Laura Inzerillo & Francesco Acuto

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The volume consists of a collection of contributions from the seminar "Digital & Documentation: The New Boundaries of Digitizing", realized at the University of Palermo on the day of September 2^{0h}, 2021. The event, organized by the experimental laboratory of research and didactics MetaLab 3D of DIING- Department of Engineering of University of Palermo promotes the themes of digital modeling and virtual environments applied to the documentation of architectural scenarios and the implementation of museum complexes through communication programs of immersive fruition.
The event has provide the contribution of external experts and lecturers in the field of digital documentation for Cultural Heritage. The scientific responsible for the organization of the event is Laura Inzerillo, University of Palermo.

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The event "Digital & Documentation" has seen the participation of professors, researchers and scholars from University of Palermo, University of Pavia, University of Bolzano, University of Rome "La Sapienza", University of Roma3, University of Catania, Politecnico di Torino, Politecnico di Milano.

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“Ogni uomo confonde i limiti del suo campo visivo
con i confini del mondo”

Arthur Schopenhauer

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Preface

Sandro Parrinello

University of Pavia

Associate Professor of University of Pavia, European Research Ph.D. in Representation and Survey Sciences. Since 2012, he is Visiting Professor at Perm National Research Polytechnic University (Russia) and in 2015 he receives an honorary degree from the State Academy of Civil Engineering and Architecture of Odessa (Ukraine). Since 2005, he is an expert of UNESCO; in 2011 he was appointed Expert and Voting member in ICOFORT as contact person for Italy. He is director of DAda Lab. - Drawing Architecture Document Action Laboratory of University of Pavia, and director of Joint LS3D Landscape Survey & Design laboratory of University of Florence and University of Pavia.

Drawings updating and languages rewriting for the structuring of knowledge

Now in its fourth edition, the conference on Digital Documentation demonstrates how the proposed topic is getting more and more relevant as time goes by. The identity of the digital world and its products are taking on new features.
For years now we have been witnessing a revolution in the procedures that had characterised the cognitive activity related to the science of representation for centuries. It is not just a matter of a "change of medium" or a change in the methodological aspects linked to the progress of technology, but a complete reinterpretation of human-space relationship that contaminates every cultural model. This change covers indeed, within the disciplines related to architecture and heritage, each characterisation of the creative process, outlining, via new configurations, opportunities that have yet to be explored and revealed.
The digital world breaks out of those gears and constructions where it has grown up until now to contaminate every aspect of life in the most profound way. The paradigm is that of Cronenberg's Videodrome, where media produce a dystopian evolution, i.e., the birth of homo videns.
In the film, this contamination between man and media leads to a renewed perception of the world among human beings, resulting in the total fusion of the digital and the flesh as a new way of existence. What is currently happening fortunately seems to have less tragic outcomes.
The digital that we experience on a daily basis does not manifest the horror of its distortion, as it does in the movie.
The process of approaching and seducing the digital is supported by a gradual entrustment of functions that trigger the illusion of a greater control over our thoughts, and thus produce a feeling of higher safety towards said relationship.
The digital is becoming more and more soothing and is gradually replacing interpersonal activities that concern more than just relationships between people, but the relationship between people, things and experiences themselves, which are themselves becoming increasingly digital. The digital experience is made of rhythms and times that differ greatly from the real one. Its immediacy is its strongest quality.
"All and now" should be the slogan for the user when researching online. Everyone can get answers and become something else when immersed in the net, just like in Spielberg's Ready Player One, even if these answers are not yet widely used through systems that provide immersive realities.

Apart from the digital interface, the media flood is producing, through the redundancy of continuous, homologated, standardised and incessant messages, a general disinterest in both the facts and possibly the actual matter. Let us just think of the new productive dimension that information has been experiencing for years now.
A piece of news that undergoes even the slightest critical process is born old and is probably similar to a thousand

others being produced at exactly the same time. The proliferation of information causes a detachment resulting in a surrender to the digital world.

Weddings with holograms, digital works of art, cryptocurrencies, digital experiences more attractive than real ones, are just a few examples of what could be considered science fiction just a few years ago. In this panorama, the opportunities for rewriting messages, redefining ethical and cultural models, and conveying data within the digital dimension appear almost unlimited.

So, what is the role of digital documentation? I believe that the task of our generation in these times of great tension is to bring as many experiences as possible into the digital era. What will be forgotten, overlooked, or even accidentally not digitised will be lost forever.

This is a great responsibility if we think of the vastness and heterogeneity of cultural heritage. It remains very difficult to imagine how this can be read and interpreted in order to find a specific position within the complex but nonetheless ordered structure that configures the digital dimensions. I am thinking of the intangible heritage, of the sound of the many dialects, of tastes and smells, and of the many pieces of information that do not yet find a place in the digital dimension, but whose existence is linked to customs and traditions that are being lost.

But the same may be true for information held by a text or a manuscript stored in an archive somewhere remote and thus not easily accessible. The precarious nature of this information seems even too evident today; whatever will not be uploaded not only into the digital domain, but into the network in general, so as to acquire its own digital echo, will probably be forgotten.

All the research experiences presented in this fourth conference have a common denominator: proposing tools to convey information digitally in order to preserve its memory over time. In the first session, about BIM, the development of architecture information systems is focused on historical architecture and the improvement of the modelling processes with respect to the reliability and the compositional and technological interpretation of the historical artefact.

In the second session, the digitisation experiences concerning the drawing archives address the issue of data structuring when bestowing an infographic spatiality on historical memory. In the third session, on the parameterization of models, more heterogeneous experiences are described, which examine how to interact with digital representation and complex models.

Browsing through the pages of these proceedings, many faces of digital documentation emerge, such as many research trends, cultural interests, operational needs. This world rich in knowledge, through the definition of models and modelling procedures, affects the deepest areas of representation.

The volume therefore constitutes a fragment, which is added to the previous volumes, to the other experiences carried out during these study days, but also to other conferences.

It participates indeed in the process of media coverage to which even scientific research must now succumb.
Nevertheless, I am willing to believe that, as usual for the Documentation & Digital Study Days, these proceedings, which are published one year after the conference, let us look back and consolidate our knowledge. One year in the digital information field might well feel like an era.
A global pandemic and the beginning of a new war in Europe occurred in between the conference and the production of its proceedings, thereby making the future of all research uncertain. This is why this fragment, this piece of experience, seems even more important: because information systems, models and the digital world in general should be able to help the progress of human thought but never replace it.
Hence, in a historical moment torn between wars and pandemics, where social and cultural realities contaminate each other, in a process of accumulation and stratification of symbols and signs, we hope to create a language that respects this complexity and represents, protects and supports knowledge.

S. Parrinello

Laura Inzerillo

University of Palermo

Ph.D., Laura Inzerillo is Associate Professor at University of Palermo within the Department of Engineering. Graduated cum laude in Management Engineering at University of Palermo, 1995. Ph.D in Digital Survey and Representation of the landscape and Architecture at University of Palermo in 1999. She won a fellowship ata Columbia University in New York from 1999 to 2000 with the confirmation of researcher at Columbia University from 2000 to 2003 at MUD. She won a post PhD fellowship at Univesrity of Palermo from 2000 to 2004 when she became researcher. Her field of expertise are the digital survey, 3D representation, Descriptive Geometry, reverse Engineering, monitoring. She is editorial member of several International Journals, reviewer member in other several International Journals, chief in editor of a special issue in MDPI Journal. She is actually authors of about 150 paper, 3 monographies, 2 chief in editor books and she won a best award paper. She has been involved in several international and national projects. Actually she is involved in SMARTI ETN - Sustainable Multi-functional Automated Resilient Transport Infrastructures European Training Network HORIZON20-20; in REMED - Application de l'économie circulaire pour une construction durable en Méditerranée ENI CBC MED European Union.

THE NEW BOUNDARIES OF DIGITIZATION:
FROM BIM TO PARAMETRIC MODELLING

This conference was the first appointment held using an hybrid mode: the first after the pandemic period. For this reason it was characterized by a particular enthusiasm due to the beauty of the meetings in presence and not in a remote way. In this background of happiness, we held our meeting. Moreover, Palermo had not appeared on the international scene, in the scientific disciplinary sector ICAR 17, for several decades and this occasion represented an expected and hoped-for return from the scientific community of the sector. Why do we talk about new boundaries of representation? In what sense do we mean the boundary of representation? New technologies take over more, and more rapidly, over those just introduced in the world of digitization and acquisition. The experiments of young researchers reach such avant-garde levels as to constitute a new starting point. The experience of the less young researchers and the innovativeness of the most immature researchers become a perfect glue for an effective and accurate methodological approach. The D&D conferences were born with the aim of giving voice to the research of young researchers to open new horizons of investigation in collaboration with the professors of the area, engaged for years in the various fields of research.

The themes that go beyond the boundaries of one's knowledge to expand to those of the scientific community, have been addressed in this fourth edition of the international conferences D&D, Documentation and digitization. It was not only a presentation day but a training day where the experiences and the passion of the speakers guaranteed an active participation of the guests.
The scientific insights, the methodological rigor, the passion and enthusiasm, with which the research was conducted and, consequently, handed down to us, have been driving forces for the entire scientific community.

Given the extensive participation and, given the versatility of the research ideas, three sessions have been planned: the first relating to BIM, the second to the digitization of archive drawings and the third to parametric modelling and video mapping.
The first session saw, as protagonists, researchers from Turin, Milan, Naples, Rome and Pavia. Daniela Oreni focused the research on the question of the 3D modelling within the BIM structure, the HBIM for the conservation and restoration of historic buildings and their representation. The Building Information Modelling is going to cover all design all over the fields of interest, in these last years. It is a new methodological approach of digital modelling which, with its interoperability, uses the tools and methods between tradition and innovation of the representation of anthropized reality whether it already exists or is in the design phase. The practitioner who intends to use BIM as an operational tool, must have matured the essential concepts of digital modelling and interoperability

between architectural and structural design with particular attention to aspects not only stylistic-architectural, but structural and plant, etc. working on the built heritage and on the one to be built; he must be able to compare contents, tools and modelling methods for the interpretation of the typical complexity of the built and the under construction.
He must possess skills in the communication of information typical of advanced modelling, skills in relationships for teamwork, familiarity with BIM tools and methods, processing capacity of a BIM concept map, creativity in the preparation of technical data sheets that illustrate the theoretical contents for a more immediate and user-friendly approach. However, it often happens that the professional, by necessity, improvises himself as a BIM connoisseur, without having the appropriate skills, creating complex and difficult to manage BIM models. The role of the researcher is to experiment and propose new simplifying methodologies of the BIM model; to implement interoperable concept maps of great effectiveness and simplicity at the same time.
Pierpaolo D'Agostino
Marika Griffo focused her research on the semantics through models in their ex-ante and ex-post classification processes. The 3D survey obtained by a photogrammetric or laser scanner process has innumerable potentials. However, the point clouds obtained from data processing represent a single and indistinct object, deprived of any ontological structure. Therefore, it is necessary to perform a deconstruction and classification of the cloud in order to create a semantic and explanatory model. Thanks to this deconstruction, the final model is easier to read and interpret. How does all this intervene in BIM modelling? When should semantic classification be introduced in BIM? In reality, the semantic code is created ex-ante through the use of hierarchical models in BIM space. The model obtained contains ontologically defined objects which are grouped by analogy or equivalence or are separated by diversity. In both cases the system is built thanks to a semantic construct, which has the purpose of organising the data in such a way that their classification is truthful and effective. Ultimate and fundamental goal of modeling is the understanding of the object.

Laura Inzerillo

Keynote Speakers

Cecilia Bolognesi

Politecnico di Milano

Cecilia Bolognesi Graduated in Architecture at Politecnico di Milano, PhD at University Institute of Architecture Venice, she is currently Associate Professor in the Scientific Sector ICAR/17 at the Department of Architecture, Building and Construction at Politecnico di Milano where she is responsible for the implementation of the Digital Skills in the Master degree of the School, Scientific Director of the Labora Laboratory (Fisical and Virtual Modelling laboratory of the athenaeum), part of the Scientific Committee of the SaperLab Laboratory (Computational Modelling Laboratory).

She has experimented with operational and methodological application in national context, mainly related with tangible and intangible case study, focusing on the relationship between survey, representation in the field of digital heritage and BIM environments. She has collaborated in several public contexts dedicated to modelling from the territorial scale to construction scale to finalize BIM and Virtual Environments.

She has held conferences, curated some monographs and several papers on different topics: modelling, BIM, HBIM, Virtual environments and representation. She is responsible for projects on Virtuality and Digitalization, Digitalization and BIM and HBIM and Task leader in H2020 projects regarding Virtual and Augmented implementation.

DIGITIZING IN THE 2.0 ERA

Abstract

Since the digitization of the built environment has become part of the goals of both the scientific community and the construction world, we have witnessed the rapid increase of studies and research aimed at the representation and management of models both of existing buildings and new architecture; from the first rudiments of BIM in the early 2000s, the BIM path is seen as a gradual path of growth, which is refined with the goal of the involvement of all actors related to the construction in a synchronous manner so much as to define collaborative BIM as the maximum degree of maturity that can be achieved. However, the difficulties that connect the path of BIM though mature to the way of Cultural Heritage are still many and many knots yet to be unravelled.

Da quando la digitalizzazione dell'ambiente costruito è entrata a far parte degli obiettivi sia della comunità scientifica che del mondo delle costruzioni, si è assistito al rapido incremento di studi e ricerche finalizzati alla rappresentazione e alla gestione di modelli sia di edifici esistenti che di nuove architetture; dai primi rudimenti del BIM nei primi anni 2000, il percorso legato al BIM è visto come un graduale percorso di crescita, che si affina mano a mano con l'obiettivo del coinvolgimento di tutti gli attori legati alla costruzione in maniera sincrona tanto da definire il BIM collaborativo come il massimo grado di maturità raggiungibile. Tuttavia, le difficoltà che legano il percorso del BIM pur se maturo al modo del Cultural Heritage sono ancora molte e molti i nodi ancora da sciogliere.

Scan to BIM and Level of Accuracy

In the U.S. regulatory framework, the maturity of the BIM method faces increasingly refined specifications as of the first definitions of LODs, explicitly defined as Level of Detail. At the same time in Europe, grows a market increasingly focused on the existing, developing necessary comparisons with Heritage and HBIM. In the Italian standard, LOD will be better and more detailed defined by LOG and LOI; we no longer speak of object detail but of LOG as Geometric Attribute Level and LOI, Level of Information Attribute Development (UNI 11337-4:2017). The Italian standard translates LOD as the level of object development by assigning a scale of values that proceeds from the symbolic representation of objects gradually with an increased degree of specificity: from LOD A, a symbolic representation to LOD F or G, an executed and updated object (Pavan, 2019). This simple division into LOGs and LOIs is enough to make one understand how the state of the art of BIM in Europe lives a different season from that in the U.S., having to deal with the built, the Historic Building, the Cultural Heritage.

Forced by the necessities of representing the existing, the concept of LOA, Level of Accuracy, is introduced among BIM developers; it is a concept necessary in a Scan to BIM modelling framework to express the accuracy needed between the definition realized by the point cloud and the model that is stitched on top of it. In the U.S., the topic of declining the BIM process in Heritage is methodically approached in a seemingly simplified manner, just think of current manuals. Among them those of the Institute of Building Documentation that give space to analyses of discrepancies between point cloud and BIM model stitched on them with simple observations and didactic instructions. “Building Better Within Existing Conditions” describes us as comparing point clouds to 3D solid models with extreme simplicity: “The accuracy of 3D models intended to represent existing spaces can be validated by visually comparing them with 3D point clouds. This is done by identifying deviations; areas where 3D model geometry exists but point cloud data does not, or vice versa. To validate the accuracy of the 3D modelled existing-to-remain systems, 2D section views are placed at locations of interest, or spaced regularly over a 2D floor plan using a 3D modelling tool. Differences between the point cloud and the 3D model are found and annotated manually in the section views.”(Institute for building documentation, 2016).

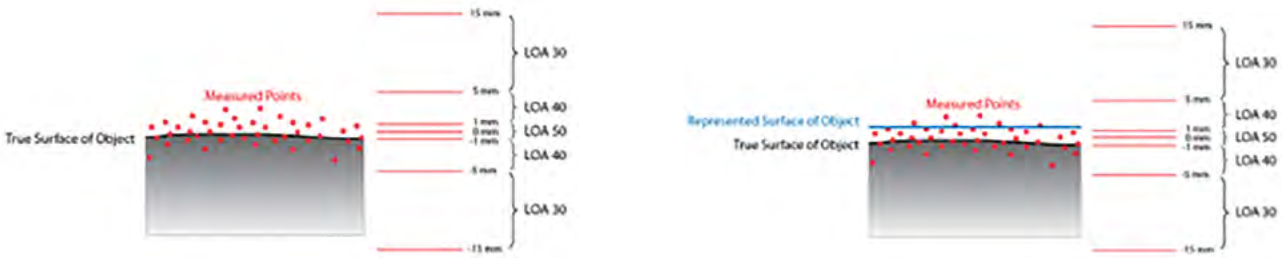

Fig. 1 - the level of accuracy between the scan data its representation in a model from Guide for USIBD Document C220TM

The documentation of the existing is associated with a theme of measurement and difference between the existing represented by the point cloud and the model, edited on it. In the European framework at the same time, the components related to the representation of the historical artifact become an increasingly refined process that incrementally develops all the potentials related to the world of digitization; Scan to BIM processes at first take advantage of the advancement of technical tools such as time-of-flight TLS that over time develop models integrated with high-resolution digital cameras for chromatic capture of materials, confining photogrammetry to increasingly specific areas (Fiorillo, 2019).
In recent years HBIM enters an increasingly mature phase; modelling by objects no longer seems sufficient to tell all the peculiarities of a geometry proper to historical models. In a first phase there is no possibility of modelling Cultural Heritage objects and modelling software offers objects -placeholders- with respect to which only the measurement of a distance, first geometric, can be established. In a second phase, we see the possibility of modelling by masses, in which modelling is also done by subtraction of volumes. In a third phase, the current one, nurbs surface modelling software relates to normal parametric software and offers the possibility of modelling within the most complex platforms already (Rhino, 2020).

An era of platforms

Once the full mastery of the model is obtained, the research does not stop and always progresses in a Web 2.0 perspective: in the digitization process that goes through the HBIM chapter, all the tools for managing the model, including cataloguing, or detailed description for its maintenance, enter. We are in the realm of CDEs (Common data Environment) for BIM models with respect to the new built; in the Heritage field it is a flourishing of platforms that define maintenance possibilities with respect to the artifact but also of collection of documents or data bases that can refer to the model itself. There are growing number of platforms that need to find possibilities to make available to a less prepared audience the management of models for the maintenance of buildings; platforms that override the age-old issues of interoperability or the obvious incapacity of networks and the in-local memories of the PCs provided (Apollonio, 2017) . This area also seeks to address some of the endemic shortcomings of models in the management of model textures and materiality; the libraries offered by modelling software are too primitive for a field such as Heritage, and the creation of Decals to refer to the model still a poorly efficient tailor-made path.

Digitizing in the age of Web 3.0

We know that with the approach of Web 2.5, the one we are currently experiencing to be clear, or better the next 3.0, there are several issues with which an update with respect to BIM, HBIM, and digitization of Cultural Heritage is expected and in which we are working already.
In the current structure of the web, the next generation of Internet technologies relies on Machine Learning, Artificial Intelligence (AI) and blockchain technology. And it is not just that, some technologies more than others are crucial in the fulfilment of what is called a fourth industrial revolution: new computational technologies and quantum computing technologies in current stage of development have made computers millions of times more powerful; Artificial Intelligence has opened up the possibility of computation and training of neural networks through Machine learning ; blockchain is only in its early stages and has opened up the phase of decentralization of data without intermediation; VR AR and XR are a field only in its infancy; the possibility of 3D printing, IOT open up vistas in which we are taking our first steps.

Now on the doorstep of the fourth industrial revolution, the structure of the BIM process increasingly makes use of algorithmic and computational systems. At the heart of this revolution is the automation of industry, with the exploitation of artificial intelligence, blockchain and robotics. With a view to innovative projects in terms of digital transformation, services, design methodology and technology in the construction supply chain, the use of these tools, represents a path that is as necessary as it is constantly evolving. It is through this new approach to the design and management of the artifact in construction that new challenges have inevitably arisen, including:

- The difficulty of the applicability of geometric and informational data to more advanced forms of graphical representation (VR, AR and Metaverse);
- The difficulty in the creation and management of sharable standards in the linguistic plurality of models;
- The issues related to the management of data ownership (privacy) and quality in geometric-informational terms (LOD);
- The sharing of data processed manually or with automated processes and algorithms that are still not appropriate.

It is only through a broader consideration of the tools and methodologies available today (including: BIM, Blockchain, Metaverse, AI, computational design software and advanced visualization tools) and on the processes of contamination between these tools that procedures and methodologies useful to the BIM process in the 3.0 environment can be defined; procedures aimed at improving the representation, sharing the data management of models in the virtual environment, and the visualization of attributes necessary for description in the Heritage environment. We are far from established procedures reason why, in this unstable system, is the time when the most interesting research can happen, and the most useful experiments open.

An experiment in querying the BIM model in the Holographic environment

A hot topic in the 4.0 era is the alignment between the visual quality of models within a processor with a traditional laptop and that of the most modern immersive tools specifically a Holographic table, encompassing in the experiment the attempt to manage model information data while in an immersive environment.

Background

Even if in recent years BIM has grown in diffusion and technicalities bringing many benefits to the AEC sector, the visualization process of a 3D model out of a flat screen, in the space, seems to have not yet had a real output if not limited to certain sectors: video games, with immersive virtual reality, some augmented reality applications in the field of industrial automation or aerospace using specific devices. Also, many of today's challenges in Cultural Heritage practices concern the need to have a visual assessment of 3D models that is as accurate as possible (Reaver, 2019). The growing gap between a real spatial visualization of designed solutions of buildings and remote access to Heritage (that in the future we will probably no longer have) necessitates better 3D Visualization tools enabled by digital technologies towards new paths of virtual construction practices (Marasco,2018).
Virtual, Augmented, Mixed reality with Holography seems to be the right tools to create complex architectural representations that enable cognitive understanding of space more like reality world just for their possibility to offer an immersive environment and interactive use; they can improve the understanding of the Heritage through the integration of virtual information, expanding immersion and environmental knowledge (Anderson et al 2020). Only through a serious

analysis and contamination through these worlds a complete path can be developed to better represent and use a 3D Visualization (Jouan, 2021).
Here we evaluate a form of virtual approach useful for CH resulting in line with the expectations of the 2021-2024 agenda of the European Union (EU): a stereogram in a Hologram Table, a BIM model of a residential building of the nineteenth century. This experience shows many critical issues that are the open challenge to reflect upon regarding:

- accuracy of the models in the visualization stage
- scale of the digital replica
- interoperability of models, devices, platforms
- size and storage of models, size of a projection space
- viewing information related to models
- interfaces between the model and user
- usability by several users at the same time

The Hologram Table consists of a horizontal surface (2.1m x 2.1m) with four integrated projection device and it is one of the equipment of the new LaborA - physical and virtual modelling laboratory (Politecnico di Milano). It is composed of a large and flat surface (2.1m x 2.1m) and a metallic frame structure to which all technological components required for the holographic display of 3D models as well as the wooden panel of the top plane are attached (Euclideon, 2013).
The workstation connected is a standardized Dell 5820 workstation (Dell, 2020) equipped with two Radeon WX 5100 graphic cards (AMD, 2020). Four main projectors of the hologram table to display the 3D model on a flat screen. Interaction with the holograms is performed with a specially designed wand, which, as though the glasses, uses an infrared tracking system to calculate their position and orientation in space. The spheres on the wand and the glasses are used to compute their correct position.
Tracking equipment consists of tracking domes and controller, Radio Frequency Dongle and Sync Emitter, which are USB connected to the PC. Sync emitter will receive light from glasses and wands and sync all devices to work together.
The flat-screen area comprises a rear-projection material (white cloth) that is sandwiched through a 10 mm thick acrylic sheet and a 1.5 mm one. This area (1390 mm2) is the central display where holographic display takes place. The system projects the 3D models so that they appear to rise from the centre of the table to a height of approximately 0.7m in a hemispherical volume (Makey, 2019).

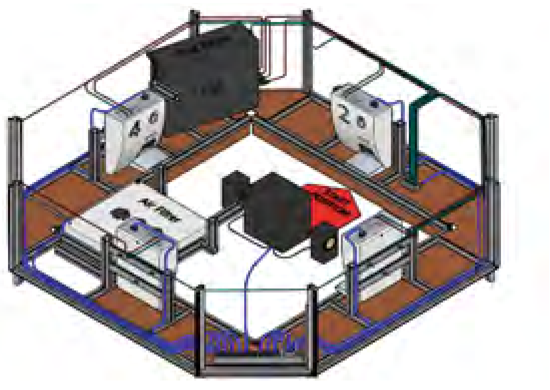

Fig. 2 - on the left the Hologram table set up; on the right the glasses and the wand

A holography of a BIM model: a residential building

A holography of a BIM model: a residential building Via Lulli is the case study: a low-cost residential building of the early 900 century surveyed for future renovation but also to test its transformation into a BIM model for its holographic fruition; the research topic has concerned the validation of the workflow from the 3D digital survey to the holographic visualization, then developed with a tool for automatic extraction of information in the innovative Hologram Table© environment.

