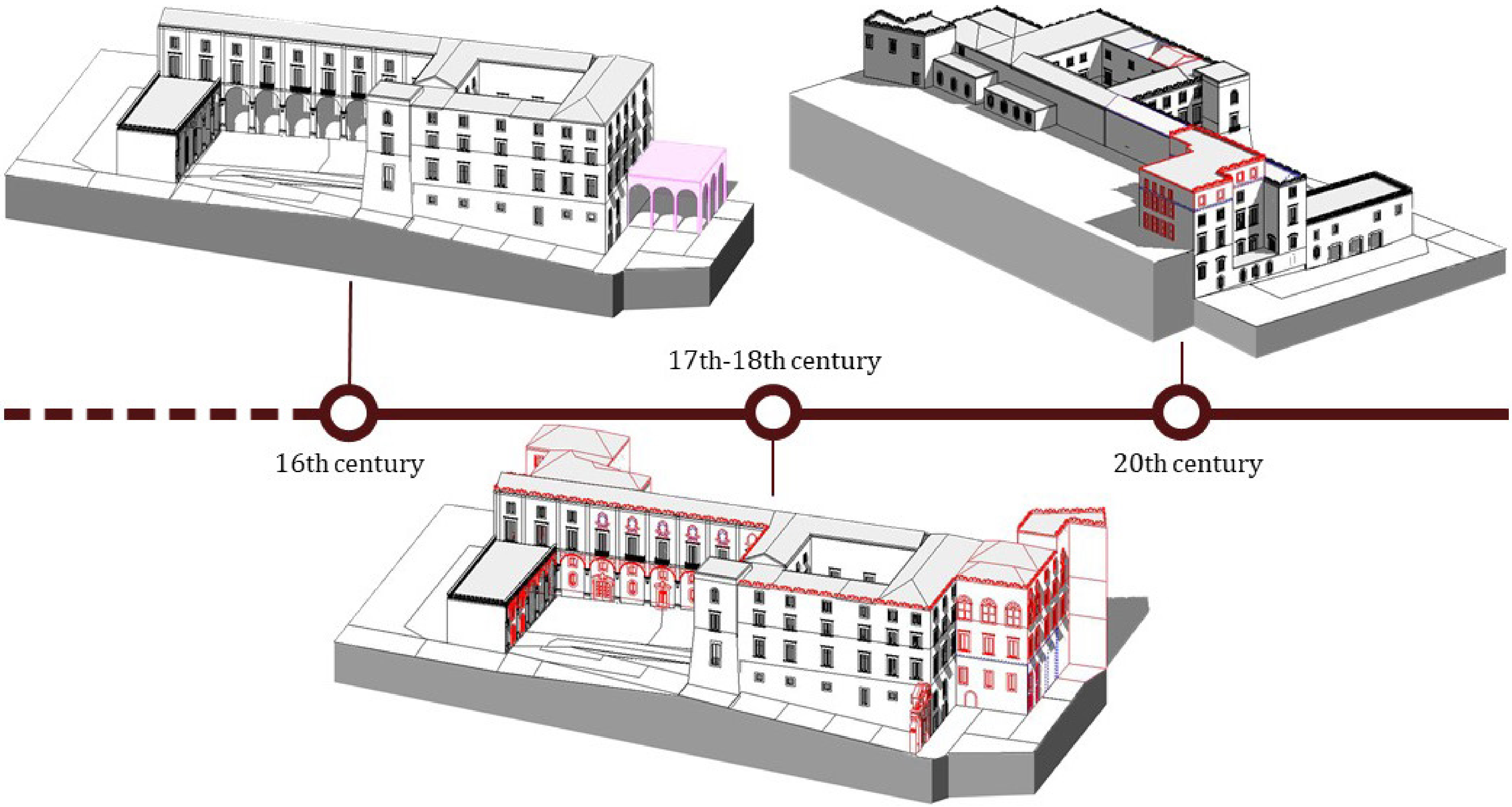


Fig. 13: Informative reconstruction in comparison of the model with the Plan of the fund commonly known as Cellamare, Naples, State Archives, second half of the 18th century (previous page, elaboration by G. Antuono).

Fig. 14: Definition of the marks and characterization of the instance and type parameters that integrates the descriptive documentation and historical-iconographic graphics usable with hypertext in the cloud (in this page, elaboration by G. Antuono).