The ability to query a 3D BIM model visualized in a 3D space in front of the operator and not simply through a desktop is a completely new field in research with many potentialities. In this case the first survey was totally set up with RTC360, a high-speed time-of-flight scanner with scans of 2 million points per second with simultaneous capture of spherical HDR (High Dynamic Range) images. The point cloud obtained was pre-aligned cloud to cloud in situ with Cyclon app and then registered in Register 360 proprietary software, obtaining a cloud of 19 scans set up with resolution 8mm and 1.390.581.390 points. The survey campaign last one afternoon for outside elevations and common spaces. The point cloud obtained from the previous survey was processed

Fig. 3 - a typical workflow in Hologram Table

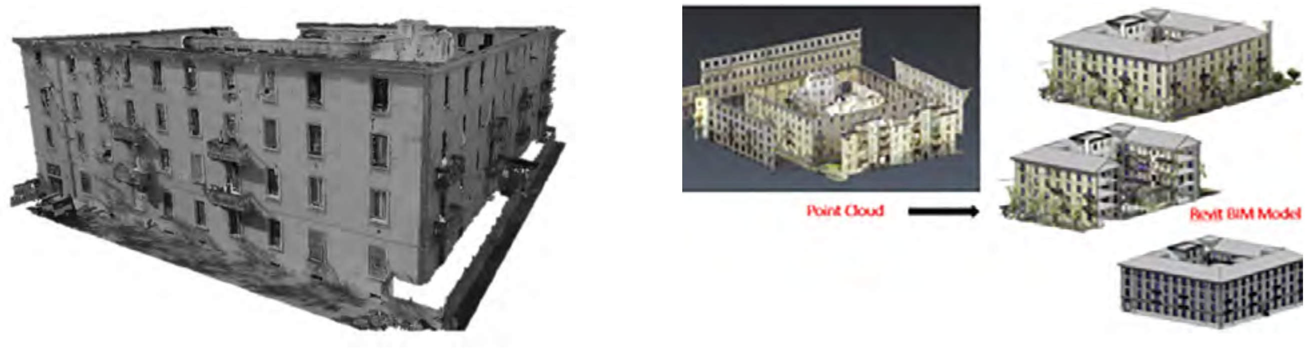

Fig. 4 - From the point cloud to the BIM model to the Holographic view

in automatic cleaning through proprietary software to clean noise and redundancy of points; the e57 file (43GB) was then exported from into Autodesk Recap 2020 to obtain RCS format (4.13GB), allowing the upload in Revit 2020 and the subsequent modelling

For the modelling, a LOD300 has been set, as it is strictly necessary and sufficient to verify the workflow and the information exchange required for the research in progress.

The research therefore focused on the possibility of reading not only the geometry of the mesh model, but also the information data, images and detailed elements in an immersive environment explored through the Unity platform, creating scripts, and also using the tools of the "Unity Toolkit Sample".

The Holographic table thus experiments an interactive mode of visualization and the possibility of implementing information on objects throughout the model, ready to be semantically enriched by users. The complete scripting procedure has been released for public.

To do so, after the modelling phase, the model has been exported from Revit with Datasmith Exporter Plugin-Unreal Engine (Unreal Engine Development Team, 2021).

This plugin allows you to obtain files still containing geometrical objects, Mesh and Texture exported from Revit and to visualize them and their metadata in the Hologram. In the final steps of a long experiment the user can move rotate and resize the model and automatically view the properties of the elements present in the original BIM model just selecting individual objects with the magic wand of the table. In addition, to facilitate the use to the user, a menu has been implemented, to be managed with the wand keys, where more options are available.

Conclusion

Although the applications of web 3.0 and the fourth industrial revolution are also the place of comparison for BIM in its most current applications, the Holographic fruition in its 3D dimension facilitates the representation and enjoyment of the existing with a spatiality that is very close to the real but the process is still far from fully satisfactory implementation. It has the possibility of being implemented with tools and instruments for its semantic study and deepening. However,

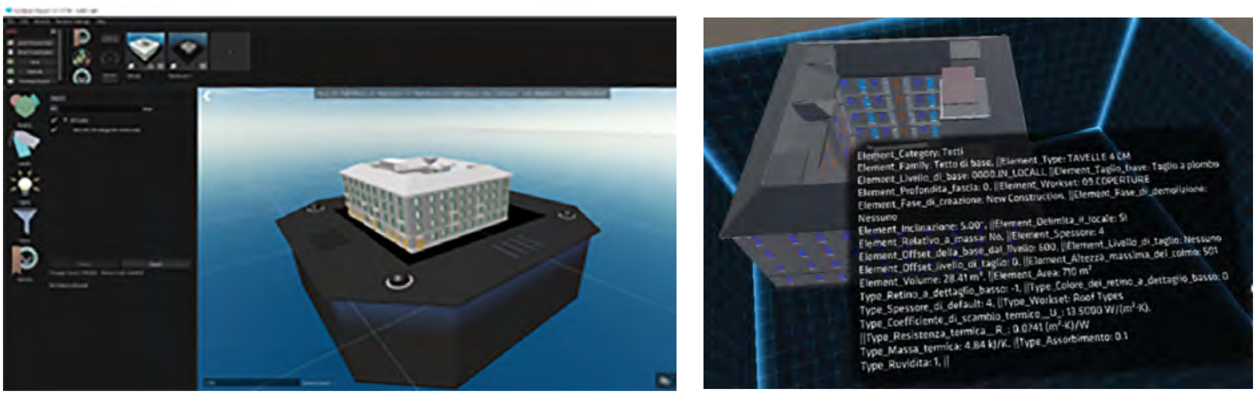

Fig. 5 - On the left Revit Model in Euclideon Presenter; on the right the data in the model projected on the Hologram table.

there is still a long way to go as many aspects are not solved. The reproduction of digital models in the table can be done either with the visualization of point clouds or with textured mesh models but in both cases, and with different results, it is an excessively time-consuming process. In addition to this, interoperability problems are also an issue; the ability to visualize models of any size in the holographic table necessitates application development in the cloud, to support usage otherwise limited by the size of the models. From these and other issues we can say that innovations at least in holographic model visualization, especially in the multi-user field are only in their infancy. The possibility of querying the dataset provided in the BIM objects and textures is only now beginning to have even commercial visibility and the following possibility of expanding the themes of informative reproduction and accurate visualization.

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SESSION - I

BIM

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INTRODUCTION

The contributions critically reflect on the characteristics and uses that the three-dimensional digital models set up through an HBIM approach and referred to the built heritage can be usefully employed not only to support the design activity but also for integrated multidisciplinary approaches related to conservation and documentation initiatives.
The reflections that emerge from the critical analysis of the various case studies illustrated by the invited speakers are particularly interesting: the authors measure themselves on a multiplicity of themes all referable to the discipline of Drawing, such as the scale of representation and their relationship with the granularity of the model. Moreover, the quantification of the deviation between the numerical model -intended as the outcome of the sampling of representative parts of an artifact or part of it- and its conversion into a mathematical model, in which the numerical codes are structured and organized to describe geometric shapes, dimensions or qualitative information useful for their representation.
In the BIM approach, the mathematical model assumes the additional connotation of information model, where some workflows can provide algorithmic approaches that integrate Visual Programming Language systems, highlighting strengths and weaknesses of the most recently designed workflows. This allows to outline future research perspectives, in relation to the exploration of the potential of automatic classification through Artificial Intelligence algorithms, which constitute the boundaries of research and, although of extreme interest, cannot yet be considered as fully defined and shared standards.
Another issue discussed in the following contributions is the opportunity to integrate the alphanumeric attributes of the BIM virtual environment with an ontological structure of data, aimed at the production of a more structured database and able to fully define the logical relationships between the parts.
With regard to the restitution of reality-based artifacts, it is more appropriate than ever to dwell on the evaluation of the best technologies for the optimization of mobile scanning survey protocols and the three- dimensional representation of the historical built heritage, to be adopted for an effective process of measurement and subsequent restitution of the artifacts. For specific activities characterized by a high level of complexity such as those illustrated below, it is crucial to define strategies, approaches and structured protocols to implement shared work actions, so as to obtain elaborations of a very high-quality level consistent with the limited time that projects and consultancies foresee.
Through interoperable practices it is therefore possible to conceive operational scenarios in which all the actors involved can directly implement the data recorded in situ in an agile and accessible way. To do this, it is essential to support the object-oriented paradigm with the conceptual aspects of relational approaches useful for the management

of heterogeneous, numerous and constantly updated data. From a more scientific point of view, the application of these principles will allow us to face and define new methodologies for the knowledge (and representation) of the Cultural Heritage through more transparent processes. Therefore, the reflections on integrated approaches of investigation leading to new forms of Drawing able to expand the frontiers of our discipline in the direction of a greater formal qualification and in the permanent relationship between architectural space and information space appear extremely interesting. In this regard, the London Charter defines the principles to be followed for the three-dimensional representation of Cultural Heritage, in line with the values of transparency, communicability and repeatability of the methods and results of the modeling processes. We agree that knowledge is the first stage of preservation, and the described research fully confirms this assumption.

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HBIM FOR HISTORICAL HERITAGE CONSERVATION AND RESTORATION ACTIVITIES: THE QUESTION OF THE 3D MODELLING

Abstract

This paper intends to make a series of reflections on the characteristics of a three-dimensional digital model and HBIM of the built heritage in support of the project and the conservation activities; one of the main objectives is to highlight the limits still existing in the effective use of this tool in restoration sites, despite the developments in research.
The considerations exposed derive from the analysis of a series of case studies faced in the last years, confronting with themes such as the scale of representation of the model, its division in complex elements and the real possibility to scale the models according to the different necessary objectives, the controllability/comparability of the models and the three-dimensional contents represented, according to standards and graphic modelling codes not yet defined and shared.

Il presente contributo intende fare una serie di riflessioni sulle caratteristiche di un modello digitale tridimensionale e HBIM del patrimonio costruito a supporto del progetto e del cantiere di conservazione; uno dei principali obiettivi è quello di mettere in luce i limiti ancora esistenti nell'uso effettivo di tale strumento nei cantieri di restauro, nonostante gli sviluppi della ricerca.
Le considerazioni esposte derivano dall'analisi di una serie di casi studio affrontati negli ultimi anni, confrontandosi con temi quali la scala di rappresentazione del modello, la sua scomposizione in elementi complessi e la reale possibilità di rimodulare i modelli in base ai diversi obiettivi necessari, la controllabilità/confrontabilità/ dei modelli e dei contenuti tridimensionali rappresentati, secondo standard e codici grafici di modellazione non ancora definiti e condivisi.

Introduction

As it is well known, BIM is a process management tool; in the case of historic buildings, this tool manages all the activities related to a conservation and restoration interventions, starting from the collection of data up to the management of the construction site and planned maintenance of the asset over time. The geometric and morphological complexity that characterizes the stratified ancient structures and the large amount of heterogeneous data that are essential to designing and managing a restoration site, make the construction of an HBIM particularly complex (Brumana 2018).
In recent years many researchers, at an international level, have dealt with different topics related to BIM for historical heritage. Among interrelated research themes, the most frequent topics are about the issues of parametric three-dimensional modelling (Volk 2014, Dore, 2015, Brumana 2020), starting from complex data surveying (Adami 2021), ontologies and sharable vocabularies (Acierno 2017, Della Torre 2020), interoperability between different software, proprietary and open source.
At the same time as progress has been made in the creation and testing of BIM models for historic buildings, regulations, both at an international and national level, have also changed and evolved. They provided increasingly specific indications and guidelines, aimed at the future massive use of these tools including the management of construction sites on existing heritage and not only in the service of a new architecture.
Nevertheless, there are still many difficulties in the creation of HBIM for historic buildings and numerous limitations related to their real use in the restoration sector.
In this panorama, the issue of the identification of shared standards of three-dimensional representation is fundamental, to guarantee both a correct transmission of information and a real sharing of data among the different actors involved in the process. All the issues related to the possibility of comparing and integrating different models, both geometrically and informatively are linked to these above-mentioned aspects.

A necessary change of perspective

The use of BIM for the project and the restoration site requires, beyond the operational and technical issues, a series of theoretical reflections on the need to update and rethink some modes of representation, traditionally used in the cultural heritage sector. These reflections concern both the characteristics and levels of detail of the geometric model and the way in which qualitative information is represented in three dimensions (e. g. thematic maps) (Fig. 1). In fact, the issue today is to transfer representation, description, and design methodologies, now consolidated in the field of restoration and prevalently two-dimensional, into a parametric three-dimensional model conceived as a dynamic database, shared and continuously updatable, with information of a different nature. This requires some changes of perspective on the part of the field of representation, interacting with the different actors involved in the process of conservation and restoration, called upon to determine each time the specific objectives of the HBIM model to be created; overall considering the logic of organization of information that underlies modelling by elements (Fig. 2).
Therefore, it is not simply a matter of transferring into 3D the information that was traditionally represented in 2D (e. g. thematic mapping), but identifying new ways of organising information, which by its nature is discontinuous, inhomogeneous and with different levels of detail depending on a specific part, and codifying new shared graphic languages. These needs are also fundamental for representing three dimensions' geometric information that is often unknown, both geometrically and constructively, since it is internal to existing structures and therefore not always detectable. Information regarding the different layers

present (e.g., plaster), the depth of the various pathologies of deterioration, and the real constitution of the internal parts of the masonry are also often unknown, for which it often happens to have very accurate survey data of only one of the two sides (typically the intradoses of the vaults). The difficulty of modelling this type of information is not operational, given that there are many possibilities offered by the tools available and that the parametric objects can be updated continuously (for example during diagnostic or construction activities) (Banfi 2022); the question is instead more general

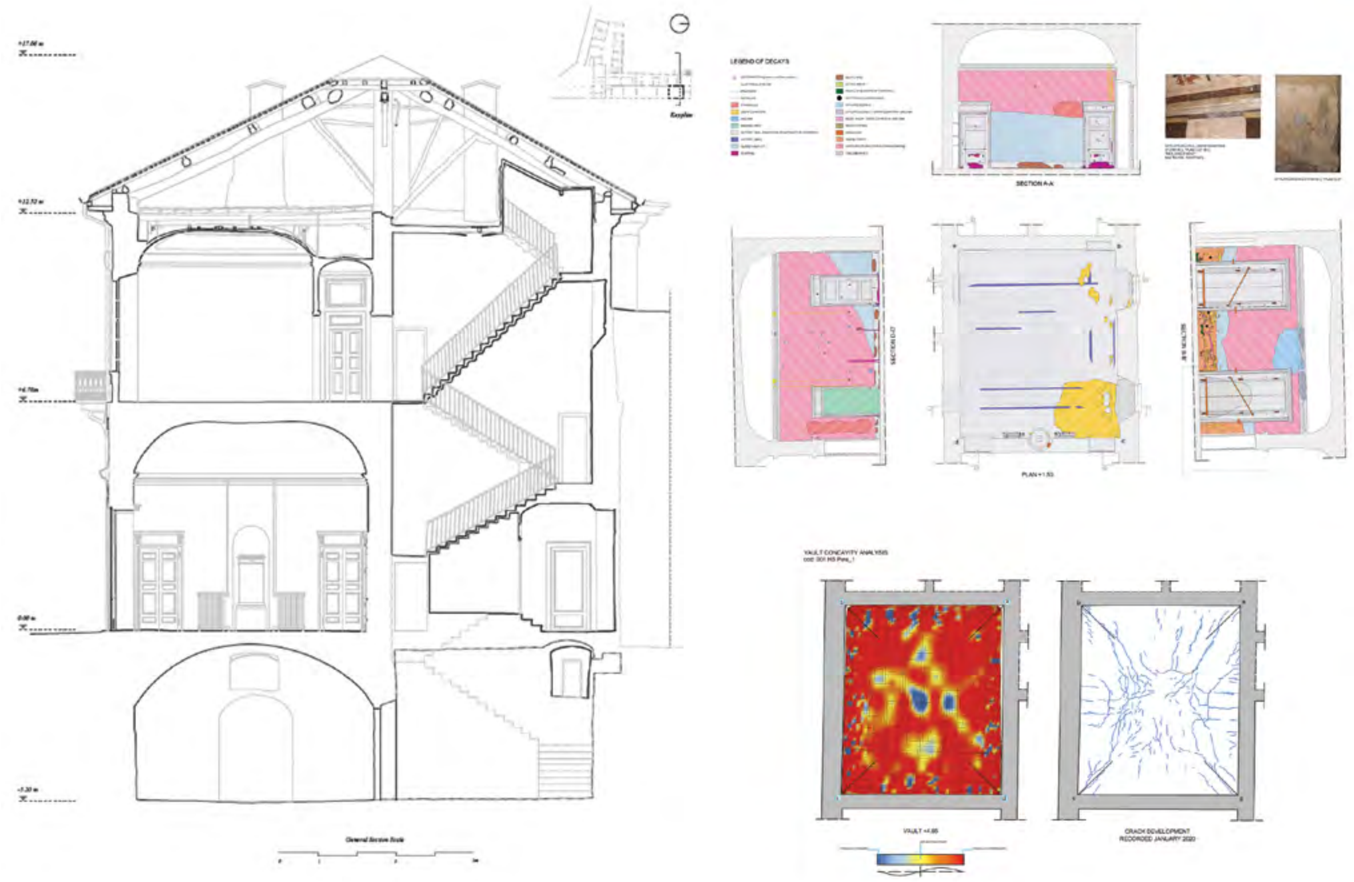

Fig. 1 - Villa Sottocasa in Vimercate (MB): classic two-dimensional representations with indications of degradation pathologies in the Greek Room on the ground floor.

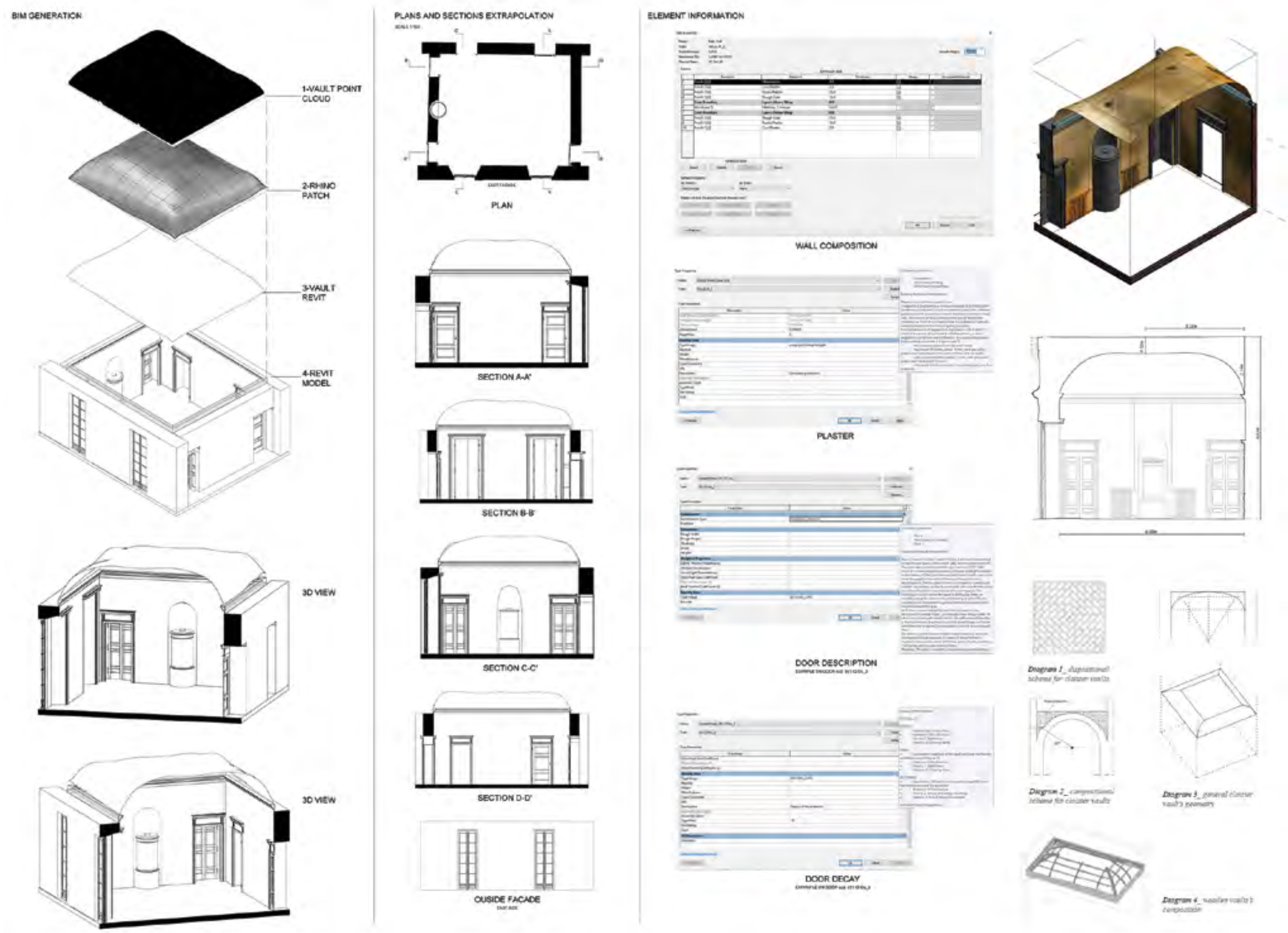

Fig. 2 - Villa Sottocasa in Vimercate (MB): the construction of the HBIM model of the Greek Room using the scan to bim process.

and theoretical and concerns the possibility of identifying new, shared standards of representation.
This change of perspective obliges us to think in three-dimensional terms from the outset, without passing through two-dimensional representation in all its forms.

HBIM for the conservation and restoration of historic buildings: objectives, potential and limits

The need for a change of perspective has been dictated in recent years by the desire to use and adapt BIM software also for the representation and management of historic buildings, with all the consequent difficulties, well documented in the literature. Although, BIM was born as a process management tool, from the research carried out in recent years is evident that HBIM models have been more often used for the documentation of a state of art or project simulations, rather than for the building site, since there are still many objective difficulties in the use of these tools for historic buildings. This issue can be explained by the need, first of all, to deal with a tool created for different purposes, which has led many scholars to test the potential of BIM in applied research on real buildings, not necessarily followed by construction site activities, in order to identify a repeatable and sustainable workflow of activities, from survey to representation and management.
The main difficulties connected with the diffusion of these tools in the restoration sector, outside the university and research sphere, are linked to various factors, mainly related to the skills required by designers and clients, the time and cost of creating complex models, and the real interoperability between software. A lot has been done in this direction, both with university and post-university training, with the work of groups such as Buildingsmart Italy (for example on the issue of open-source software, interoperability, etc.) and construction regulations; nevertheless, the road to widespread use of HBIM for restoration sites still seems long.
However, the experiences conducted to date have clearly shown, even more than for other tools, the need to establish the objectives and uses of an HBIM model for the built environment from the outset: a. for the documentation and cataloguing of information; b. for the management of the site or the maintenance of the building over time; c. for touristic fruition; d. for the visualisation and sharing of knowledge (e.g. virtual reality, augmented reality, etc.); e. for design simulations. In addition to this, it is essential to evaluate the different actors involved on a case-by-case basis, in order to determine all the needs related to the interoperability of the model with other software (e.g., those for structural or energy analysis) (Parrinello 2021).
Whether we are dealing with historic buildings or archaeological remains, the question of the geometric modelling of the asset is inevitably a central issue in the construction of an HBIM for site management, starting with the accuracy of the initial survey data. Currently, the research has produced excellent results with "scan to bim" techniques, using both laser scanner and photogrammetric data.

A question of representation: the need to define three-dimensional modelling standards for historic buildings

Although the question of representation of parametric modelling is only one aspect of the issue of constructing an HBIM for a historic building, its realisation raises several fundamental questions that already need to be answered at the stage of acquisition of the survey data:

- What should be the geometric level for a 3D/HBIM model for the building?

- What is the level of simplification of the model and its elements?
- How many models are needed?

The first question inevitably refers to the problem of the scale of detail, representation of the model and the controllability of the result. The Italian UNI 11337:2018 standard has defined the need that for historic buildings, the subject of a conservation project, s created an "As built" model of the building, with all the operational and economic difficulties that it entails, without however defining objective parameters. According to the traditional method of a two-dimensional representation of a restoration project, as required by the competent *Soprintendenze*, the starting point are graphical drawings on 1:50 scale, with the possibility of scaling down where necessary and delegating much of the more detailed information to specific analytical sheets. Transposing all this geometric data, but also information, into a three-dimensional parametric model means first of all understanding what needs to be the scale of detail of the elements to be represented, which by their nature are geometrically complex, irregular

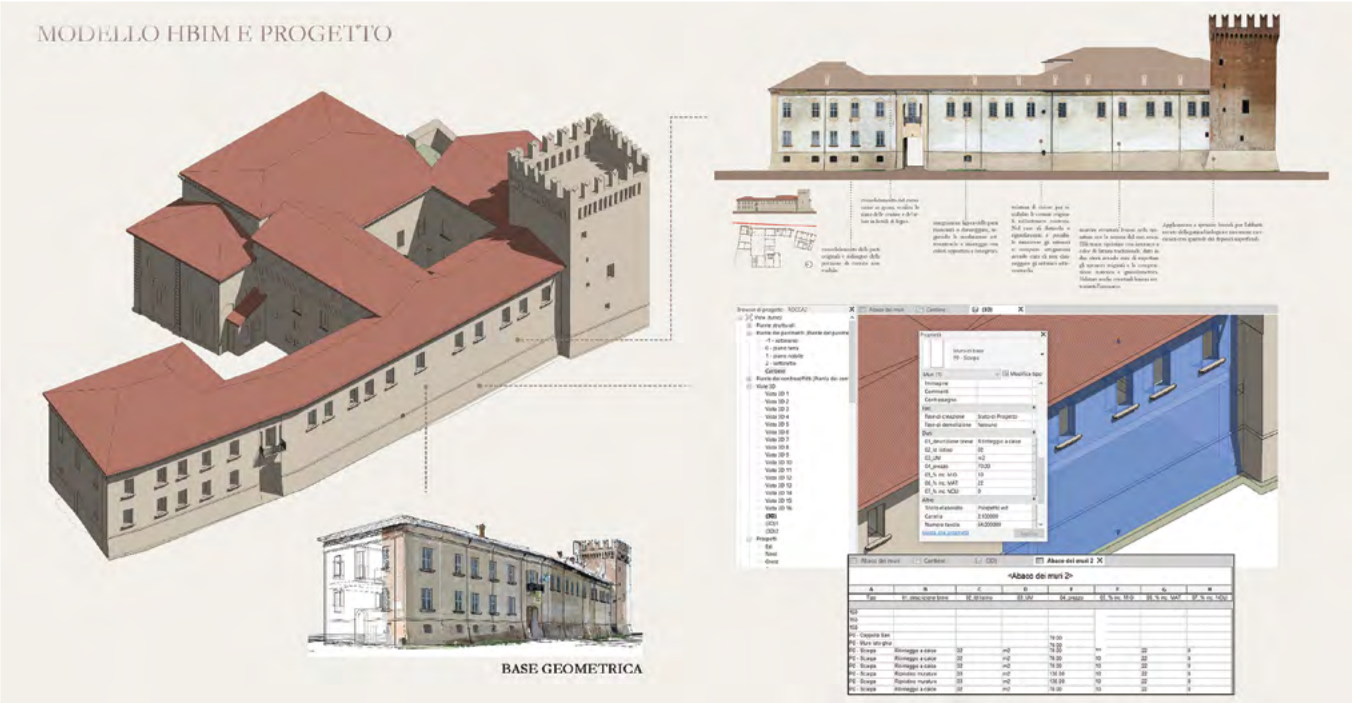

Fig. 3 - The Rocca estense di San Martino in Rio (RE): HBIM model for façade conservation project management.

and inhomogeneous; all this taking into account the fact that today's modern surveying techniques allow us to have an enormous and extremely accurate amount of data, at a scale of representation that is even more detailed than that required in many circumstances.

Thus, what does an "As built" model mean for the existing buildings? A model on a scale of 1:50, with a tolerance of 2-2.5 centimetres in the definition of the geometry of the elements? Or on a scale close to 1:1, as now is possible using "scan to bim" techniques, either from laser scanner or photogrammetric data? And then, there are a whole series of difficulties connected with the expenditure of energy to carry it out and with the management by the various interlocutors involved in the process (e.g., Public Administrations). These issues are not resolved even in the European UNI EN 17412-1:2020 standard, where the concept of "Level of Information Need" appears instead of "LOD", underlining the need to always define the use before defining what information is needed, thus avoiding "information waste".

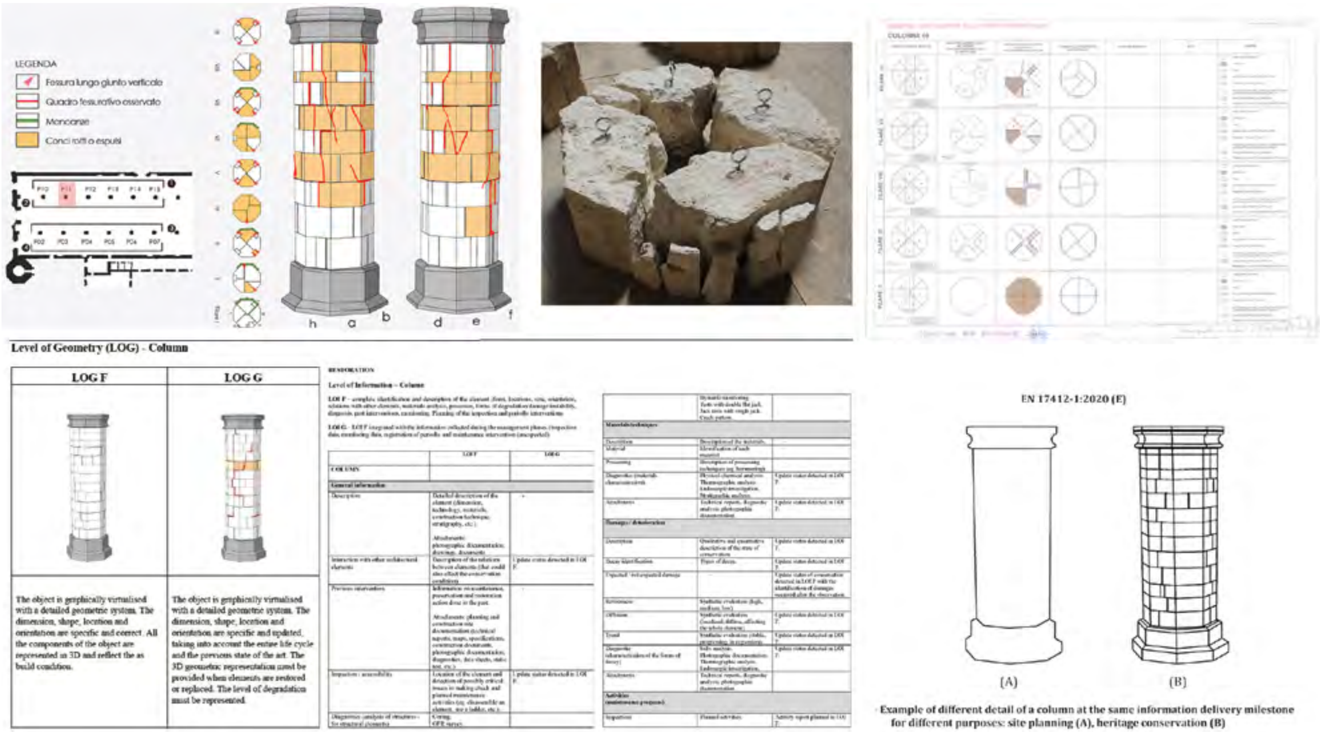

Fig. 4 - The experience of the HBIM model for the restoration site of the Basilica di Collemaggio in L'Aquila at the service of the construction of UNI standards (UNI 11337:2018, on le left; UNI EN 17412-1:2020, on the right).

There are two aspects to consider when it comes to the model's controllability and therefore the processes of model making: on the one hand, the geometric accuracy of the model concerning the survey data (standard deviation, etc.), and on the other the representative congruence of the elements concerning the scale used. If, as regards the first aspect, this control and verification can be carried out within the modelling software and as regards the second aspect, there are currently no shared parameters that allow this to be done. Accordingly, he questions that arises is whether it is possible to define this minimum quality level of a model for cultural heritage, as is the case with tolerance at two-dimensional representation scales. This is based on the assumption that the question of scaling of models is not currently feasible and that one can only work by progressive decomposition of the initial elements, in a critical, manual and therefore very time-consuming and costly manner.

Conclusions

The level of knowledge of a historic building derived from the cognitive investigations carried out and it typically varies in level of depth depending on a point of interest. Therefore, it is non-equally distributed point level of knowledge, which is reflected in the real impossibility of modelling all the parts with the same degree of precision, often proceeding by making geometric and informative hypotheses about hidden parts.

When it comes to creating an HBIM for the management of a conservation and restoration activities, it is fundamental to address first of all the questions of the parametric model, with the consequent need to define precise standards for the geometric model, as well as for the information data, in order to facilitate the sharing of data at different scales, starting from clear objectives defined a priori. To date, there are no methodological indications in this direction, making the comparison between different models and between the information contained and associated with individual elements eminently complex.

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TOWARD THE AUTOMATION OF DIGITIZATION.
BIM EXPERIENCES OF MANAGEMENT, CLASSIFICATION AND RECONSTRUCTION OF BUILDING AND ARCHITECTURAL COMPONENTS.

Abstract

The article focuses on the use of automated processes of classification and reconstruction for the digitation and the management of the built heritage, including both valuable and conventional buildings. It summarizes a research path followed in the last years, concerning new Cloud to BIM approaches for the recognition and the reconstruction of complex objects and shapes, both from images and point clouds. Some case studies will be presented, detailing specific innovative approaches involving visual scripting and programming, highlighting strong and weak points throughout all these experiences. Finally, future research perspectives will be outlined, in relation to the exploration of the potential of automated classification through Artificial Intelligence algorithms.

Il contributo focalizza l'attenzione sull'utilizzo di procedure di classificazione e ricostruzione automatica per la digitalizzazione e la gestione del patrimonio costruito, sia di pregio che di edilizia convenzionale, tratteggiando un percorso di ricerca intrapreso negli ultimi anni sui nuovi approcci procedurali nell'ambito del Cloud to BIM per il riconoscimento e la ricostruzione di oggetti e forme complesse, da immagini come da point cloud. Verranno presentati alcuni casi studio, entrando nel merito di specifici approcci innovativi di visual scripting e di programmazione, evidenziando i punti di forza e debolezza delle esperienze condotte, nonché le prospettive future di ricerca del potenziale della classificazione automatica per mezzo di algoritmi di intelligenza artificiale

Introduction: Connections between real building and digital clone. Toward modeling automation

Parametric and algorithmic modeling is acquiring an increasingly crucial role as a fundamental tool at the base of virtualization and automation processes for management and fruition of the cultural
heritage. This is also fostered by the digital evolution that has affected the tools for the maintenance and renovation of the building stock. In fact, Building Information Modeling (BIM) notoriously represents the current solution for new constructions, and a possible future solution for existing buildings (Volk, Stengel & Schultmann 2014). Concerning the latter, its development depends on two factors: on one hand, on the realization of coherent digital models that represent digital clones of the existing building; on the other hand, on the necessity to create suitable digital platforms for the input of data obtained from the surveys, serving as adequate databases for the parametrization of the digital instances within the information model. Moreover, the creation of information models in applications concerning structural management is an expanding research field, based on the idea that BIM data generated and acquired during the life cycle of a building can improve interactions with it, in compliance with OpenBIM paradigm and with the so-called information maturity level 3. At the same time, 3D visualization allows improving cognitive and perceptual reasoning for problem solving, avoiding difficulties related to the mental spatialization of constructive elements.
Moreover, BIM visualization provides accurate geometric data that can support the analysis of operational purposes regarding interventions and checks. At the same time, there is an increasing number of applications that integrate BIM technology with FM through IoT approaches, which allow establishing a communication between the real building and its digital clone through interfaces and dashboards designed for analytical data reading. Despite the evident advantages resulting from the interaction between BIM and 7D model (for the management of a building during operation phase), there is still a limited knowledge on implementation requirements, including information modeling for the sector of Facility Management (FM), interoperability between FM and BIM technologies (Carbonari, Stravoravdis & Gausden 2015).; moreover, operators in FM sector lack BIM skills. Besides, difficulties with respect to the interaction between the material object and the digital twin pose some issues toward a feasible implementation of BIM logic, where, typically, solid modeling is compounded and augmented by information parametrization. Indeed, although commonly several applications use information without associating it to the geometric and formal component of 3D modeling, at the same time such approaches are deeply abstract, and require the employment of workforce with specific skills, in order to interact with digital data without a user-friendly interface.
Concerning information sharing and BIM-oriented database population, several applications integrate BIM technology and FM, use identification systems that allow tagging through RFID (Radio- Frequency Identification) devices or QR codes. Nowadays, this strategy is particularly effective and rapid in relation to the obtainment of single data, while it appears to be limited with respect to punctual georeferencing within a formal virtualization of the digital clone (Kim, Passant, Breslin, Scerri & Decker 2008).. This led to the definition of a workflow in order to indicate damages to a physical component in a way that allows real-time transformation into information that can be associated to the digital clone. The process is aimed at automatizing direct tagging with solid instances, by integrating VPL and routines within Python and relating real-world coordinates and digital coordinates within the BIM model, in order to allow the association of parametric data. For this purpose, an operational approach (fig. 1) is currently

being implemented at the REMLab (Laboratory of Survey and Modeling) of the University of Naples "Federico II", in order to apply information tags through spherical images (Pereira, Eiris & Gheisari 2019), directly linked to the model and viewable in a BIM environment. In the search for rules to implement and manage the built and the digitized heritage, the experimented workflow makes use of metadata linking through their geo-references within the BIM model itself.
The workflow also provides the possibility to realize a virtual tour of the physical environments that correspond to the digital clone. The visualization of spherical images in a BIM environment requires georeferencing them through the creation a specific algorithmic scripting that allows importing and integrating data entered by the operator among the parameters associated to BIM instances: this operation generates an alert message and localizes the damage on the model. The workflow can be applied to any element in the model, by defining punctual coordinates in a tag within a spherical image; the latter can be directly viewed in the parametric digital clone through an automated process. Hence, the photo no longer represents a simple viewable image, but rather – in accordance with BIM philosophy – a data container itself, which can be used to optimize management and maintenance activities. Through this approach, maintenance operators can interact with a widely used system – panoramic view-based navigation – aimed to detect and signal anomalies, that requires limited IT skills and knowledge.
Indeed, automation modalities for information populating processes have stimulated the comprehension of the

Fig. 1 - Synthesis of the digital process that relates data acquired in the real world with information tagging on spherical images, linking them to metadata through their geo-references within the BIM model itself.

boundaries for the automation of processes for the population of the geometric component of BIM models – intended as the virtualization of the real spaces – in addition to its information content. That means automatizing processes involving the recognition of unstructured data deriving from digital surveys and the generation of solid instances within BIM platforms, opening the way for experimentations involving techniques such as artificial intelligence and machine learning. This may become a crucial subject, especially in the Italian context, which houses – as it is well known – a vast heritage that requires restoration and requalification processes, rather than maintenance interventions: in those cases, a higher degree of standardization could be accepted with respect to digital representation in order to speed up operations, independently from how valuable the building is. The research, aimed to the creation of structured data models, defines possibilities for their use in automated reverse engineering processes in a stable and common way, in combination with manual interpretation and modeling.

Through a specific scripting-based approach, the research has established rules both for the characterization of data associated to the elements, and for the recognition and the digitization of architectural elements (fig. 2) and building components, such as masonry walls. The objective is the automated extraction of suitable information to classify and model the underlying structure from orthophotos obtained

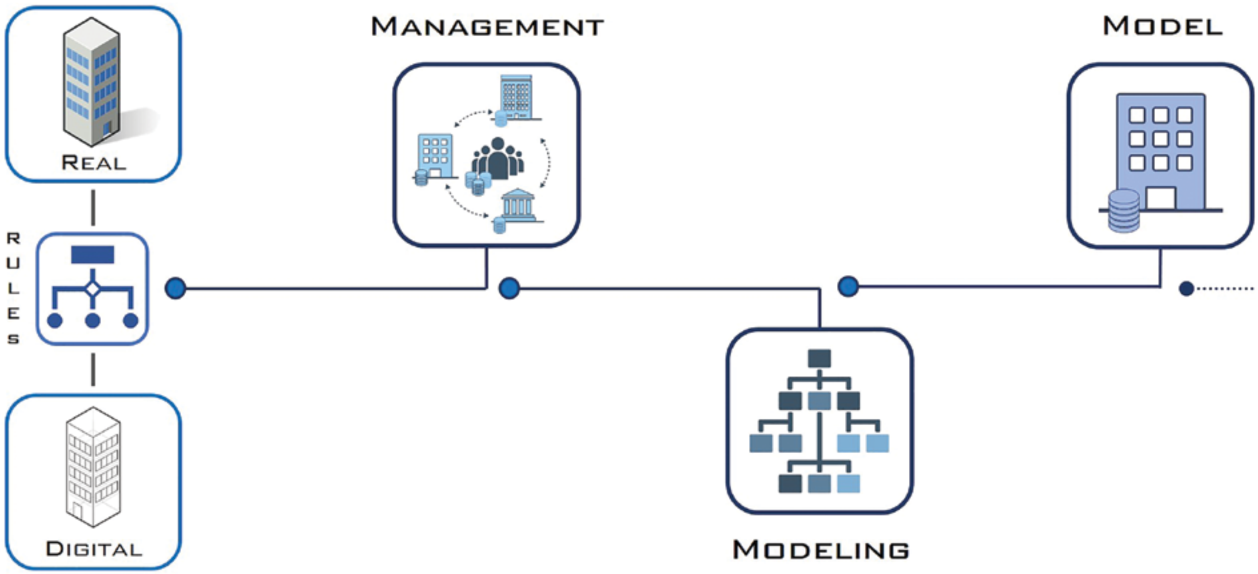


Fig. 2 - Overview of the experiences with visual scripting and programming for the management of the building stock and for the automated reconstruction of building and architectural components.

through image-based techniques, using “edge detection” to identify the key areas of masonry walls and to determine anomalous geometric characteristics that imply forms of decay. This specification, despite being often crucial, could be very difficult to realize in an automatic way, especially when operating on historical buildings, where various construction techniques could have been employed.

Pattern Recognition and modeling algorithm experiences

In order to contribute to the automation of this processes, and in parallel with the activities described above and related to the population of parametric models, a research activity aimed to the definition of automated workflows for the digitization of the historical and cultural heritage is ongoing. Its main tool is machine learning, employed to obtain real-time cognitive feedbacks from the building, aimed to the management of the existing building stock in order to introduce BIM methodology in Facility Management (FM) processes.

As it is well-known, there has recently been an intense development of research activities that use images and point clouds to detect and model architectural characteristics. The automation of these processes of parametric modeling from data acquired through image-based and range-based integrated survey techniques currently represents a very active research field (Czerniawski e Leite, 2020). On one hand, new approaches with visual scripting and programming have proven to be a useful tool to produce an interaction between the material object and its digital clone in processes destined to the management of the existing building stock; on the other hand, they could also allow a simplification of Scan to BIM digitization processes through automated recognition of objects and complex parametric shapes (Caetano, & Leitão 2018).

In particular, the interest toward digital reconstruction through algorithmic processes and as-built modeling procedures has led to research other methods that use point cloud images for the recognition and modeling of architectural characteristics (Tommasi, Achille & Fassi 2016; Giannattasio, Papa & D’Agostino, 2019). Specifically, a modeling algorithm and a data analysis

algorithm have been structured; the two have been used for the digitization of two buildings of the University of Naples Federico II, resulting in two paradigmatic examples of BIM models for the digitization of the whole building stock of the University (Giannattasio, Papa & D’Agostino, 2020).

The first possibility provided by the introduction of these visual scripting tools in Dynamo has been the development of an application with Pattern Recognition, on the sections of the structural elements of the Faculty of Veterinary Medicine, both from vector data and from point clouds obtained through a digital survey. The second result has been the creation of complex objects by simplifying shapes, coherently with the computational natural of the BIM object related to the external porch of the Office Building of the University of Naples Federico II (fig. 3): this allowed speeding up the modeling process, which is usually not immediate.

In the first case, an analytical CADToBIM (fig. 3, A) algorithm has been developed, and provided to the technical department as a tool to simplify BIM data digitization into semi-automated modules: its function is to identify recurring elements in a CAD drawing based on 2D geometric primitives. Considering the initial data as a set of base geometric forms, the next step has been the creation of a database of graphic signs, to be used as a reference for ordinary or recurring objects within a building. In particular, the set was limited to quadrangular or circular components, setting vector measure as an additional pre-defined parameter for section recognition. While circular sections can be easily individuated due to their axial symmetry, quadrangular sections could not. The discretization of these latter required more time, due to the nature of the line objects

that make up the sections of the structural profiles within the building. Due to the impossibility of a direct recognition of multi-linear vector elements, it was necessary to detect single "linear" objects, excluding curved objects, elements without intersections and double lines. The result of this operation has been a set of points, divided in groups that represent the vertexes of corresponding quadrilaterals. These are organized in order to create respective closed surfaces, identified through univocal colored mark – related to the normalized numerical value associated to the area – and exported in a BIM environment. In this way, automatic positioning was substituted by a tagging process that allowed the recognition of 2D vectors, differenced by color. The algorithm attributes identical parameters within color classes and simplifies the following object input process by placing a point in the center of the section: this optimizes the CADToBIM process.
Moreover, a specific modeling algorithm was realized for the reconstruction of the external colonnade of the office building (fig. 3, B), characterized by elements with a continuous yet irregular shape. Coherently with the ScanToBIM approach,

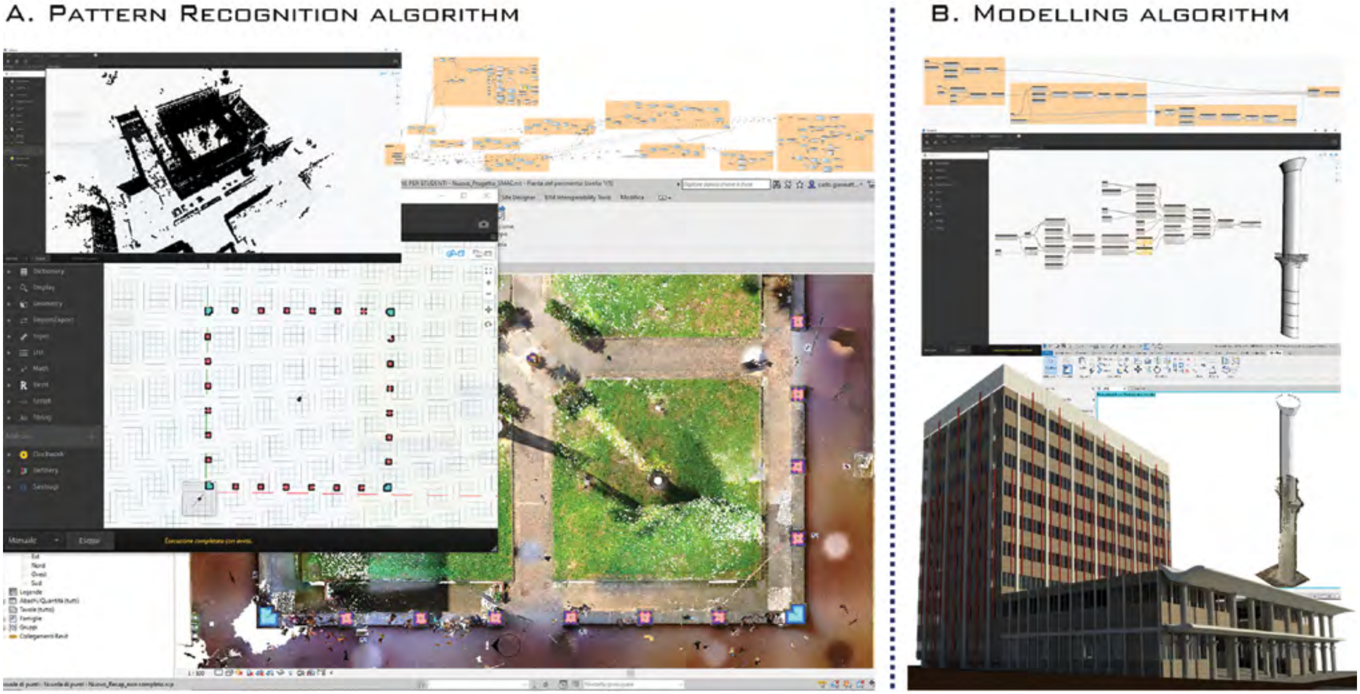
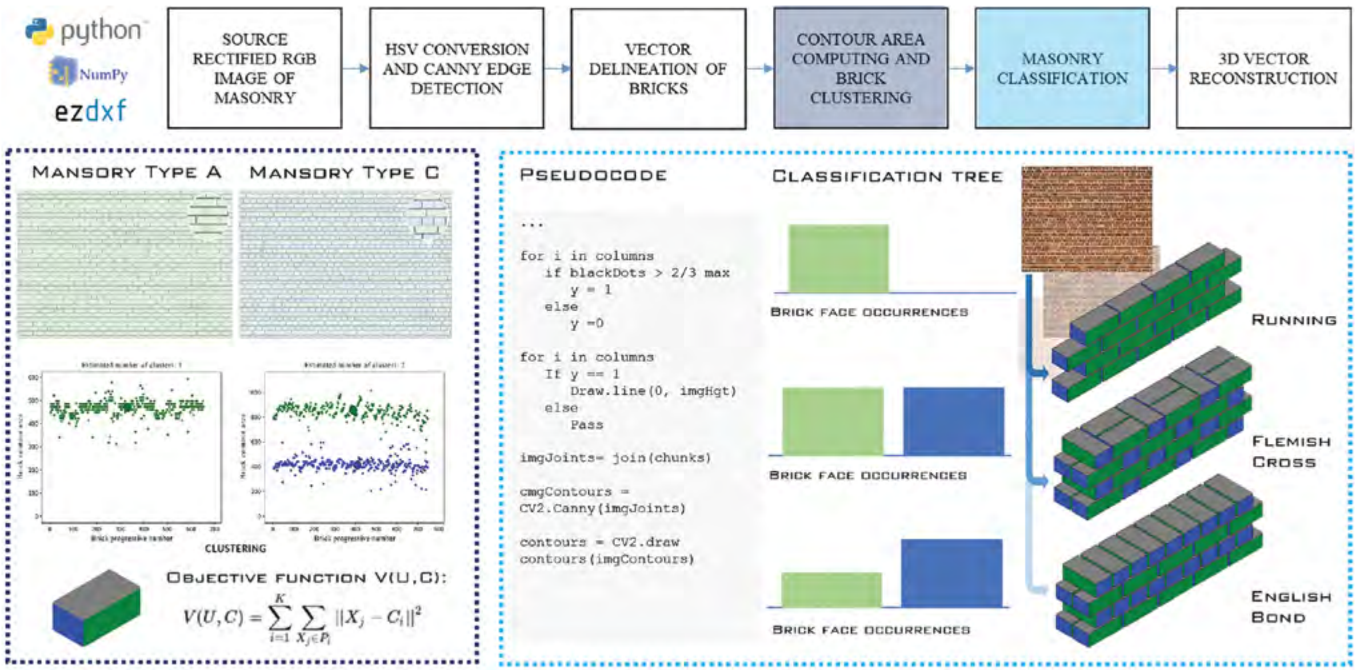


Fig. 3 - Results of the visual scripting programming processes for the recognition (A) of the sections of structural elements in the internal courtyard of the Faculty of Veterinary Medicine, and digital reconstruction (B) of the external colonnade of the office building; both edifices belong to the building stock of the University of Naples Federico II.

the algorithmic reconstruction of the geometry of the real object has been verified by comparison with the point cloud generated through a digital stereo photogrammetric process. The sequence of the vertical lines has been reconstructed in the set through visual scripting, as a class of interrelated objects with computational validity that simplify the interaction between point clouds and BIM objects.
Further experimentations have been carried out in the field of algorithmic procedures and automated as-built modeling processes for digital reconstruction (Valero, Bosché, Forster & Hyslop 2019): some have involved methods that use images extracted by point clouds to detect and model architectural characteristics. In this framework, a crucial element is represented by the morphology of building walls, due to their complexity; various techniques can be implemented to extract adequate information for the classification and the modeling of their structure.
The experimentation was based on RGB photograms acquired through image-based techniques (D'Agostino & Minelli, 2020), used for edge detection and for the identification of the key areas of the walls, that is the regions delimited by the mortar joints between bricks. This is a crucial passage for the process of classification of the morphology of the wall, as it allows the segmentation of single bricks, and the following phase of 3D reconstruction.
Both the Canny algorithm (Canny, 1986) and the 2D continuous wavelet transform – using the HSV channel for image extraction – show good results in edge detection and object extraction from orthophotos: this allows defining an automated process of classification, reconstruction and transposition of parametric models for the various examined walls. (fig. 4). These operations are aimed at finding the intersection points of the lines constituting the contours of the single bricks, defining the area of each closed border used to classify and reconstruct the structure of the wall. Machine learning techniques are used in the classification phase (fig.