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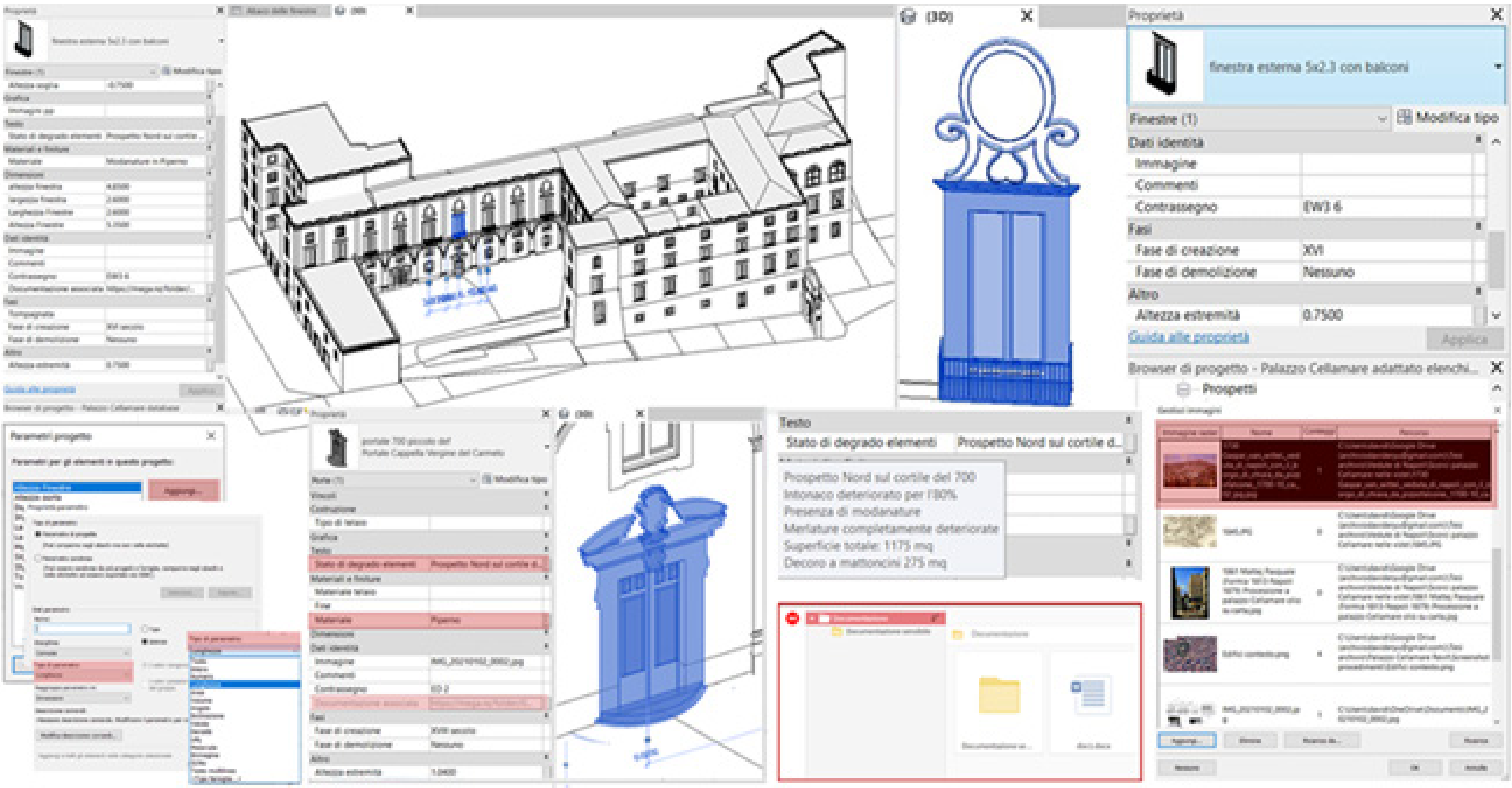
(3D)
Proprietà
finestra esterna 5x2.3 con balconi
Finestre (1)
Modifica tipo
Dati identità
Immagine
Commenti
Contrassegno
EW3 6
Fasi
Fase di creazione
XVI
Fase di demolizione
Nessuno
Altro
Altezza estremità
0.7500
Guida alle proprietà
Applica
Browser di progetto - Palazzo Cellamare adattato elenchi...
Prospetti
Testo
Stato di degrado elementi
Prospetto Nord sul cortile d...
Prospetto Nord sul cortile del 700
Intonaco deteriorato per l'80%
Presenza di modanature
Merlature completamente deteriorate
Superficie totale: 1175 mq
Decoro a mattoncini 275 mq