Fig. 4 - Examples of Neapolitan buildings used for the application of the algorithm for the recognition of periodic wall textures: on the left, an exterior view of Palazzo Cellamare in Chiaia; on the right, an exterior view of the Sferisterio in Fuorigrotta.

5): in particular, a data clustering-based approach has been implemented for the recognition of bricks whose exposed sides have different dimensions.
Finally, a Mean Shift clustering algorithm has been used for the quantification of the detected clusters and of the number of frontal and lateral bricks, in order to perform an automated classification of each analyzed wall into two categories. In fact, the 'facing' bricks have a lower boundary value, while the bricks arranged in a long way are characterized by a higher boundary value. Values related to local errors in the delimitation of the contour lines of bricks are highlighted in the anomaly detection phase: this allows removing from the dataset bricks whose contoured area is significantly different from most of the others. These anomalies are presumably related to the presence of decay areas on the walls, which reduce the entity and recognizability of mortar joints.
The first phase of brick recognition and classification on the whole masonry wall is followed by the in-depth reconstruction of the examined wall, through the UV coordinates of the key points of brick edges. These are transposed into cartesian



$$V(U,C)=\sum_{i=1}^{K}\sum_{X_j\in P_i}\|X_j-C_i\|^2$$

```
...
for i in columns
   if blackDots > 2/3 max
      y = 1
   else
      y =0

for i in columns
   If y == 1
      Draw.line(0, imgHgt)
   else
      Pass

imgJoints= join(chunks)

cmgContours =
CV2.Canny(imgJoints)

contours = CV2.draw
contours(imgContours)
```

Fig. 5 - Synthesis of the classification process of the morphology of periodic masonry with a homogeneous brick size, with a focus on segmentation and classification phases of the single bricks needed for the following modeling phase.

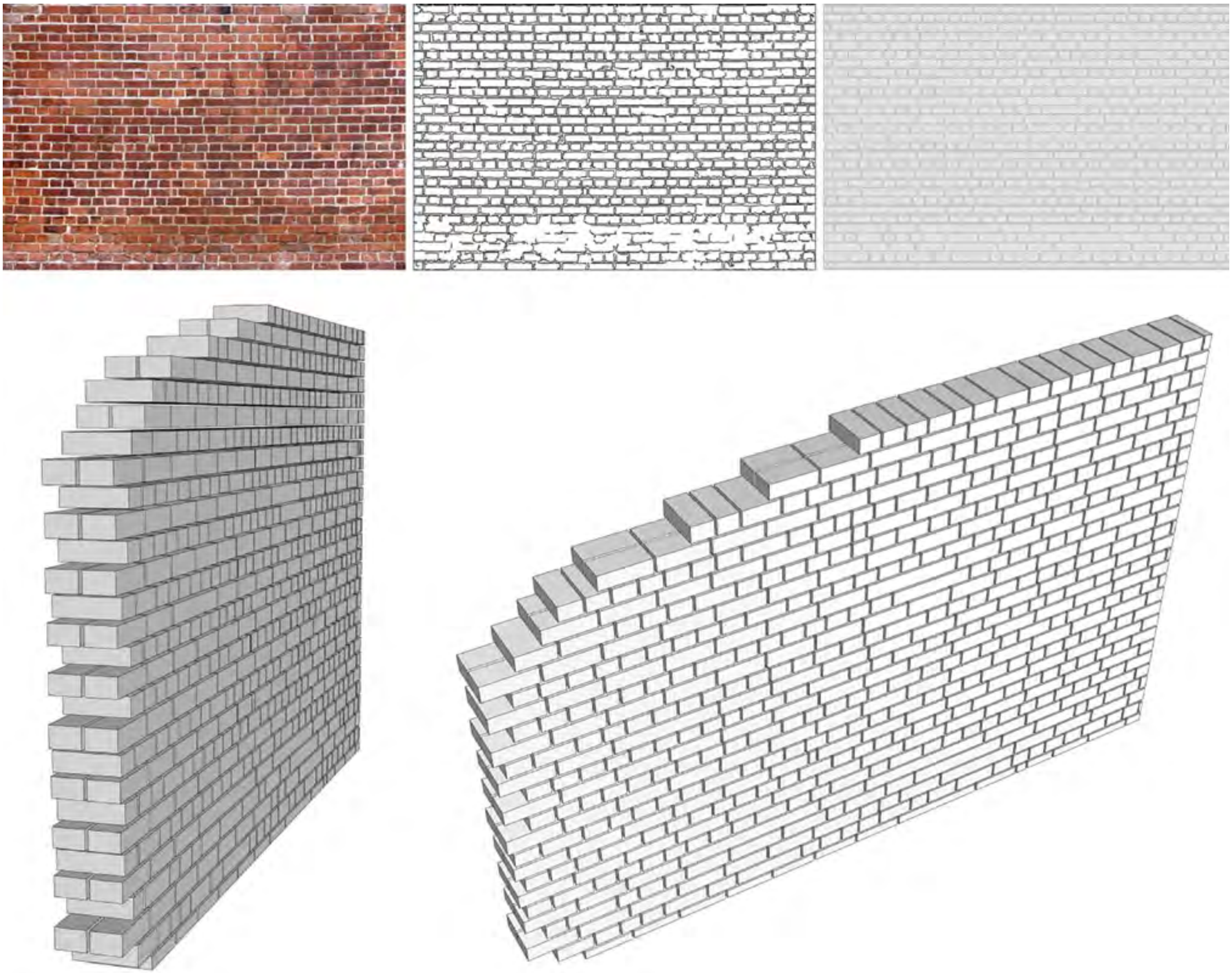


Fig. 6 - Detail of a 3D reconstruction (some bricks have been removed to show the section of the wall).

coordinates in order to obtain a vector for the recreation of the 3D geometry of the wall, coherently with its typology (fig. 6).
The outlined approach, tested on images of several walls with a single bricks size, shows good accuracy and reliability with respect to real conditions and states of decay, and it seems significant also in relation to the possibility of extending this workflow to masonry wall with heterogeneous brick sizes. However, a high image noise level on the surface of the bricks might lead to blurred contours and to the representation of false vertical joints, causing a categorization in a higher number of clusters according to the arrangement and typology of bricks.
The results of the method for classification and 3D reconstruction are indeed encouraging but could be further optimized. In the ongoing research activities, this is being experimented through the integration of other typologies of parameters (for examples, extracted from the analysis of the indexes associated to thermal images), condition variables and logical operators that could improve the calibration of the algorithm with respect to the recognition of different textures.

Conclusions and future developments

The paper has presented the results obtained in experimentations concerning the management, classification and reconstruction of building and architectural components. These pave the way for the implementation of innovative approaches for the automated recognition and the parametric digital modeling of the architectural elements characterizing historical architecture, including structural components (for example, wooden trusses), non-structural components and finishing layers. Despite being far from completion, this work offers several insights, considering that the outlined classification procedures for periodic masonry can allow overcoming anomalies related to local errors in edge detection and poor contour definition. Likewise, the research shows an optimization in the detection of visible defects on the bricks for other typologies of masonry, through the characterization and calibration of the algorithm according to the indexes of the thermal images. This solution offers encouraging results with respect to the possibility to generate a detailed reconstruction of the variable arrangement of the elements and – for particularly complex cases – of the width of the wall. Moreover, these procedures of classification and automated reconstruction are directing research on the digitization and management of the building stock toward virtual reality applications. In fact, this will allow a real-time identification of the mortar joints by using the approach studied for raster images, extended to video sequences in order to allow a real-time recognition and vectorization of masonry walls (fig. 7).
In conclusion, the interest toward the automation of processes of geometric identification and BIM model population represents an occasion for domain implementation that foreshadows interesting developments related to the innovation – in representation and virtualization – within this research field. The will to overcome the challenges of the digital transition is in fact a premise for cultural growth: while a recurring mistake is the belief that it can be achieved through a mere technological implementation, it actually requires a methodological transformation related to the definition of new processes and to the rethinking of the existing ones. Only in this way, the use of information models, IoT solutions, A.I., etc., can have a decisive impact on activities where the scientific community is increasingly involved, with a key role both in communication and process management.

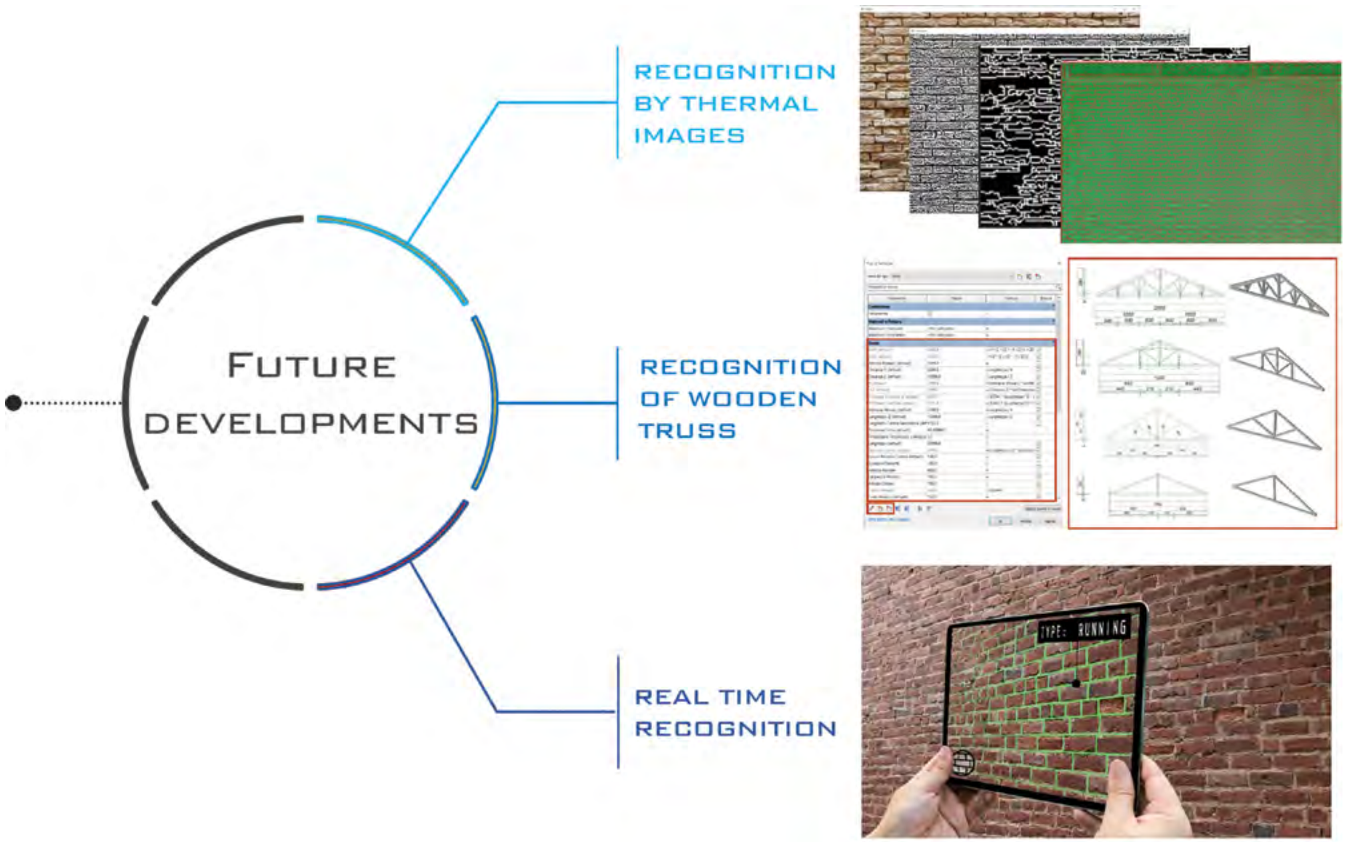


Fig. 7 - Overview of the future developments: optimization of the recognition from thermal images, automated recognition of trusses, real-time recognition of masonry textures.

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SEMANTICS THROUGH MODELS.
EX ANTE AND *EX* POST CLASSIFICATION PROCESSES.

Abstract

Point clouds derived from survey operations arrive in the three-dimensional virtual space as a single object, without an ontological structure. The deconstruction and classification of the cloud defines a hierarchical interconnection of the parts and allows a much more complete reading level.
In the BIM environment, on the other hand, the definition of the semantic code is achieved ex ante through inherently hierarchical modeling. Each digital object builds relationships of subsumption or equivalence with the other ontologically defined elements.
If from an applicative point of view, these two types of Information System concur to define two different strategies of transformation and manipulation of data, from a theoretical point of view, their function of ordering and contextualizing data is almost identical. In both cases, in fact, the system is built thanks to a semantic apparatus, which is given the task of organizing the data in an appropriate manner and defining logical relationships. Beyond the clear analogies between the two workflows, the contribution intends to investigate the possibility of interconnection between the two systems for the expansion of the object understanding. The topic will be explored on the Santa Maria della Pace cloister, designed and realized by Bramante in Rome.

Le nuvole di punti derivate dalle operazioni di rilievo approdano nello spazio virtuale tridimensionale sot¬toforma di oggetto unico, privo di una struttura ontologica. La scomposizione e classificazione della nuvola definisce l'interconnessione gerarchica delle parti e permette un livello di lettura decisamente più completo.
In ambiente BIM, invece, la definizione del codice semantico è realizzata ex ante tramite una modellazione intrinsecamente gerarchizzata. Ogni oggetto digitale costruisce rapporti di sussunzione o di equivalenza con gli altri elementi ontologicamente defi¬niti.
Se dal punto di vista applicativo, queste due tipologie di sistema informativo concorrono a delineare due strategie di trasformazione e mani¬polazione del dato diversa, da quello teorico, la loro funzione di ordinare e contestualizzare i dati è pressoché identica. In entrambi i casi, infatti, il sistema si costruisce grazie ad un apparato semantico, a cui viene dato il compito di organiz¬zare i dati in maniera adeguata e di definirne i rapporti logici. Aldilà degli evidenti parallelismi tra i due flussi di lavoro, il contributo intende investigale la possibilità di interconnessione tra i due sistemi per l'ampliamento della conoscenza dell'oggetto. Il tema verrà declinato sul caso studio del Chiostro di Santa Maria della Pace, progettato e realizzato da Bramante a Roma.

Classification processes

The study is developed by analyzing two different types of information systems, the first one, is related to the numerical discretization of reality and uses numerical models, the other, instead, concerns the interpretation of reality through parametric models of representation.
Working in heterogeneous fields, the two approaches have multiple points of procedural and logic intersection. The interaction between the two systems contributes meaningfully to the production of a unique digital model that makes explicit the entire life cycle of the architectural heritage, but also That clarify how different contents are structured. With this aim, the research starts from the analysis of ways of composing the architectural model in order to evaluate the affinities and the compatibility.
With respect to this premise, the study deals with the information systems developed in the field of numerical modeling, focusing on segmentation and classification strategies for the semantic organization of data. On the other hand, HBIM approach will be analyzed for the construction of ex-ante semantically structured parametric models.

The state of the art in semantization

The thematic deconstruction of an object is performed by an association process that links together a phenomenon that is identified on the object itself and a similar one already existing in our mental archive. This identification is applied by dividing the digital model according to known criteria with a codified language shared by the operators in the sector. With reference to point clouds, this division corresponds to segmentation and classification process which is performed on the basis of a logical structure and carries out the transformation from data into information[1].
The ex post deconstruction allows the study of the single parts and the association to each of them of additional 1D, 2D and 3D information, the following phase of classification of the parts allows a hierarchization of the model which functional to its study.
Segmentation is carried out by means of informatic procedures with different degrees of automation; from manual segmentation to assisted segmentation using machine learning methodologies. The manual segmentation is a valuable tool in archaeology, for example, for the identification of stratigraphic phases or for the selection of significant portions for restoration purposes. In these conditions, in fact, it is not possible to identify on a sample 2D or 3D features that can be then predicted and computed on an entire dataset.
On the contrary, when selection criteria are free from a strongly qualitative interpretation of the phenomenon a different approach can be hypothesized.
On this second case, interactive segmentation can be used as an approach to the deconstruction of point clouds. This type of classification relies on analysis functions for a dynamic selection of point clouds. The approach requires a preliminary step in which segmentation criteria must be translated into morphological and geometric features embedde to the point cloud[2].
Grilli et Al. (2017) provides an extensive overview of the types of features generally employed for segmentation operations, 3D features meanly relies on LIDAR point clouds from the territorial scale to the detail scale of architectural elements. The algorithms used in this sense automate the recognition of contours (edge-based), regions with similar properties (region-based) or portions with morphological characteristics similar to those of a geometric reference model (model fitting).
In the context of assisted methodologies, the machine learning approach is applied by identifying a training area on the point cloud, in which the specialist performs a manual segmentation and classification, in a second phase, the rule for segmentation and classification is learnt and applied to

the entire dataset.
Switching to parametric modeling, the semantic apparatus finds its congenial expression through BIM systems. In them the specialist builds the model by adding information on the basis of an already codified structure. This graphical reference database is thought and validated for an ex ante semantization. At this point, the problem is to find an adequate lexicon that serves as a support for the composition of the model. The construction of such a lexicon seems far from obvious, each built architecture is a unicum to which is difficult to apply standardized codes. On the other hand, we can state that even if each built object owns an indefinite number of features to univocally identifying it, it is still possible to extract typological, morphological or constructive selected features which are shared with other similar object. These common feature are then codifiable. On this path, HBIM finds a successful application in giving shape through the 3D digital model to the specific kind of architecture conceived and constructed by using codified proportional or stylistic rules.
In BIM environment the code is structured by identifying "categories" and "families", which are then characterized through "type" parameters, for the constructive characters of each object typology, and "instances", for those features connected to the compositive choices to specify each object characterization in the context of the building.
With reference to the historical architecture instead, the code is transmitted through the treaties. In fact, starting from their decoding we can re-propose those same parameters in a virtual environment.
Apollonio et Al. (2012), for example, focus their research on the analogy between the role of classical treatise with the role of BIM approaches. In both cases, in fact they are the genesis of the ideal model and the reference for all the variants we can detect in several buildings based on that ideal model. On the same topic, Giovannini (2017) continues an approach to deconstruction already set by De Luca et Al. (2007) and proposes the parameterization of the order by decomposing it by successive partitions; Bianconi et Al. (2018) propose the parameterization of the five orders of architecture to investigate the variations on the theme proposed by the main treatise writers; Rossi (2019), instead, identifies a progressive sequence that, starting from the archetype, as an expression of the highest degree of standardization and inferred from the treatises, passes through the prototype, the geometric and arrives to the as-built.

The survey of the cloister

The research on the documentation and representation of the Bramante cloister starts with the research project "Amen. Augmented Museum Environment Network"[3]. In this context, starting in 2019, a 3D documentation campaign started[4]. It was needed to provide 3D data to allow following stages about designing real and virtual contents for the museum and to document the state of the art through digital models for managing purposes. Following the well-established methodologies of massive survey, an integrated acquisition campaign was conducted: data capture by 3D laser scanner was extended to all the main rooms of the cloister and the museum rooms, the photographic acquisition by drone allowed to collect data of the roof and of the internal elevations of the cloister, the topographic survey, finally, was set as the main reference system for the optimization of the photogrammetric processes and link together the point clouds derived from Structure from Motion with those produced by laser scanner (Fig. 1).
This complex acquisition system was processed to generate a three-dimensional point cloud produced by integrating all the available data and aimed at collecting the geometric and radiometric properties of the object.
The point cloud thus characterized has constituted the data base for the experiments here presented for what concerns both point cloud segmentation and construction of a model

in a BIM environment. In both cases, the topic involves the composition and deconstruction of the architectural order investigating the strategies of hierarchical semantic attribution of architectural elements.

Architectural order at the cloister

The digital deconstruction and recomposition of codified architectural elements is here declined with respect to the study of the architectural orders employed by Donato Bramante in the cloister of Santa Maria della Pace in Rome. The architecture of this space, in fact, proposes a rich assortment of design solutions and compositional variants that are

Fig. 1 - The cloister of Santa Maria della Pace. Laser scanner point cloud visualization.

diriment for the construction of semantically structured three-dimensional models.

The use of four architectural orders - the Tuscan pilaster, the Ionic parasta, the composite pilaster and the Corinthian column - arranged on two levels[5], allows, in a certain sense, to test a methodology of investigation on different "case studies" and, at the same time, highlights the complexities related to the seriality of a certain design language which contrasts the singularity of each element realized and documented through the survey (Fig. 2).

The reading of the cloister was done by working with progressive partitions. This method[6] allows to recognize three main hierarchical levels for each order to which corresponds a more and more detailed characterization of the elements. The first level resumes the firmitas of Vitruvius, it corresponds to the detection of macro-elements endowed with their specific structural value. In this phase we distinguish the pedestal, the column and the entablature. The second level,

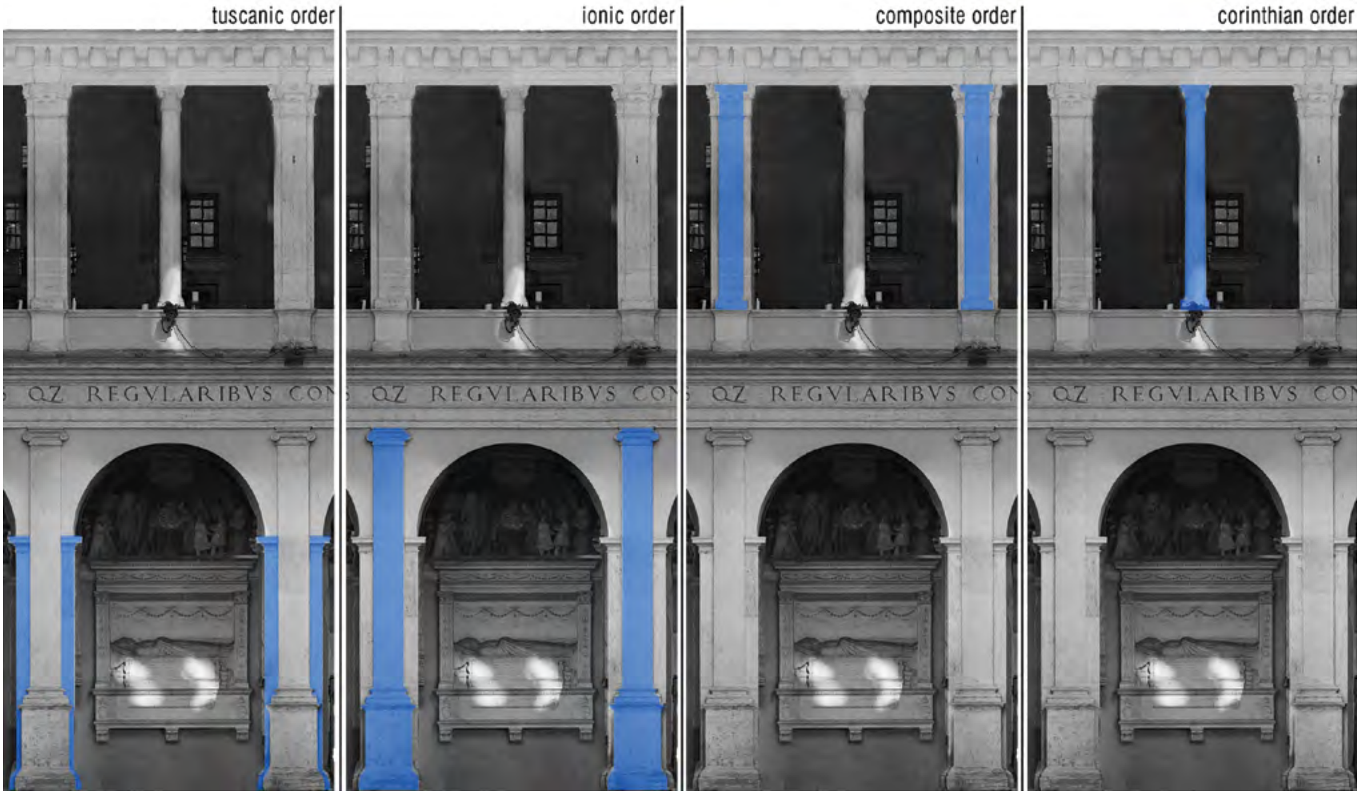


Fig. 2 - The four architectural orders of the cloister. From left: tuscanic, ionic, composite and corinthian orders.

corresponding to the utilitas, allows to identify the elements endowed with functional autonomy and to decompose, for example, the macro-element "column" into capital, shaft and base. The last level concerns the venustas, the decorative characterization applied through the composition of the different moldings. From a theoretical point of view, this approach to deconstruction is well known and allows the scholar to read and analyze the architectural order, its translation in terms of digital modeling is not consolidated as well (Fig. 3).

The experimentation

The first experimentation on the object focused on a portion of the cloister consisting of an entire bay and including the portion of intersection between two of the sides. This selection allows to face all the stylistic solutions and, therefore, to set up a segmentation procedure iterable, even in an automated way, on the entire complex. The cloud of points generated from the survey operations has been decomposed ex-post

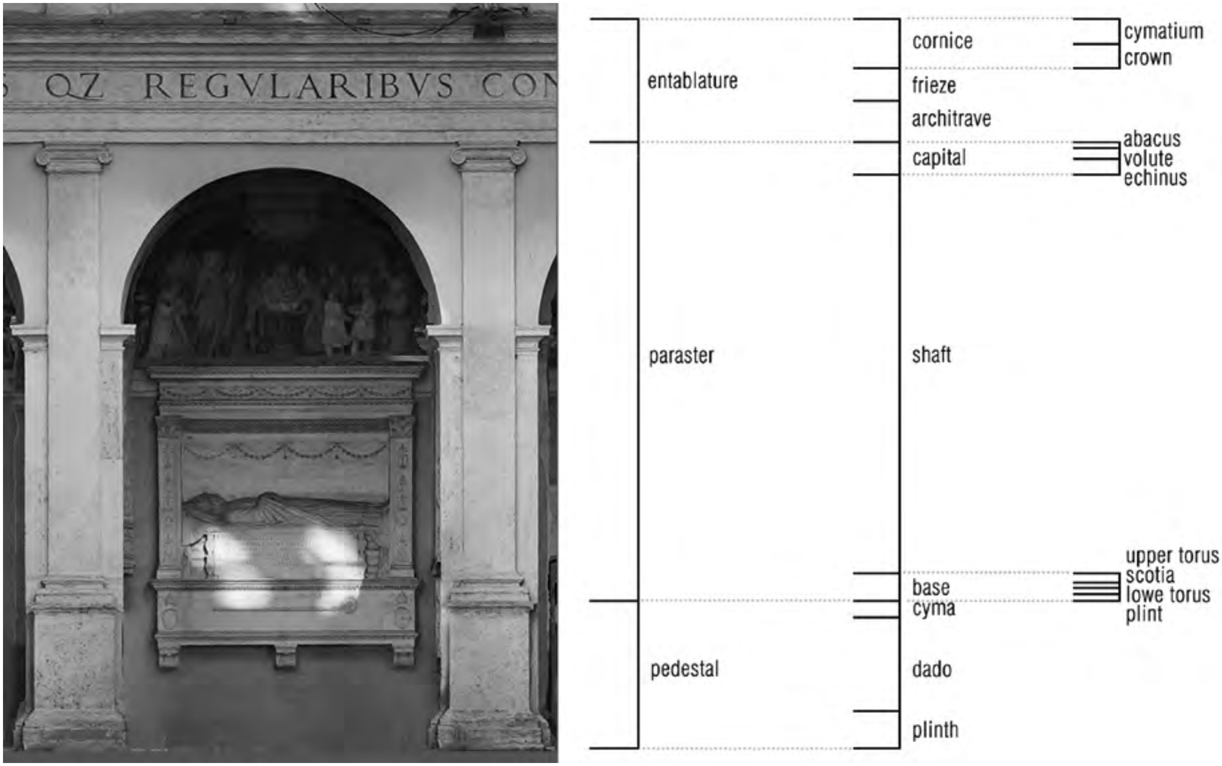


Fig. 3 - The composition of the architectural order. From left to right, the three progressive levels of division: firmital, utilitas, venustas.

in a progressive way using manual segmentation tools. Subsequently, the classification of the elements has allowed to attribute to each portion a semantic meaning and to explain the hierarchical relationship between the parts[7].
Generally, the process of segmentation of point clouds does not provide for the attribution of distinct classes to the same set of points, this constraint makes, in fact, univocal and monothematic classification excluding the attribution of other properties of the elements. Following this principle, it is not possible, for example, to carry out a classification taking into account both the identification of architectural elements and to the mapping of decay phenomena or construction phases. This layered approach can be performed only duplicating the source point cloud. Beyond this limitation, the result obtained is a segmented and classified point cloud with a multi-level approach, one for each of the three Vitruvian levels (Fig. 4; Fig. 5).
The ex-post deconstruction procedure on the point cloud has

Fig. 4 - Point cloud segmentation and classification process

allowed to approach the monument by observing with a closer eye its characters and its semantic structure. This process of knowledge is at the basis of the construction of an ex-ante model in which the construction of each element presupposes the global awareness of the whole architecture. Following the same principle of firmitas, utilitas and venustas, the modeling in BIM[8] environment of the cloister was set up by generating ad hoc nested families parameterized according to the main morphological and compositional features that were tracked directly on the point cloud. With this principle, with respect to the general category of the architectural order, the nested families of the Tuscanic order, the Ionic order, the Composite order and the Corinthian order were modeled. Each of them, in turn, is composed of further nested families related to the Vitruvian triad up to the modeling of the single compositional element (Fig. 6).

As a further step, each element belonging to the nested family is connected to the correspondent classified portion of point cloud so to allow different users to access both the parametric model to the numeric one using just one virtual space.

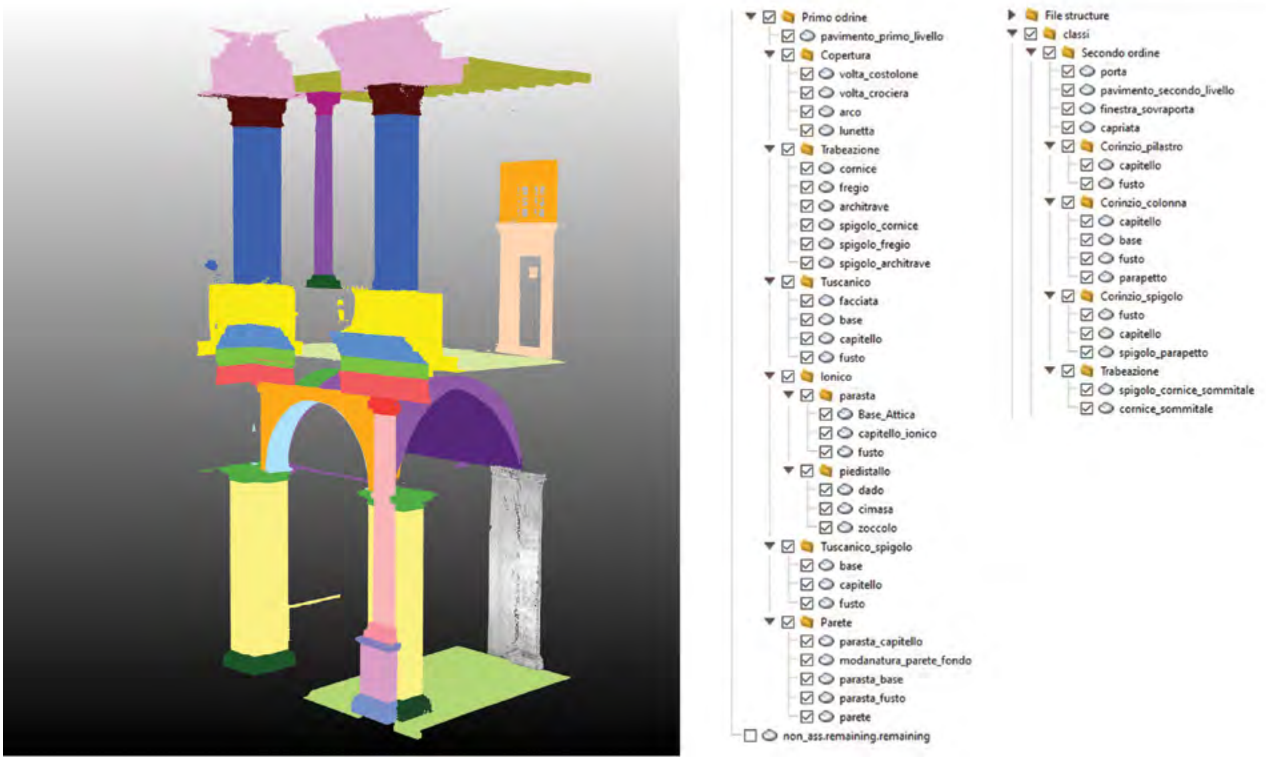
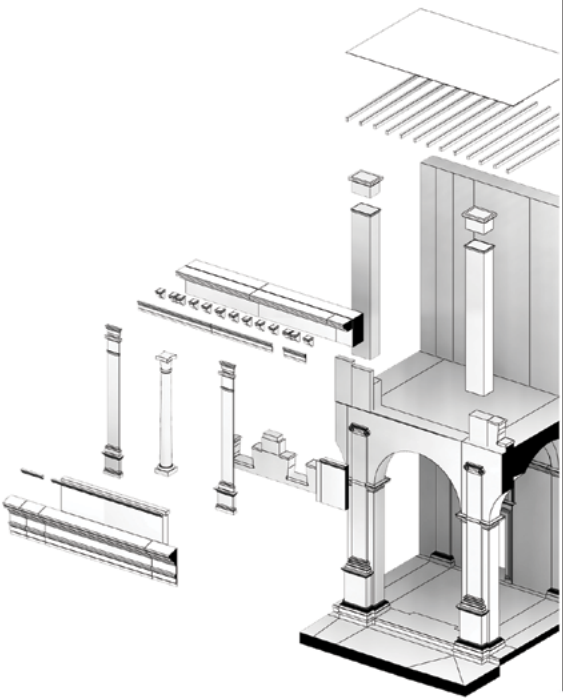


Fig. 5 - Point cloud segmentation structure and classes of one bay of the cloister

The modeling of the four architectural orders leads to define an abacus of compositional solutions parameterized to ensure a certain level of reusability, both within the complex itself and in architectures with similar characters. This approach of modeling by progressive levels is applicable to all loadable families while it still maintaince a greater rigidity in the case of system families which are included in the project models and depending on the embedded software general settings. The entablature, for example, belongs to the latter type of family. The experimentation here conducted is directed towards the application of automated segmentation processes based on machine learning algorithms. The objective is to extend the multilevel classification of the point cloud to the whole cloister and to evaluate, subsequently, the best connection strategy between the element univocally identified and catalogued on the point cloud and the corresponding "type" in the BIM environment. This leads to the issue of spatial association between the two information systems analyzed: on the one hand, it is possible, through the BIM tools, to build a "type" iterated several times even if with variable properties from



Family name	Category	Family type
cross vault	generic model	loadable family
entablature	wall extrusion	system family
tuscanic pillar	architectural column	loadable family
ionic paraster		
capital	generic model	generic model
abacus		
voluta		
echinus		
astragalus		
shaft	architectural column	loadable nested family
attic base	wall extrusion	
upper torus		
lintel		
scotia		
lintel		
lower torus		
facade	wall	system family
floor	floor	system family
corinthian column	architectural column	loadable nested family
...		
corinthian pillar	architectural column	loadable nested family
...		
beam structure	structural frame	structural frame
roof	roof	system family

Fig. 6 - BIM structure of architectural order elements

time to time, on the other hand, we have available, through the point cloud, the element in its singularity, disjointed from all other elements typologically related. With this assumption it is possible to weave the relationships between these two systems in such a way as to allow to analyze both single characters and serial ones at a time (Fig. 7).

Conclusion

The experimentation intends to underline a certain circular relationship; the discrete models generated by segmentation and classification of point clouds are predisposed as instruments of analysis endowed with their own autonomy, in the same way, the continuous and parametric models favour the process of analysis directing, in a certain sense,

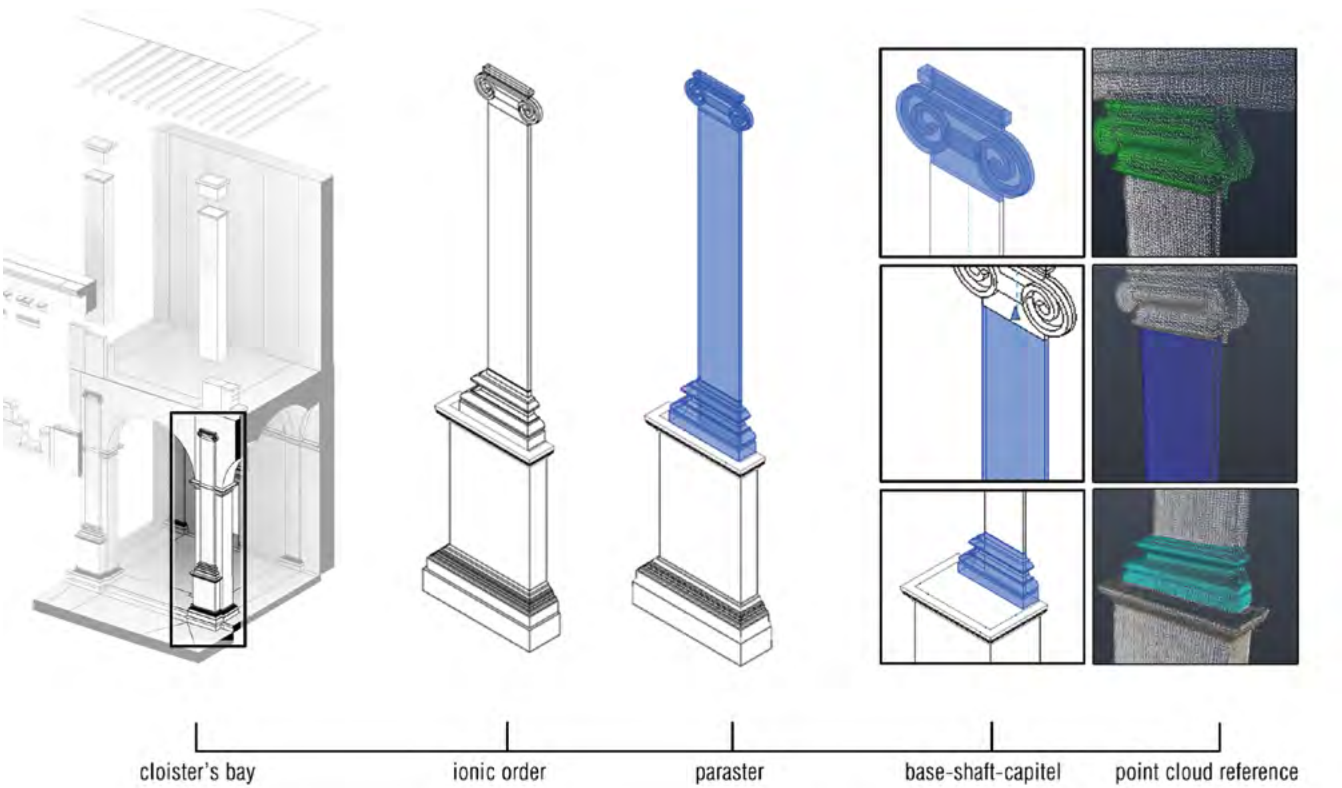


Fig. 7 - Structured semantization process and point cloud correspondence

the researcher's gaze. The possibility to gather in an unique virtual environment both models, is necessary to the transfer of the entire cognitive scaffold. The model so intended is generated from the connections that it is possible to think and to construct between the various informative sources, these connections represent the digital infrastructure of support to the understanding.

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Notes

[1] For a discussion of knowledge levels, see Ackoff 1989.

[2] The non-commercial software VisCore, for example, allows, through the interactive development of lines of Java code, the real-time customization of a set of "brushes". The brushes act in a selective way to segment the point cloud according to criteria defined by the user through the code, acting on the properties expressed by each point (normal value, relative coordinates with respect to a reference plane, etc.). On this topic please refer to Hess 2017

[3] Funding DTC Lazio Lead partner: DART S.r.l./Centro Culturale Internazionale S.r.l.- Chiostro del Bramante Partner: Fondazione Mario & Maria Pia Serpone, Segni d'Arte, Università La Sapienza, Dipartimento di Storia, Disegno, Restauro dell'Architettura (DSDRA) - Scientific responsible for DSDRA: Alfonso Ippolito

[4] Research group for survey and parametric model have been coordinated by Carlo Bianchini and Alfonso Ippolito. The working group is composed by Martina Attenni, Paolo Castellani, Luisa Salani and the author

[5] We do not wish to focus here on the stylistic and historical-critical issues of the cloister; for a more in-depth study of the nature of the monument and its architectural features, see Bruschi 1973.

[6] See Migliari 1991 for a full description of the method proposed by Vitruvius and its potential applications.

[7] The segmentation and hierarchical classification were carried out using the set of tools integrated in the CloudCompare software.

[8] The experimentation was conducted using Autodesk Revit software.

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SCAN TO H-BIM, DRAWING INFORMATION AND MODEL SHARING PROTOCOLS.
THE CASE STUDY OF THE CASTIGLIONI BRUGNATELLI COLLEGE (PV)

Abstract

The paper proposes a reflection on methodological protocols for developing scan to H-BIM information models on historical architecture. The case study is the Castiglioni Brugnatelli College, the first university college in Pavia, founded in 1429. In 1954 became the first lay female college to be established in Italy.
The experimentation conducted included the development of drawings and models to provide an updated knowledge base of the collegiate complex's interior rooms and external environments.
The H-BIM model aims to allow the managing body of the complex to develop proposals for maintenance and improvement interventions consistent with the image and historical importance of the building.
The goal is to understand the weakness and limits of scan to BIM systems applied to historical architecture.
The application of mobile laser scanner systems in Cultural Heritage context cannot fail to consider the architectural decoration and an explanatory need that contemplates the imperfect in all its structural, constructive, and ornamental constructive components.

Il contributo propone una riflessione sullo sviluppo di protocolli metodologici per la realizzazione di modelli informativi di tipo scan to H-BIM sull'architettura storica. Il caso studio è il Collegio Castiglioni Brugnatelli, il primo collegio universitario di Pavia, la cui fondazione risale al 1429, e che diviene nel 1954 il primo collegio laico femminile ad esser stato istituito in Italia.
Gli obiettivi della sperimentazione condotta includono lo sviluppo di disegni e modelli volti a fornire una base conoscitiva aggiornata degli ambienti interni ed esterni del complesso collegiale per consentire all'ente gestore del complesso di sviluppare proposte di intervento manutentivo e migliorativo congrue all'immagine e all'importanza storica ricoperta del manufatto edilizio.
Obiettivo la comprensione di quale limite descrittivo e rappresentativo viene imposto dal loro utilizzo nei confronti di una rappresentazione che, vincolata ad un'architettura storica, non può non tener conto del decoro architettonico e di un'esigenza descrittiva che contempla l'imperfetto in ogni sua componente strutturale, costruttiva e ornamentale.

Introduction

During the 1990s, no one doubted that the introduction of digital representation and capture techniques were changing the language of data characterization in architecture.
Contemporary society refers today to information modelling, VR, and AR applications due to the technological development of the representative system evolution. The ordering of space is referable to 3D models and how, despite the change of the medium, the aim of representing, communicating could provide effective enhancement and transmit knowledge. The digital 3D model message shows its usefulness when it ascends to a communicative level that is no longer affected by cultural constraints but often conforms in favor of a culture communication system increasingly projected towards sharing and global fruition. In this cultural context, images play a precise role in learning, becoming the language we use to communicate information of a predominantly visual type and establish how these can be transposed onto different areas. Pierre Lévy, a french philosopher in the pioneering essay entitled "La Machine Univers", states that information is not a thing but an event. It corresponds to something that happens rather than following traditional ontological categories. On a larger scale, the same is true for Digital culture has always been available to represent/notify state of the art.
The architectural form has become digital, giving possibilities theoretically unlimited to the contemporary design and conservation process.Digitization is simulation and scenario. The digital architecture is used as a preliminary and decision-making step on how to create, or rather execute, by applying to the model technological criteria linked to the environmental and conservation sustainability of the building.
The use of computational tools and algorithms are contemporary methods helpful in generating new architectural forms, manufacturing methods, performance optimization, and artifact management. This influence also involved management systems and the development of maintenance plans for architectural, cultural and landscape assets. In the digital age, management planning has become digital and the tools used are developed and updated in step with technological innovation.
The leaders in the technology sector have developed various types of portable mobile 3D mapping solutions. The systems

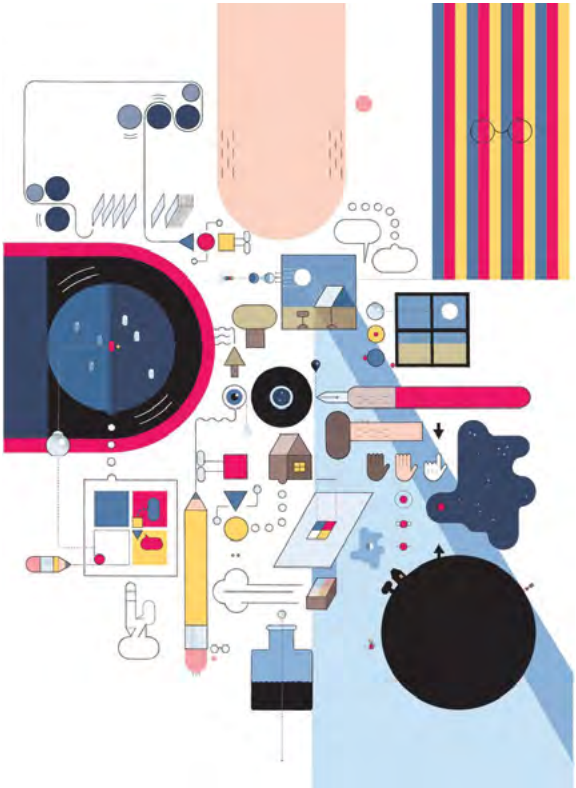


Fig. 1 - In Chris Ware's illustrative compositions, a representation scheme is proposed that makes explicit the concept of image selection through the development of models that result from an analytical process made up of observation and re-elaboration of the data. Credits: © "Comics Collage - Circle", 2018 Chris Ware / Galerie Martel.

and product categories are designed for rapid detection procedures and associated with scanning operations to generate rapid acquisition models. These tools are used in the construction sector in the various fields of application, from architectural surveys to plant engineering and territorial analysis.
The DAda-LAB & PLAY research and experimental teaching laboratories of the Department of Civil Engineering and Architecture (University of Pavia), under the coordination of prof. Sandro Parrinello, have been researching the development of tools and methodologies for optimizing mobile scan-ning survey protocols and three-dimensional representation of the built historical heritage.
No 3D data collection technique can be used correctly without experimental implementation to understand the potential for accuracy, limitations, and benefits of rapid detection technologies. In its most generic definition, a Mobile Mapping System (MMS) is a mobile tracking platform used to acquire data on the go. The first examples of MMS systems date back to the late 1980s.
The tools were mainly mounted on vehicles. Today, they are reduced in size and weight for manual use by the operator.[1]
The research, developed by the laboratories, proposes a reflection on the relationship between 3D integrated point cloud databases and the connection with modelling platforms.
The main goal is to define a three-dimensional database as an outcome of "fast" survey operations, deepening the acquisition methods through the use of an MMS system. The 3D database obtained will be oriented to shared H-BIM parametric modelling.The case study is the university building of the Castiglioni Brugnatelli College, the first university college of Pavia, whose foundation dates back to 1429. In 1954 became the first lay female college to have been established in Italy. The project was developed from an integrated fast survey acquisition experimentation involving a 3D digital database and a parametric model.
The H-BIM model is developed based on an integrated digital acquisition process of the "Scan to BIM" type. It was possible to produce metrically reliable 2D and 3D digital drawings, both of the internal and external complex environments, to develop proposals for maintenance and improvement interventions consistent with the image and importance of the building. The scan-to-BIM methodological protocol was developed through shared modelling experimentation of different elements that qualify the constructive characteristics of the complex. The H-BIM model intends to represent the complexity of the monumental apparatus.
The search for the shape adhering to reality requires a constant process of verifying the metric reliability and adherence of the model, in its morphometric components, to the 3D database.