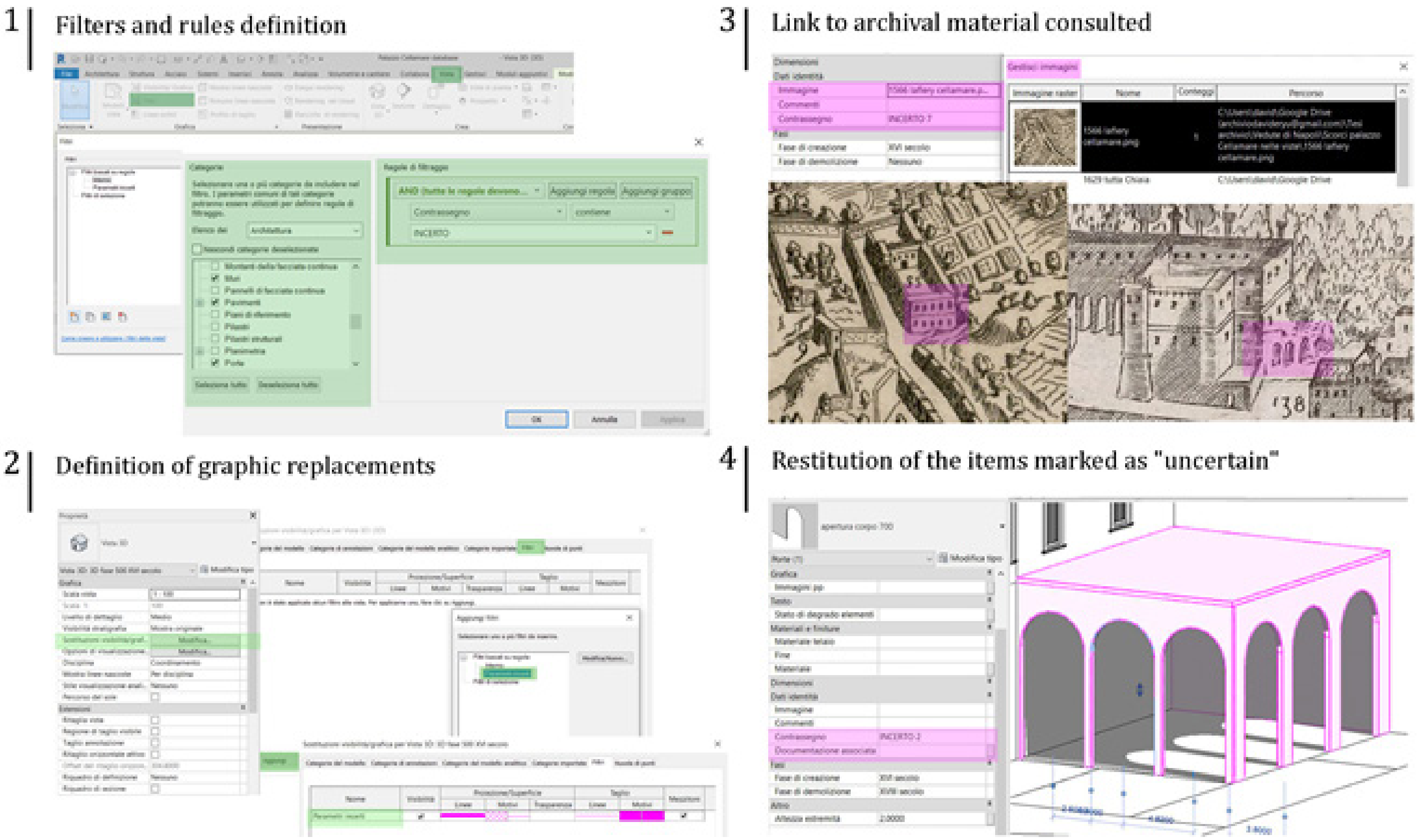

Fig. 15: Summary framework of the structuring of the phases of the building model in the description of its historical transformation (previous page, elaboration by G. Antuono).

Fig. 16: Schematic of the methodological approach for the graphic-informative treatment of «uncertain» historical-evolutionary data in the construction of the evolutionary phases of the building (in this page, elaboration by G. Antuono).

Fig. 17: Workflow scheme for digitizing and cataloging the information of the architectural objects of the semantic model and their cloud-web sharing (next page, elaboration by P. D’Agostino).

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Palazzo Cellamare Database Online
www
Palazzo Cellamare Database Online
Researchers
Designer/Company
Owners/Institutions
Restoration technicians
MEGA