Fig. 2 - Historical photos of the Castiglioni college, date unknown. Online source: http://www.collegiocastiglionibrugnatelli.it.

Digital documentation strategies: SLAM technology and scan to BIM processes

The development of algorithms and sensors optimized for digital surveying and new technologies for rapid motion detection allows the elaboration of new acquisition protocols to create digital models.
In this particular moment, it appears necessary to reflect on applying the tools to study data management and processing systems to protect, enhance, and disseminate cultural heritage. From this intention, the collaboration between Leica Geosystems and the DAda-LAB & PLAY Laboratories of the Department of Civil Engineering and Architecture of the University of Pavia was born, in a synergistic relationship for instrumental experimentation and the definition of a methodological protocol for data acquisition and management. The goal is to validate the fast acquisition processes of extensive surveys and consider the instrumental potential and the accuracy of the geometric data.
Among the different mobile laser scanner acquisition systems in commerce, the Leica BLK2GO mobile system was used for experimental purposes.
The technology developed by Leica Geosystems results from a combination of different simultaneous mapping systems. The system uses the GrandSLAM technology, a combination of three systems (LiDAR SLAM, VISUAL SLAM[2] and IMU) which allows the user to keep track of the environment characteristics, record the trajectory of the entire scanning session, and obtain a single set of data for the whole space.

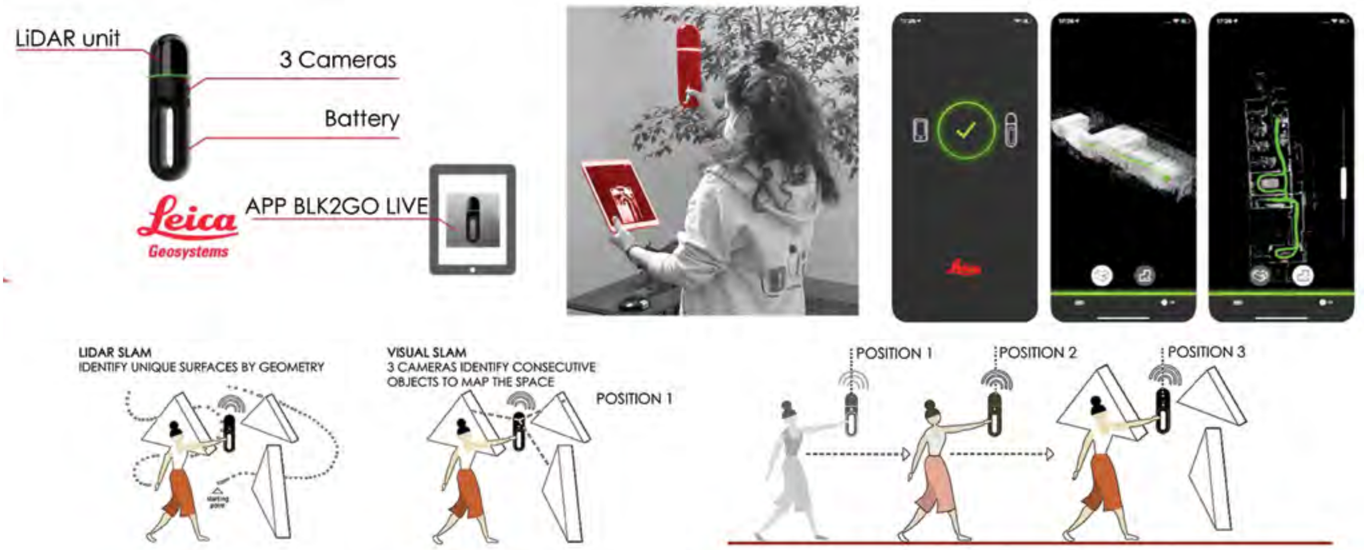


Fig. 3 - The BLK2GO operating system: It is possible to monitor the path and the data acquired directly on the tablet using the BLK2GO Live application during the acquisition phases. This system allows you to make an essential preliminary check of the data quality that the operator is acquiring.

The simplified geometric shapes, the small dimensions, and the reduced weight introduce new innovative ways of shooting on the move reducing the physical constraints for the digital acquisition of complex environments. The tool's ease of use is made evident by a single button.
This allows the switch-on of the instrument, the start/end of the scan, and taking photos along the path controlling the 12-megapixel front camera.
Despite the simplicity of use designed by Leica Geosystems, the user directly impacts the instrument's use and the scan set's success. It is recommended to study the instrument and put into practice an adequate methodological approach to the relevant project to be carried out.
The MML SLAM tools' performance is strongly linked to the shooting scene presence of texture and light for Visual SLAM and stable and distinctive geometric characteristics for LiDAR SLAM and the trajectory followed (distance from the object type of movements, speed of movement).[3]
The advantage of being light tools and designed for surveying in motion through the direct manoeuver of an operator makes this type of tool suitable for transport and fast survey actions.
The point cloud data obtained with the Leica BLK2GO shows, thanks to the GrandSLAM technology, a Range Noise value of +/- 3 mm and an Indoor Accuracy of +/- 10 mm.
To acquire the data with mobile laser scanner instrumentation, paying attention to the route planning phase is essential. It is essential to define, previously, the survey project. Within the project, it is necessary to foresee different levels of in-depth and detail to obtain complete databases by minimizing the occlusion of different types of tools used to acquire the 3D database.
The different tools choice for the digital database generation is dictated by conscious analysis of the functional relationship between the tool and the constructive characteristics of the building to limit. Each tool was chosen for specific shooting purposes to reduce waste of time, the economic sustainability of the project, and database size management. The current structure of the building is the result of several progressive interventions.
In the complex remains a trace of the original construction that documents the long history of the building, its changes of ownership, and changes in its intended use. The restoration action was completed in the 1950s. The construction phases outline a macro division of the building structure: a first block, the oldest, dated 1457, is spread over three floors (excluding cellars and attics) and presents the characters of the fifteenth-century brick masonry left exposed; the second extension block of the historic building built on four floors excluding the basement of the cellars and the attics. The fifteenth-century building has a U-shaped plan that defines a large rectangular courtyard that flows into a subsequent courtyard resulting from the annexation in 1970.
Remarkable in this building remains the oratory, which presents paintings of great interest dating to 1475, attributed to Vincenzo Foppa and Bonifacio Bembo. The approval of the Superintendency for the T-shaped expansion arrived on 24 July 1953 (with the specific obligation to plant the gardens with tall trees to mask the fronts of the building). The construction site opened on 28 following April under Antonio Romagnoli's supervision. The new Castiglioni Brugnatelli Women's College opened in 1954-1955.
In the first building there are the common rooms (refectory, library, rector's apartment, caretaker's apartment, and offices) and some student rooms, while the new wing is all intended for the students' rooms.[4]
The building has about 98 bedrooms and community spaces such as canteen, library, and study rooms.
The complex areas were divided into blocks identified by an alphanumeric code that has been assigned to each room belonging to the single block. This coding strategy was helpful in organising the folders of the cloud drive storage. The integrated survey methodology has seen the use of different tools chosen based on an analysis of the spaces and the advantages and limits[5] of each instrument:

- a terrestrial laser scanner[6] (TLS type Faro CAM 150) for the acquisition of external spaces (facades, courtyards) and in the attics;
- the BLK2GO[7] was used inside the internal rooms of the building; the capture was carried out by subdividing the walkable surface of the building into 28 paths by designing overlapping points between contiguous paths of no less than 20% to ensure greater control of the overlapping during the data recording phase;
- a Phantom 4 pro-RTK drone[8] drone for the covers capture, large format B&W targets have been positioned in strategic points to allow the control of the union of the databases during the data recording phase;
- a Canon Eos 1200D camera for photographic documentation

Fig. 4 - The current configuration of the Castiglioni College.

of all the acquired environments and the photogrammetric acquisition of the external fronts and some detail elements. The data resulting from the acquisition of each instrument were first processed individually using specific software for the import/processing/export management of each data. Once the point clouds of the individual portions were obtained, they were recorded together in a single 3D database.

The Cyclone Core software uses approximately 30 corresponding homologous points for registration. The database was then divided into layers to facilitate reading the different portions of the building. The preparation of this type of integrated dataset allows the partialized display of the data through the choice of specific display parameters:

- Division for interiors, exteriors, roofs, attics, and cellars;

Fig. 5 - The survey activities saw several operators view the field simultaneously on different acquisitions. This allowed a significant reduction in acquisition times.

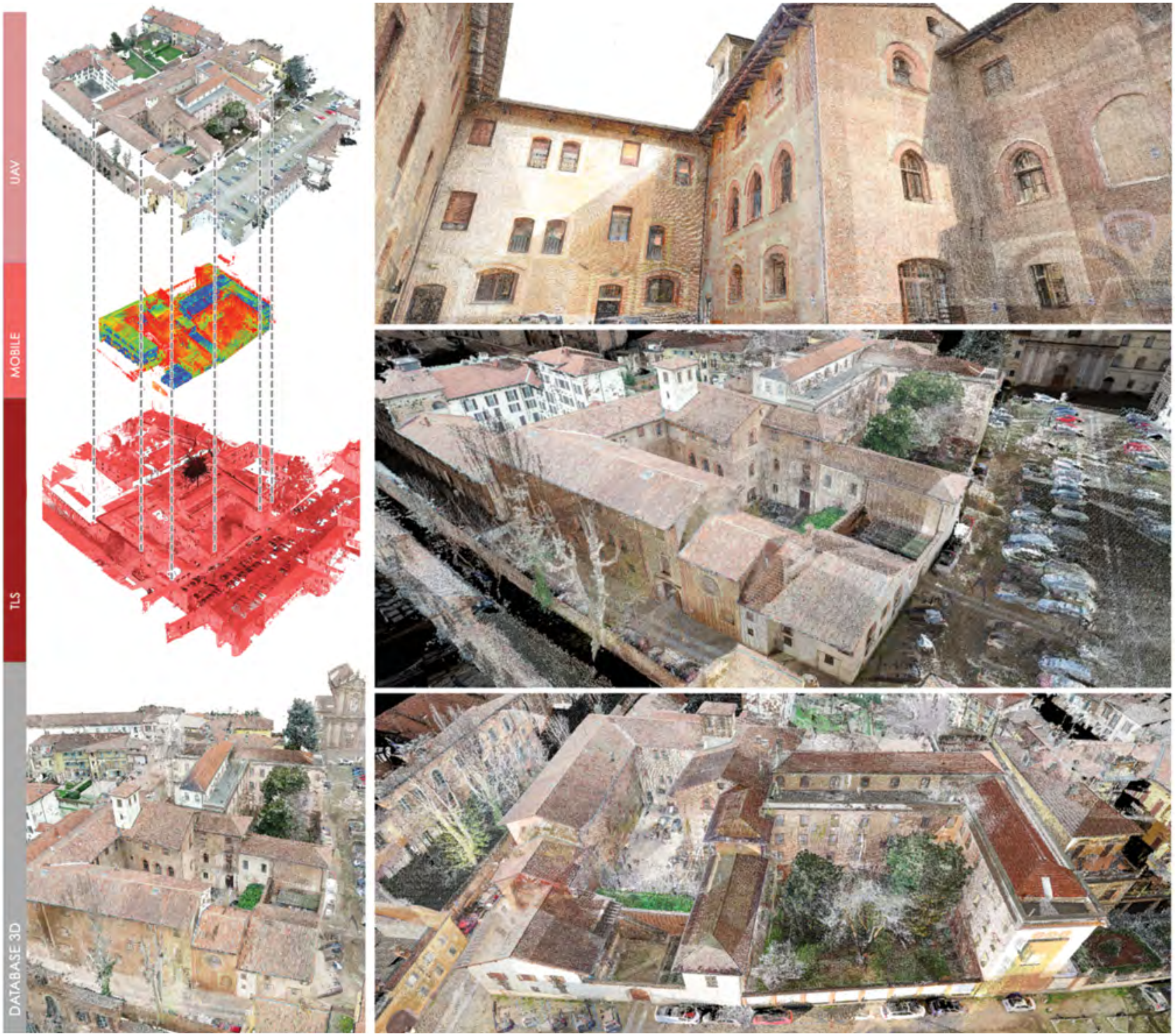
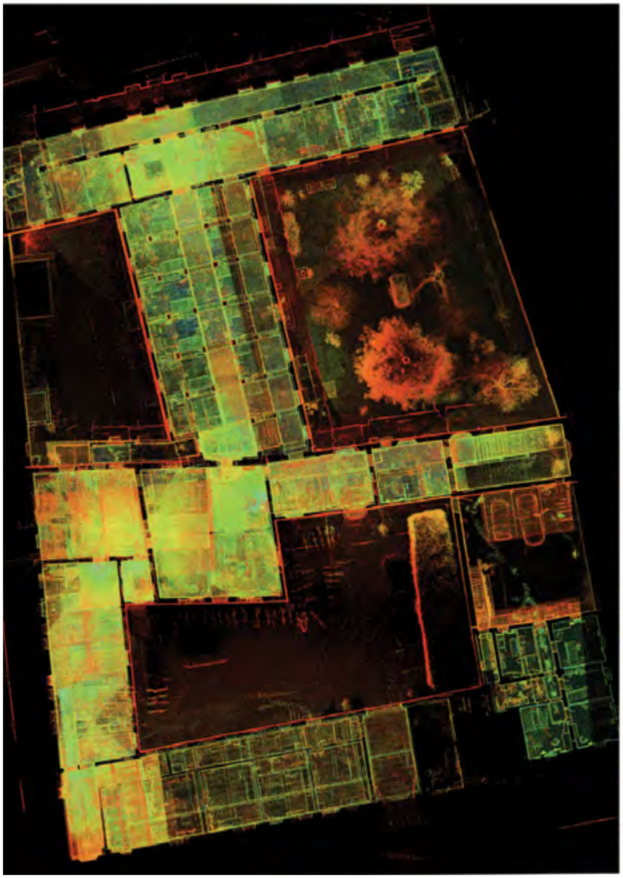


Fig. 6 - Result of the union of the three databases in a single reference system.

- Colorimetric (UAVs, TLS, BLK2GO);
- Reflectance colors (TLS, BLK2GO).

The registration error calculated based on the alignment of the targets oscillates between a min of 0.008 m and a max of 0.034 m.

A discretized management of the point cloud from the acquisition phases to the processing and recording phases facilitates data reading. Avoiding overlapping data redundancies could generate errors of the various elements during the subsequent stages of H-BIM modelling. The point cloud data is discretized for the critical drawing of the profiles useful for the extrusion of the model elements.



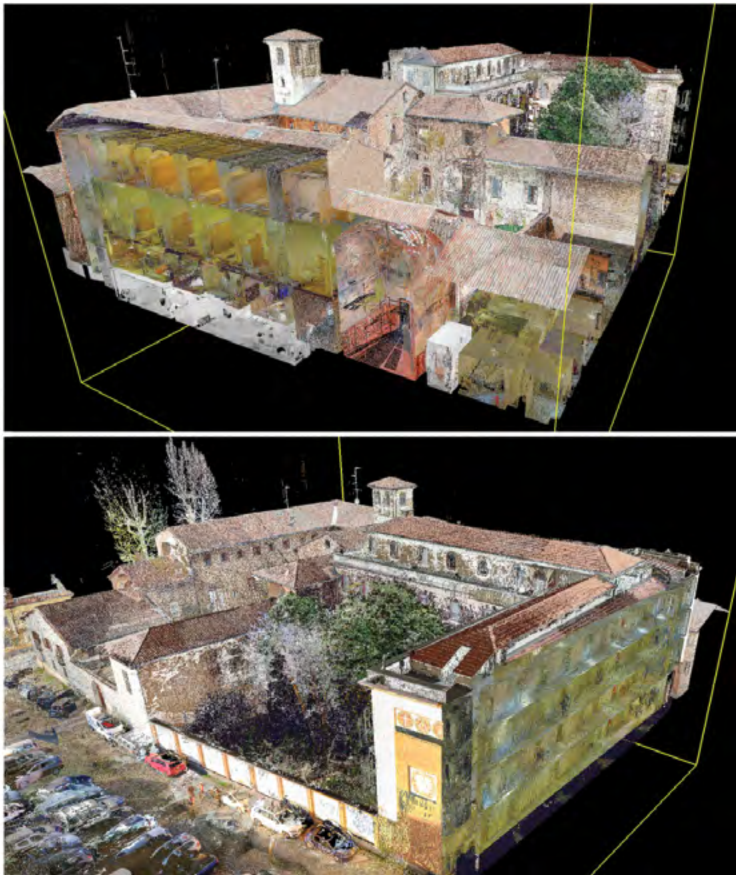


Fig. 7, 8 - Result of 3D point cloud database.

Cloud collaboration for the development of the H-BIM model

The second phase of the experimentation involved analyzing how the data acquired through fast survey protocols could help develop an H-BIM model of the building. The model was set up using work-sharing in Revit through the Collaborative Model Server. The work-sharing method allows multiple users to share and collaborate in a coordinated manner to develop the model in a single environment. This method helps avoid errors due to file disambiguating or overlapping portions. In this case, the open-source version of sharing was tested using OneDrive as the central model's backup and storage system for the Revit management platform. A central model is saved as a source within the OneDrive space in this operating mode.

Each modeler creates a local copy connected to the central model within his workstation. Once completed, each modeler can add and modify updated and displayed elements in the central model through a data synchronization process.

Only once data has been synchronized from a local model to a central model will other users see the individual operator's changes.

An excel file shared It has been prepared, in which an element census is divided by category and position. This monitoring system is helpful to estimate the number of elements to be modeled and plan the overall model elaboration. The file is a monitoring instrument for time and quantity to guarantee final validation of cloud/model adherence and compliance verification of the elements modelling. Each element is identified with an alphanumeric code (Element ID_location / type) used as terminology for the different element families.

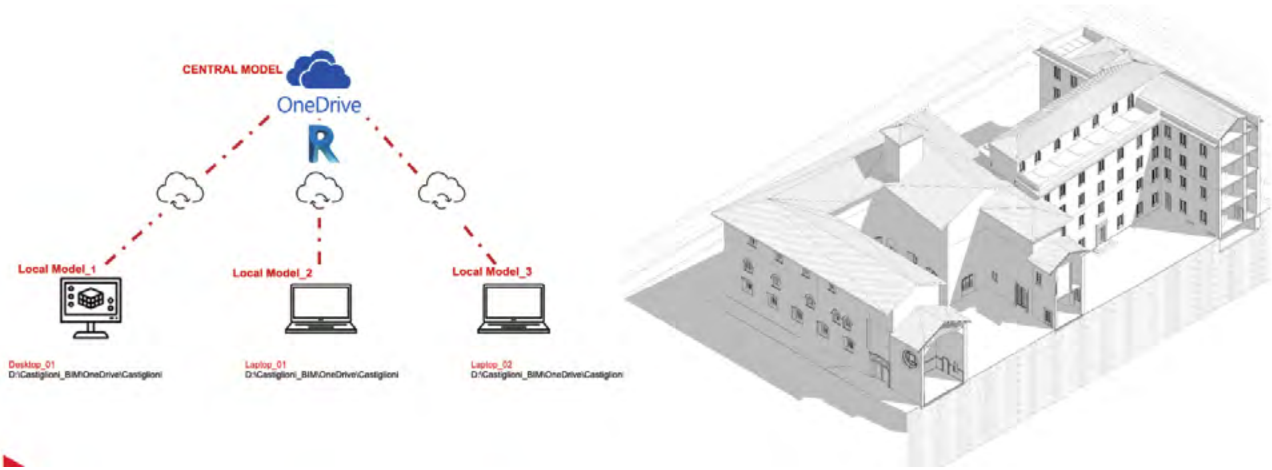


Fig. 9 - Cloud sharing systems for modelling and design are the BIM methodology's strength. It is possible to use work-sharing systems through paid server systems or shared drives such as Dropbox or Google drives for collaborative modelling. Among the advantages: material sharing, several specialized people collaborating with different skills to enrich the information system, remote control and collaboration between different offices, monitoring.

An excel file shared It has been prepared, in which an element census is divided by category and position. This monitoring system is helpful to estimate the number of elements to be modeled and plan the overall model elaboration. The file is a monitoring instrument for time and quantity to guarantee final validation of cloud/model adherence and compliance verification of the elements modelling. Each element is identified with an alphanumeric code (Element ID_location / type) used as terminology for the different element families. BIM-Oriented software allows directly through dedicated plugins or indirectly the import and recorded point cloud data. During the modelling phase, the historical architectural structure requires knowledge of the geometric and topological components of the different building components. The Castiglioni model was entirely developed using the basis of the data of the point cloud database. The cloud was used in two different modelling strategies: macro modelling of the building structure and micro modelling of the family elements. The cloud was connected to the central project file for the macro modelling phase by importing a .rcp file.
A shared reference system was set up, and different reference plans were set in plan and elevation for modelling the structure of the building (partitions, pillars, floors, roofs). Each element has been associated with a specific working workset to coordinate each modeler's work.
Micro modelling has seen complex elements attributable to

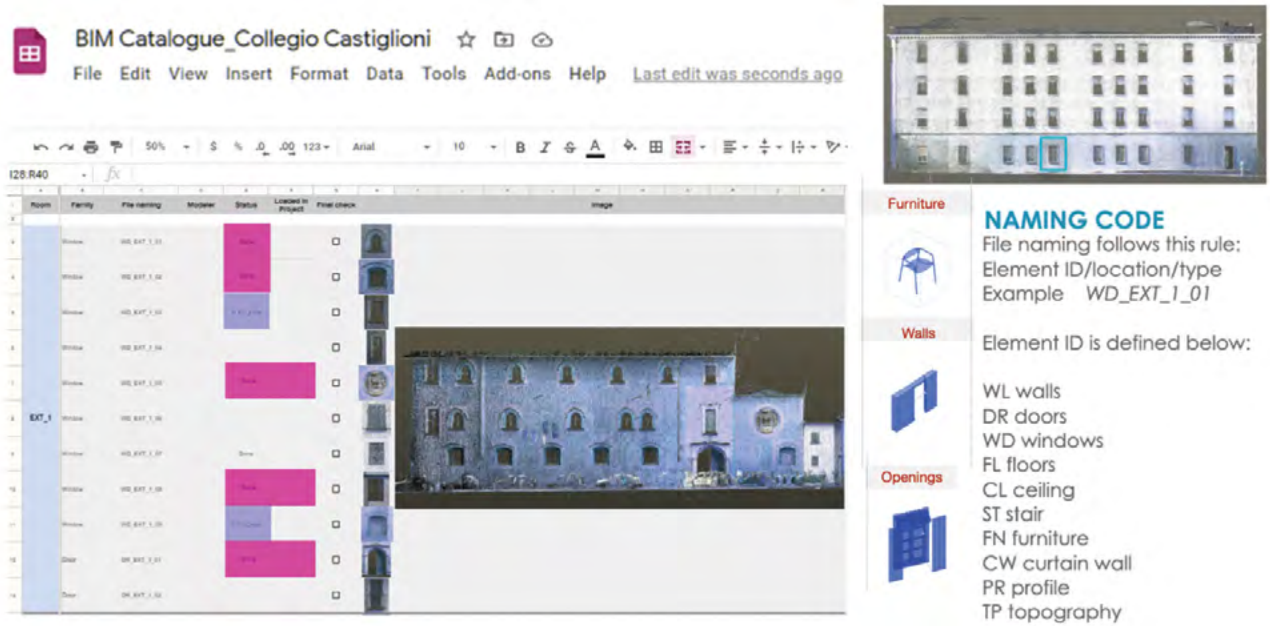


Fig. 10 - Scheme used for the census of model elements.

individual families (doors, windows, profiles, moldings, etc.). Unlike the project environment, Revit does not yet allow the point cloud import into the environment management and modelling of element families. The point cloud was isolated in portions, exported, and imported into Autocad 3D to overcome this lack. Here it was possible to work along the three axes of spatial coordinates to draw and extract the profiles useful for the extrusion of the different components for the modelling of the object. The use of the mobile laser scanner has reduced acquisition times during the survey campaign phase, but it didn't allow detailed modelling compared to the terrestrial laser scanner data. It required a continuous comparison of the photographic material available for avoiding a wrong interpretation of elements less than 5 cm thick. At the macro modelling level, the 3D structure of the mobile data was more than sufficient for modelling the "box" of the model. The choice to use new survey tools demonstrates the effectiveness of fast digital surveys in reading data and designing information. The database allows you to export 2D drawings from the 3D model to provide an updated knowledge base of complex environments. The structuring of an information system allows the institution to develop proposals for maintenance and improvement interventions consistent with the image and historical importance of the building.

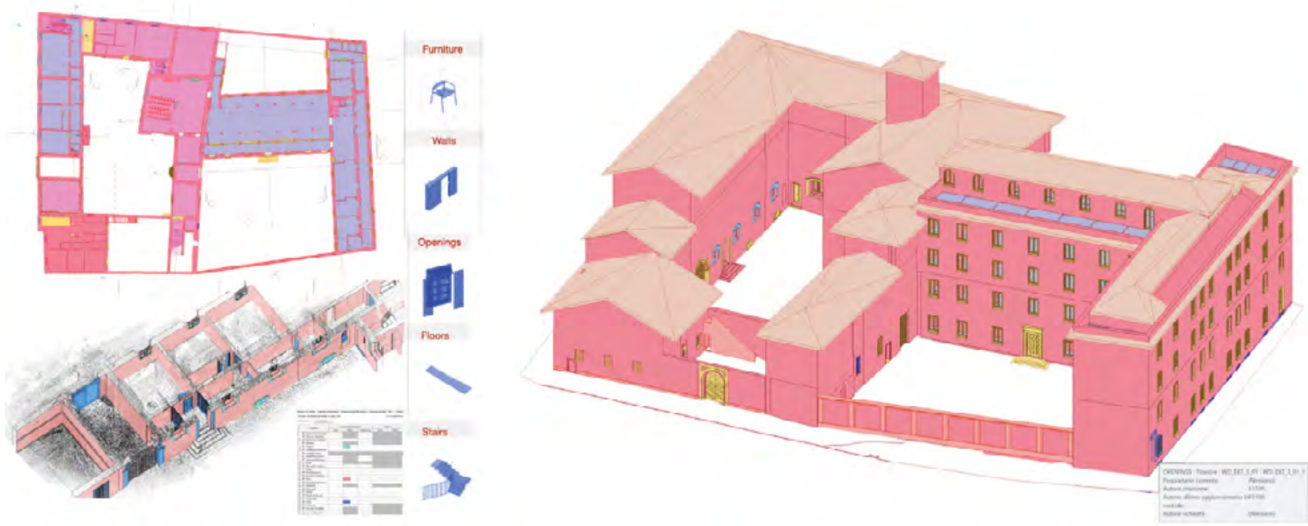


Fig. 11 - The macro modelling of the elements: within the project, an element category has been associated with each workset to allow rapid visualization by using different associated colors.

Fig. 12 - Micro modelling: in particular, for the realization of the models, in order to avoid representation errors, sections set on different layers and with different colors were carried out in Autocad 3D to verify the correspondence between the data of the point cloud and the data represented.

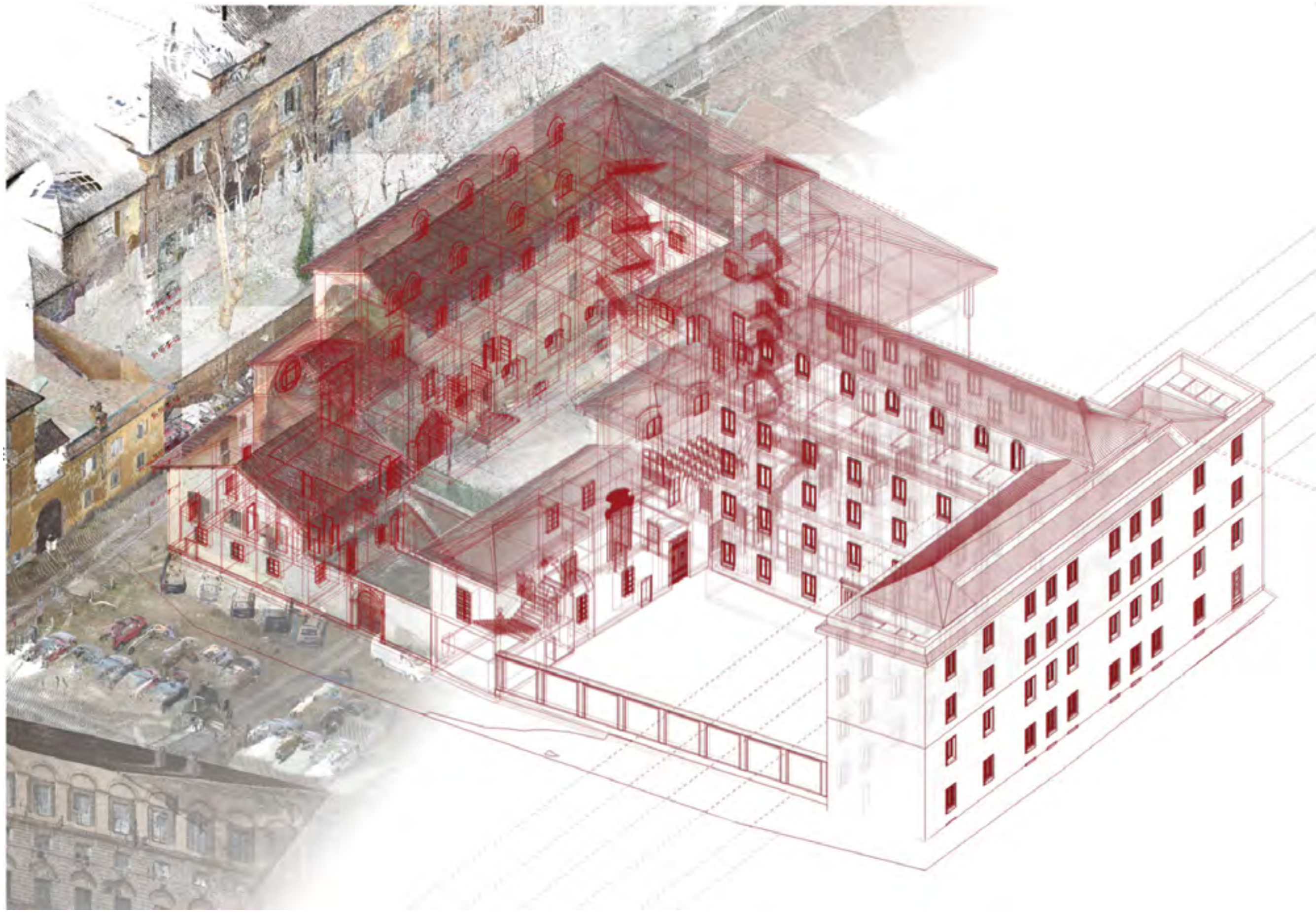


Fig. 13 - Castiglioni College: from point cloud to H-BIM model.

Conclusions

The use of 3D mode technologies improves the knowledge of the representation protocols applicable to the cultural heritage sector in line with European directives. The research developed in synergy with Leica Geosystems aims to underestimate the effectiveness of the new tools for the digital survey. The operational flows are shared with the developers to draft the methodological protocols. The research project carried out an experimental action to validate the acquisition and H-BIM digitization process. Regarding the data capture procedures, the research experimented with an integrated acquisition method to verify the validity of the scan- to-BIM process. In terms of time-consuming sustainability, the use of mobile laser scanner equipment has shown the halving of on-site work times. The activities involved six operators for four days, thus making the significant actions oriented towards the acquisition by type of instrument.

The Scan-to-BIM process develops a model on which to add the technical type information and plan the monitoring and maintenance actions. When referring to the modelling of historic buildings, the process is undoubtedly more laborious than the new buildings. H-BIM modelling cannot be separated from a careful analysis and research on the various components. The geometries of the elements must be appropriately matched and verified with the survey data, overcoming the information fragmentation of uncoordinated project systems. The H-BIM model must be conceived in the long term as a single tool monitoring for both scheduled maintenance and extraordinary actions.

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Notes

[1] See Di Stefano Francesco, Torresani Alessandro, Farella M. Elisa, Pierdicca Roberto, Menna Fabio, Remondino Fabio (2021). 3D Surveying of Underground Built Heritage: Opportunities and Challenges of Mobile Technologies. Sustainability 2021, 13, 13289.

[2] The Leica BLK2GO mobile system uses Visual SLAM technology, consisting of three panoramic cameras that identify the similarities between consecutive images to calculate the movement of the scanner in 3D space. The same cameras take photos used to give the RGB datas to the point clouds.

[3] See Di Stefano Francesco, Torresani Alessandro, Farella M. Elisa, Pierdicca Roberto, Menna Fabio, Remondino Fabio (2021). 3D Surveying of Underground Built Heritage: Opportunities and Challenges of Mobile Technologies. Sustainability 2021, 13, 13289. https://doi.org/ 10.3390/su132313289

[4] See Vicini Emanuele (2010). Il palazzo Castiglioni Brugnatelli nel XX secolo. Un manufatto ridonato all'università e alla città, Pavia: TCP-PAVIA.

[5] The limits considered include acquisition time about the square meters to be acquired, instrument operation in environments without lighting, operation of the instrument in open spaces with few reference geometries.

[6] A total of 135 RGB scans and 8 B&W scans were acquired.

[7] Those research were enforced in a collaboration between Leica Geosystems and the University of Pavia for the development of research activities, and the promotion of the different ways of using mobile laser scanners for cultural heritage.

[8] Those research were enforced in a collaboration between DJI Enterprise and the University of Pavia for the development of research activities, and the promotion of the different ways of using drones for cultural heritage. This collaboration is based on the "Agreement for the development of research activities about the digital documentation of cultural heritage and landscape using drones" between the Department of Civil Engineering and Architecture of the University of Pavia and iFlight Technology Company Limited, signed in February 2020, lasting three years.

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MODELING AND TRADEOFFS.

LIMITS AND POTENTIAL OF THE BIM PLATFORM FOR THE ARCHITECTURAL HERITAGE.

Abstract

The BIM environment arouses great and diverse interests in the field of the representation disciplines; in fact, it appears to be a system capable of providing, within a single platform, tools for analysis, visualization, documentation and management of the architectural heritage and its processes over time. The BIM approach to built heritage shows in this sense important prospects for the use and analysis of existing historical complexes, although it is still desirable to optimize the procedures and above all an improvement in management of the project. Within the complex world of digital representation of historical and architectural heritage, the research aims to reflect on the problems and potential of parametric BIM modeling for this specific field of application. Numerous studies have been carried out on the subject in recent years and with different declinations. By illustrating the workflow applied to a case study, we want to focus on the new reflections introduced, the objectives to be pursued and the problems to be solved.

È indubbio che l'universo BIM susciti grandi e diversificati interessi nel campo delle discipline della rappresentazione; esso sembra presentarsi infatti come un sistema in grado di fornire, all'interno di un'unica piattaforma, strumenti di analisi, visualizzazione, documentazione e gestione del patrimonio architettonico e dei suoi processi nel tempo. L'approccio BIM al patrimonio costruito mostra in questo senso importanti prospettive di utilizzo e analisi di complessi storici esistenti, nonostante sia auspicabile ancora una ottimizzazione delle procedure e soprattutto un miglioramento nella gestione informatica del progetto. All'interno del complesso mondo della rappresentazione digitale del patrimonio storico architettonico, la ricerca vuole riflettere sulle problematiche e le potenzialità della modellazione BIM parametrica per questo specifico campo di applicazione. Numerosi, infatti, sono gli studi condotti sul tema negli ultimi anni e con diverse declinazioni. Attraverso l'illustrazione del flusso di lavoro applicato ad un caso studio, si vuole porre l'attenzione sulle nuove riflessioni introdotte, sugli obiettivi da perseguire e le problematiche da risolvere.

Introduction

In the field of three-dimensional modeling and in the management and enhancement of historic buildings, especially with monumental nature and high architectural and cultural value, the possibility of applying a Building Information Modeling approach constitutes an interesting challenge and represents an objective potential for disciplines of Drawing and Representation. The BIM processes for new buildings or for the existing modern, have long established themselves in the field of three- dimensional representation of architecture, ensuring the control of the design and of all phases of the buildings' life cycle. An open question, and much debated in recent years, is the possibility of using the same processes in the field of monumental building heritage or belonging to the sphere of Cultural Heritage. 3D models by their nature are made up of geo-referenced units, related primarily to geometry, topology, materials, etc. At the same time, digital archiving, analysis, and information management technologies have found the substrate on which to develop their potential in three- dimensional models (Centofanti et al. 2016). The virtualization of cultural heritage has in recent decades become of interest not only for scholars and operators in the sector, but particular attention

in this field has also been placed by UNESCO in reference to the conservation of Digital Heritage and the relationship of transparency and knowledge between objects of historical heritage and their digitization. Most of the three-dimensional computer models allow to describe the geometric, topological, material and colorimetric characteristics belonging to real objects; however these characteristics, which seem to fully describe an artefact, do not take into account another series of information about the history and development over time of the architectural organism, its bibliographic and archival documentation, and all cognitive process that operator performs every time he approaches the modeling of the built historical heritage. The operations aimed at the protection and conservation of our historical heritage also impose the need to preserve all that series of data that Cultural Heritage carries with it, from historical information to relevant data, without uncritically archiving, but providing a digital space, dedicated to their archiving. BIM offers the possibility of managing an important amount of heterogeneous data which, going beyond the simple geometric aspect, can constitute a digital archive of data and information, useful for the documentation and conservation of historical architecture. The translation of the complexity of the historical building into a digital three-dimensional model raises important questions about the procedures to be adopted. According to a consolidated literature, all the operations concerning the knowledge of this type of artefacts always start with the massive data acquisitions, from numerical models (fig. 1) to textured 3D models or meshes, and 2D models. Also, for the Heritage or Historic BIM models, the substrate is made up of point clouds, TLS and SfM, about the architectural organism. The difficulty in translating the numerical model of the point cloud deriving from the survey to a BIM parametric model is represented primarily by the ability of the point clouds to describe only the surface of the monument, considering the geometric and chromatic characteristics and material. To build a parametric BIM model, you need a whole host of other information that goes beyond the scanned surface. Furthermore, the importation of point clouds within the BIM authoring platforms is equivalent to importing a "ghost", which in fact does not interact directly with the model but serves exclusively as a cast of the architectural organism on which model the elements.

Stages of methodology

The objective to obtaining the best possible correspondence between the real object and its virtual model implies a structuring of the operating methodology in stages, to optimize the workflow, but also to make it replicable and applicable to other objects of the historical heritage and consequently shared in the scientific field (fig. 2). The first phase, knowledge phase, involves the collection of data on the state of art of the architectural artefact, historical and archival bibliographic research to acquire as much information as possible on the monument, its characteristics, its history from construction to the present day. Everything must be aimed at creating a reference database, a starting point for modeling and from which to continuously draw information. The creation of the database has a dual purpose: to help and support the operator in the modeling phases, on the other it constitutes a real collector of information on the monument, which can always be consulted and implemented. The architectural survey of the object through massive acquisition also belongs to the knowledge phase, which best describes its current situation and conservation. Furthermore, considering the statements of the Architectural Survey Charter (AA. VV., 2003), in which it is hoped that the survey of each organism should possibly be transformed into an information system that can always be integrated, it seems that the integration between survey and BIM in knowledge of the built heritage offers interesting scenarios. In addition to the survey, it is desirable to carry out a series of diagnostic investigations, preferably non-destructive, of the artifact, or to search for the data of any investigations previously conducted and published; these will allow us to know the object beyond its skin, to understand its composition and will offer help

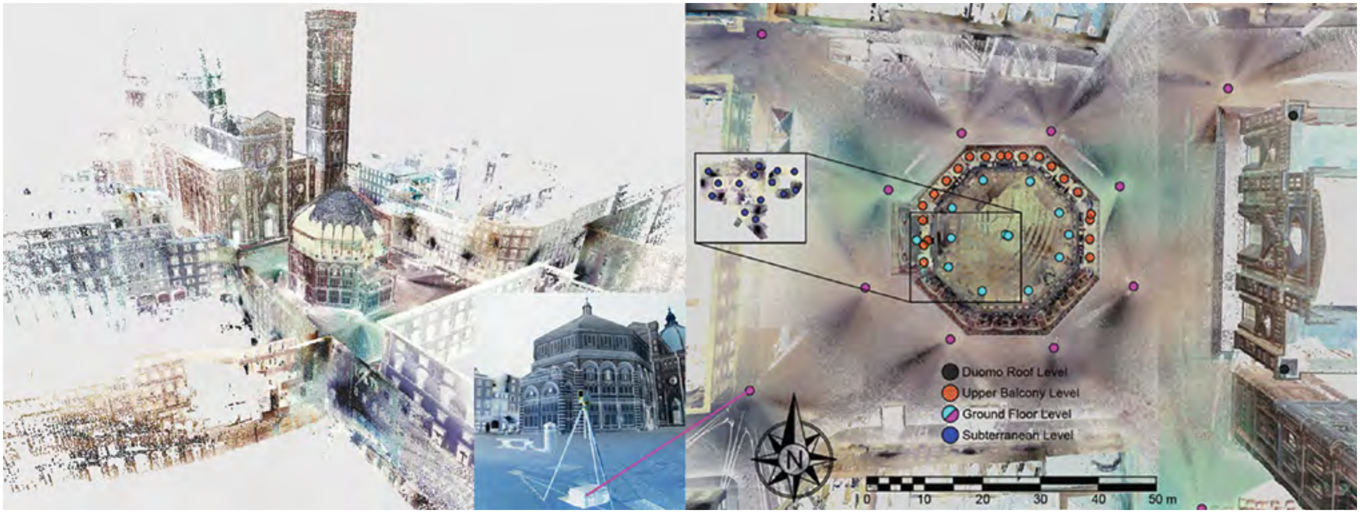


Fig. 1 - General view of the Baptistery’s point cloud and plan with scan positions. Snapshot from Viscore.

in modeling the parametric libraries of digital objects. The second phase, according to a natural process of study and deepening, is called decomposition. During this step, the organism is broken down into its ontological elements, and all the components are discretized (fig.3).

Problems and potential of the model

The Baptistery model, therefore, like all the HBIM models, presents problems and potential (fig. 5), associated, first, in the transposition of the point cloud numerical model into a parametric geometric model. The approach used in the modeling started from the dichotomous reasoning of dividing the elements into replicable or unique ones. The software used provides a whole series of familiar commands, useful for geometrically modeling replicable objects; however, the operator's effort must be to model them as parametric as possible, to ensure future changes and reuse. It is necessary to establish, first, all the different types of the same element, for example the variants of the same type of window on the facade, to plan the use of certain parameters as an instance or as a type, to ensure maximum flexibility. All this must take place after the correct discretization of the architectural object in its structural, functional and formal parts. Thus, as happens in the process that links the two- dimensional detection and representation operations, the operator's critical process plays a fundamental role more than in any other type of canonical three-dimensional modeling, as it critically transforms the objective data coming from the point cloud in a digital 3D model at the base of which there is a long process of careful study and planning of the components and parameters to be used. Modeling in BIM requires the conception and verification of a real project for the transformation of reality into a digital model as faithful as possible. The subjective choices will influence the entire construction of the model and will determine its effectiveness and flexibility in terms of parameterization. Therefore, in the case of BIM modeling, as

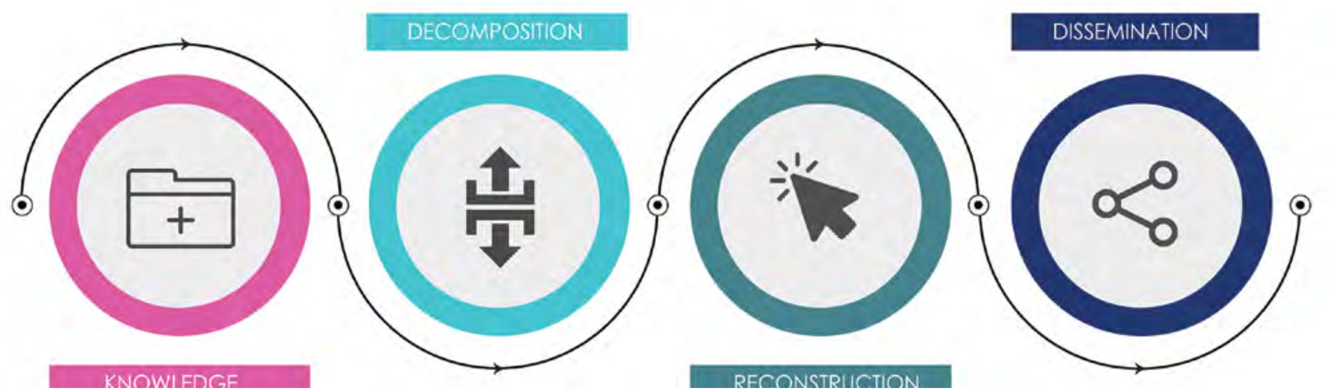


Fig. 2 - Methodological process for HBIM models.

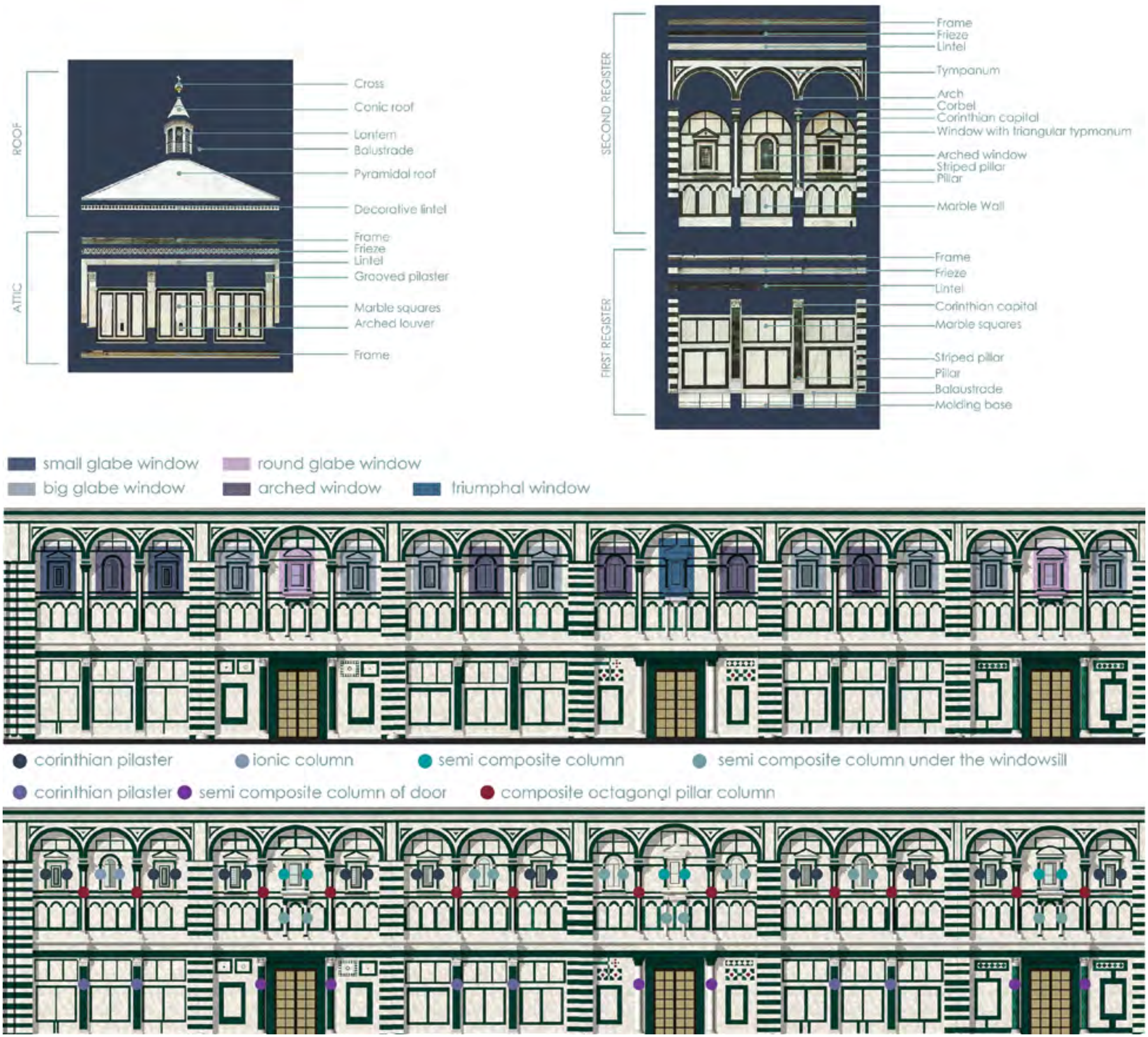


Fig. 3 - Architecture breakdown: ontological definition and hierarchical individuation of the architectural and decorative elements.