mental characteristics of the parameterised objects. To facilitate the workflows, the cloud-based applications Autodesk 3D Forge Viewer make it possible to not only integrate, coordinate and manage the BIM models, interacting with its parametric elements [Bruno - Roncella 2019, 1-24], using a methodology that combines the advantages of the immediacy of the HBIM integrated models in A360, which offers the advantages of querying the elements during navigation but only for viewing not allowing interactive actions on the properties, with the possibility of integrating and modifying the data extracted from the information schedule, exported to Excel and managed through the creation of a summary wizard in Microsoft Access. This last approach, integrated with the possibility of differentiating the paths of use of the database through the Mega NZ cloud service, allows you to define a document storage to create a first idea of separation from what is purely technical or administrative information compared to those intended for historical research connected to the tourist use of the property.
The differentiation of the access profiles is based on the information characterization requested by each user: from the mere 2D and 3D vectorial visualization of the architectural complex at appropriate scales and to its interrogation according to specific themes aimed at historical-artistic knowledge available through summary sheets (for the tourist user), up to the need to extract, manipulate and implement data for critical historical studies of «transformative and reconstructive hypotheses» of the factory [Campi et al. 2017, 133-139] (for a scholar and researcher) or to define hypotheses for the design and enhancement of the asset (for an operator or manager of the product). It follows the possibility, through a unitary model, interactive and usable in the cloud [Inzerillo et al. 2016, 16.1-16.9], to reconcile different needs by taking the opportunity to ensure continuous control of the product over time [Giannattasio et al. 2020, 311-322], but also to be able to draft documentation that can be updated from time to time. This documentation helps to «preserve the aesthetic and historical value of the monument» [ICOMOS 1975], and protect the proper allocation of resources based on a «planned conservation» approach [Della Torre 2010, 47-55].
Obviously, it is important to understand the objectives and their representation which is, in fact, always the end result of a programme mindfully developed and structured according to a precise goal, where the clarity of the model is the outcome of an analytical, interpretative and intellectual examination of reality based on simplification; this process ensures the creation of a logical paradigm available in every dedicated section.

5 | Conclusion

In conclusion, the work carried out shows that the current methodological approach concerning HBIM, and the management of data related to it, is characterized by advantages that encourage its use and development, in light of the maturity of the digital infrastructure, pervasive in technical practice. The constant trend towards the so-called Field BIM, designed to integrate the world of IOT within an object-oriented digital architecture, leads us to believe it is plausible that an approach that could be called crowd-enrichment will soon be implemented within the process of parametric modelling. Evidently, this will impact on how and on the system's ability to manage and catalogue in an orderly manner a huge mole of information characterized by high heterogeneity, both in the data content and in useful formats to their fruition.
As seen, the possibilities offered by HBIM modelling can provide new methodological approaches also in the field of historical research, with specific regard to the chance of compar-

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ing and validating the information, even more so for example – but not only – in the presence of gaps in the sources or of uncertain data interpretations.
The experience conducted still needed to substitute a complete information aggregation due to the instrumental difficulty, and a fragmented knowledge. This is not intended to imagine a software structure that summarizes the entirety of the information baggage in a single standard in an all-encompassing manner, but rather, considering the need to respond to a structure in accordance with a traditional rules and approach to the information acquisition.
The interoperability of the model, with external sources, could further affect the characteristics that an adequate CDE, for information sharing, is designed to encompass a greater number of users, in addition to those working in the more conventional BIM approach to design. The hope is to arrive at a standardized approach for the digitization and management of information material related to historical artifacts, beyond the mere technical application, exploiting BIM also in this area to limit as much as possible the percentage of interventions that cause unexpected aspects, which sometimes occur even when work has begun, slow down the executive and operational phases, up to the limit condition of blocking and incompleteness of the intervention. Multiscalar and multidisciplinary reading, it is hoped, could actually lead to an increase in the percentage of interventions carried out in full awareness of the consistency of the object of the intervention.
It should also be emphasized that such a digital architecture will require specific and specialized skills, in figures who can adequately be said to be able to manage, implement and read the entire information content with knowledge: if it is true, in fact, that in the field of digital humanities looking at the figure of a digital curator, able to organize digitization processes of archive material as well as manage data analysis and profiling systems, customer relationship management software, it is not unlikely that among the tools available to such an actor in the supply chain cultural and operational addressed to the CH, there may be those of parametric modelling, between the HBIM and data model sharing. Also in this case, the hope is not so much the need for a single figure to incorporate all the skills of those who act in relation to the Cultural Heritage, but rather to have knowledge of the various steps, so as to be adequately trained to implement the information and to discern, by exploiting differentiation processes for access credentials, which data of the database being built are assets of the entire spectrum of users and how much should become limited in use.
In this paper, the result of the authors' joint research work, Pierpaolo D'Agostino is the author of the paragraph 'Parametric modelling for Cultural Heritage. Topics and issues for a proposed method', Andrea Maglio is the author of the paragraph 'The history of the building: Methodology and sources', Giuseppe Antuono is the author of the paragraph 'Designing and sharing an infographic system', with 'Introduction' and 'Conclusions' by D'Agostino and Maglio.
Thanks to the Construction Company of engineer Paola Marone who, on the occasion of the restoration works of the Palazzo Cellamare, allowed access to the various spaces of the complex and favored the analysis of technical and documentary sources. We also thank engineer Davide Aterrano who supported and collaborated, in research aimed at the Internship in Building Engineering-Architecture, in the construction of the information database of the studio building.

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