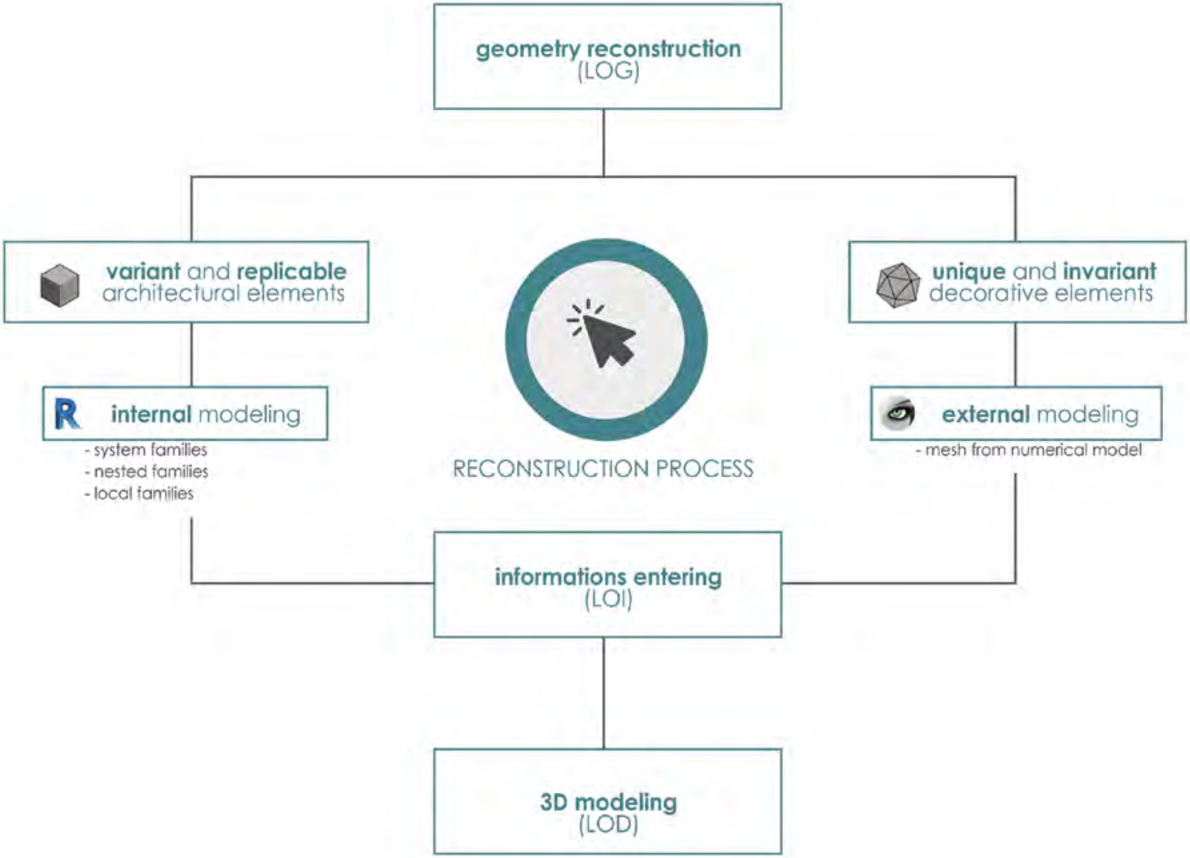


Fig. 4 - Geometric reconstruction process of the historical-architectural building in a BIM environment.

POTENTIAL	LIMITS
- document database	- transition from point cloud to parametric 3D model
- entering informations (LOI)	- semplification of the modelled geometry
- deep knowledge	- subjectivity of discretization process and representation of geometry
- interoperability	- time - consumig modeling operations
- planning, management and manteincance	- complex relationship between LODs and graphic scale of representation
- integrated and upgradeable model	- operational difficulties related to software

Fig. 5 - Problems and potentialities of HBIM models.

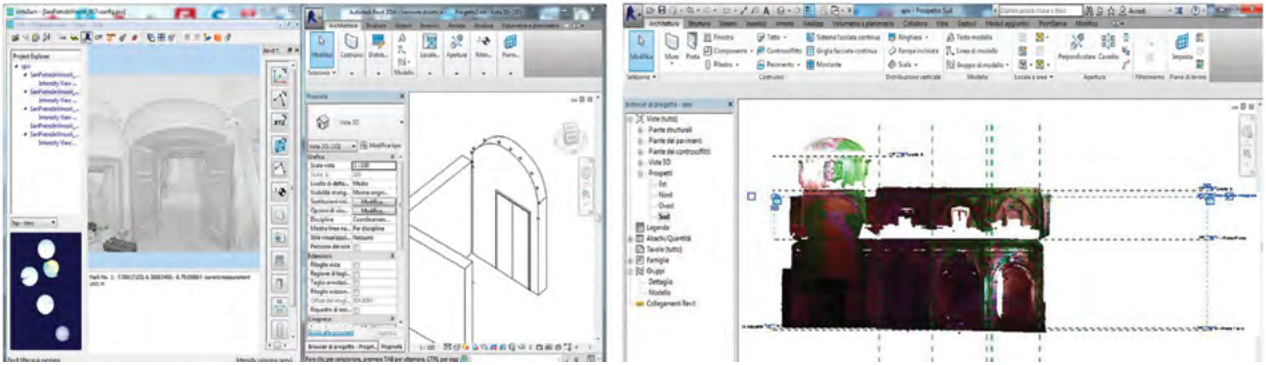


Fig. 6 - Using the Kubit Faro Pointsense plug in in Revit for automatic modeling of geometries and profiles starting from the point cloud. Images taken from Di Luggo, Scandurra, 2016.

much as in the Cultural Heritage sector, the operator must be a technician capable of knowing and discretizing the historical architecture
correctly and acquire specific training in the field of BIM representation and the ability to make the correct model design choices. By reasonably transposing the numerical model into a geometric model, the software guarantees us the import of the point cloud only within the project browser, which, however, can only be used as a basis for re-drawing the positions and profiles of the elements, without playing an active role within the platform. In the case of loadable family modeling, the Editor does not allow importing the point cloud, but only CAD formats, forcing the operator to pass 2D. The only interaction that the BIM authoring platform allows in the 2019 version is the ability to select some points of the cloud, as if they were snaps, to draw lines and geometries on it more precisely; however, it would be desirable for the software to be able to automatically track the profiles of the architectural elements to be modeled, subsequently allowing them to be modified and customized, possibly according to the principles of the algorithms used for semantic segmentation, such as spatial proximities and working by plan of belonging. In this

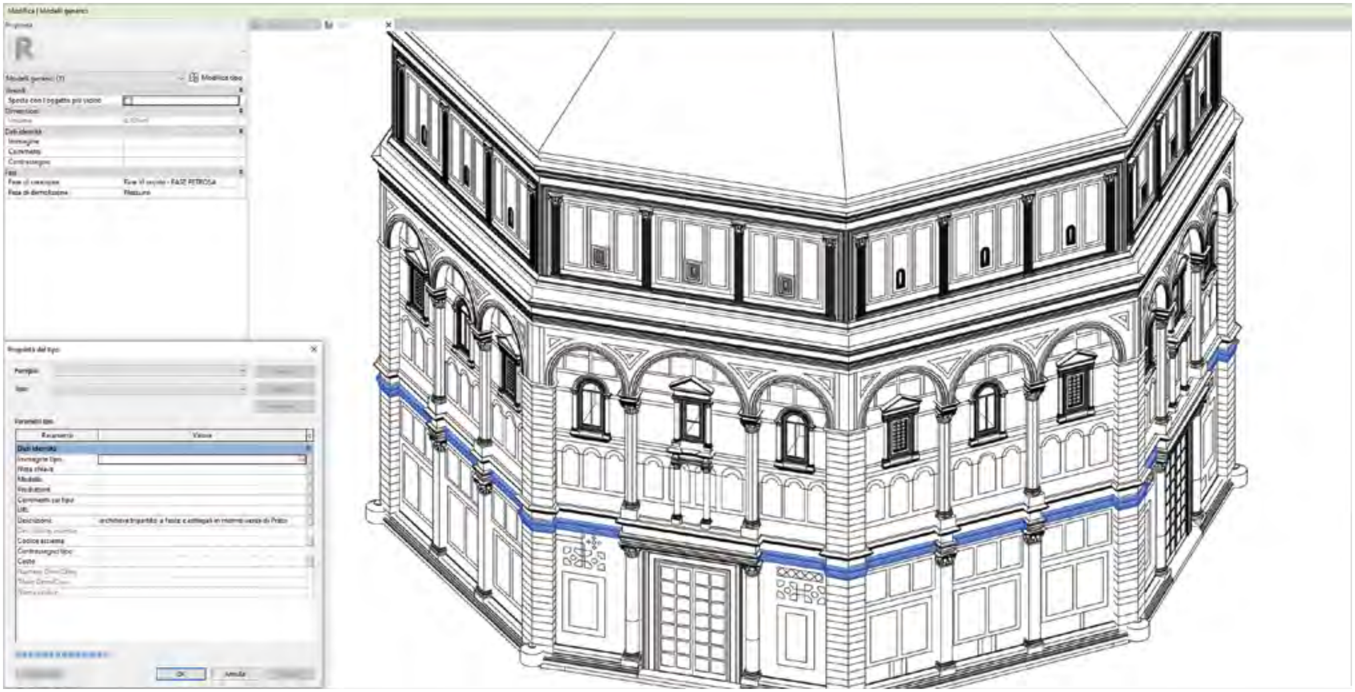


Fig. 7 - Hidden line view of the Baptistery model with the lintel of the first register in evidence. In the type properties panel, you can enter descriptions of the element, such as its composition, or other types of historical information.

regard, the research conducted by Antonella Di Luggo and Simona Scandurra anticipates this possibility using the plug-in Point Sense by Kubit - Faro in the Heritage version (fig. 6). The software adds a series of features to Revit, especially in reference to the interaction between the model and the point cloud, producing projections of acquired data for the rapid construction of 3D models (Di Luggo, Scandurra, 2016). In fact, the possibility of greater interaction between the two elements within the platform would allow greater precision in the three-dimensional rendering of the objects, therefore greater fidelity to the reality detected, also with the possibility of customization and modification by the operator, guaranteeing critical control of operations.

This possibility would transform the apparent limit of the scarce interaction between cloud and model into objective potential, partially solving the problems related to the simplification of the parametric geometric model. This last limit, linked above all to the problem of the articulation of the architectural and decorative forms of historical architecture and their transposition in parametric terms, remains despite the platform permitting different types of procedures and commands for three-dimensional restitution. The operator must make a considerable effort especially in planning and thinking about how to parameterize all the microelements that make up the object to be modelled or even simply the profile of the object. For this reason, often the modelled elements, such as columns for example, represent hybrids, i.e., they are composed of parameterized parts and simply extruded parts, making it possible to reuse these elements in another project browser provided the necessary direct changes on the geometry and not only on the parameters set. On the other hand, it is possible to insert descriptions in the property sheets of the elements and further categories of data, adding information to the three-dimensional object that in some way can make up for the incorrect correspondence between the geometric and real attribute and any simplifications made (fig. 7). The potential that BIM modeling offers, especially in the sector of historical built heritage, are innumerable and all concern digital visualization, communication of the asset, management, and maintenance of the same, finally document collection and data recognition. These advantages are expressed primarily by the ability to enter heterogeneous information within the platform in the form of descriptions, properties, and representations of the materials, as well as the potential for use of the filters present, especially those relating to the temporal dimension of the model. Furthermore, it is possible to link further sub-models to the central model in the platform, linked as external references, such as the numerical survey models, 2D drawings of the architectural artifact and the relative historical documentation. It is also possible, through the management of the model views, to view the central model and the overlapping external references at the same time, to obtain a synthesis model that helps all the actors involved in reading and understanding the artefact (fig. 8). The insertion of external references in the platform can take place in different ways: as a URL link to the model using the online upload of the material which in this case will keep the original format; through the link between model files and information files in Autodesk Dynamo; or by importing and / or exporting the tables containing the information in CAD format and subsequent importation into the Revit model, method chosen in the case of the Baptistery (fig. 9).

The platform allows the insertion of many and different types of data, which all contribute to the documentation of the monument, and therefore is configured primarily as a unique database of the architectural object; it is then transformed into the possibility of making some of this information visible, such as the materials used and the construction phases, and thus becomes the visualization and communication of the monument; finally, by making the geometric representation of the elements as close as possible to reality, it allows the planning of restoration interventions and management of the asset, also thanks to the possibility of extracting abacuses and calculations that quantitatively express the modelled

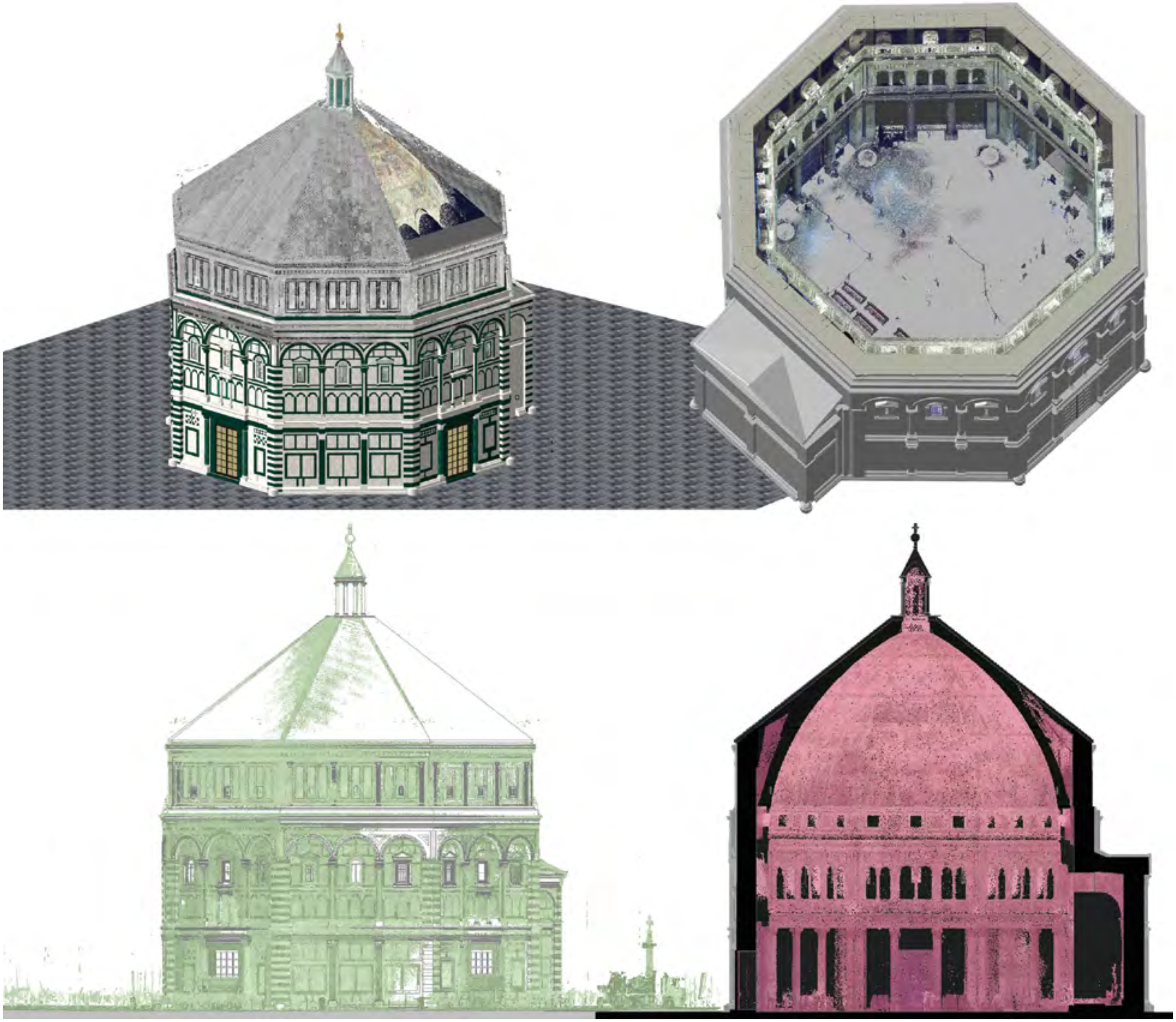


Fig. 8 - 3D view, section, elevation, and axonometric exploded view of the Revit Baptistery model with overlap of the laser scanner data integrated into the platform. Model display options: realistic, hidden line and homogeneous colors.

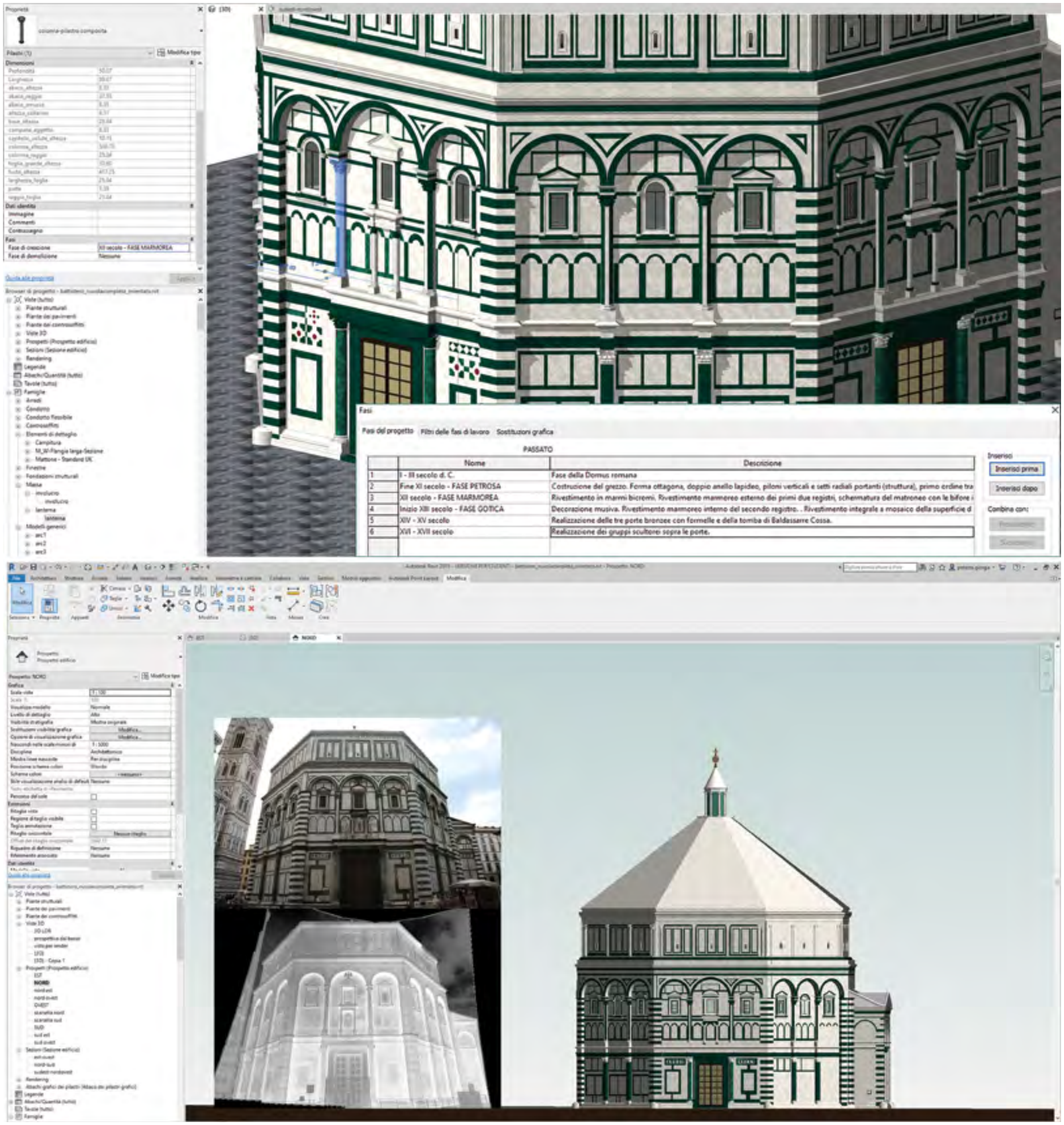
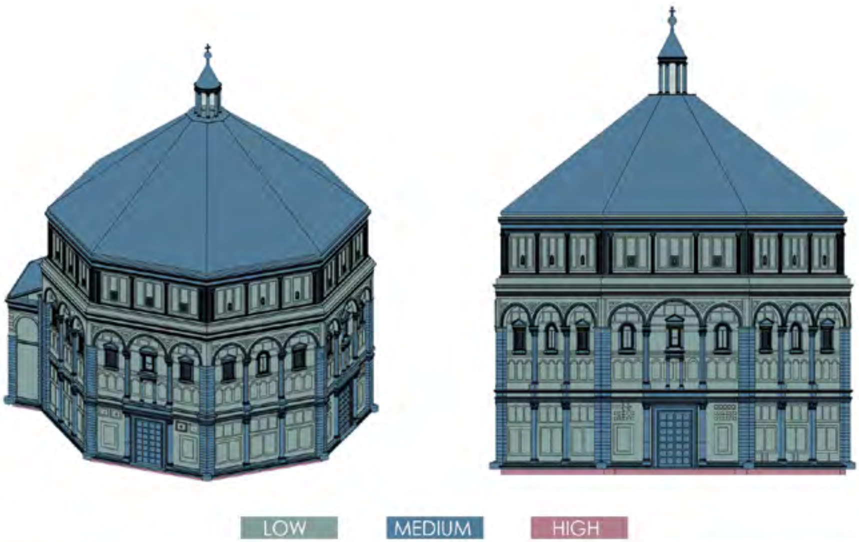


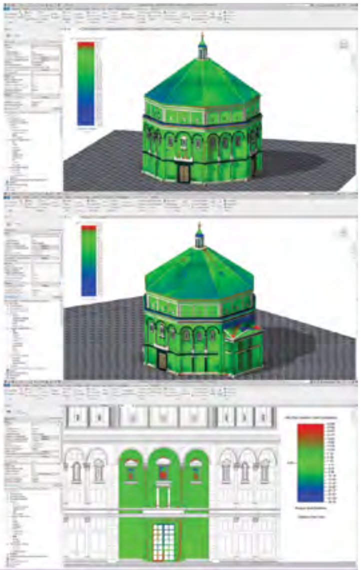
Fig. 9 - Display of the information linked to the BIM model. Above: insertion of phase filters for the association of a precise building phase to the modeled geometric element. Below: modeling of the north elevation with insertion of the real and thermal images generated by the thermal imaging camera in the data acquisition phase.

geometries, such as the surface in square meters covered with green Prato marble, or the cubic meters covered by the barrel vault of the scarsella etc. The study of historical heritage places important themes such as the passage of time and the consistency of the material that has been preserved at the center of the research. It is therefore essential to establish relationships between the acquired data of the monument's spatiality, its materiality, the construction phases, and the state of conservation, structuring the information so that it is directly related to the object represented and semantically defined. However, it is evident that in the design choices the operator makes some simplifications, as in this case, in the choice of modeling the wall thickness of the Baptistery as parametric as it is subject to slight deviations in its perimeter from an average value of 180 cm.

This type of decisions affects the three-dimensional construction and determine the coexistence of heterogeneous LODs within the model itself, as they are affected by different degrees of knowledge and different simplifications from a geometric point of view; the constructed model moves in a range of Development Levels included between LOD D and LOD E of the UNI standard, where the

geometric representation oscillates between the detailed and the specific. The amount of information and analysis available for the individual elements that make up the architectural organism determine its geometric fidelity to reality and express the level of objective LOR reliability (fig.10); however, we must consider the BIM model as always implementable in the light of new information deriving from surveys, studies and discoveries. Although in the execution of the Baptistery model we focused on the construction of the external envelope, some evident criticalities were still found in the construction of the structural parts, such as the horizontal and vertical closures. In this sense, the roofing elements, the ground floor, and the perimeter walls were modeled as system families, using the default families proposed and working on the internal stratifications to make them as faithful as possible to the built reality and using, at times, the overlap of two system families. The information content regarding some specifications on materials, finishes and interventions has been integrated into the property sheets in a description form. The limit in the use of system families is found in the impossibility of sharing them among multiple projects, since they are linked to the specific browser, but also in the need to use multiple families for the creation of complex structures, such as floors characterized by a package in masonry placed over a wooden structure. Obviously, there is also the absolute absence of some types of families in the platform, which instead are essential for the existing historical heritage, such as the vaults between the roofing elements, or the insertion of iron elements as tie rods and chains that must be included in other less coherent types of families. It would therefore be appropriate for the future to develop an application of the platform for the modeling of structures and masonry equipment in parametric mode to overcome some of the limitations found in the BIM methodology applied to the built historical heritage. A further problem more generally, in the BIM representation of historical buildings is the time taken to make the geometric attributes as faithful as possible to reality, especially for articulated geometries such as the Corinthian and composite capitals of the Baptistery. In this case, the possibility of having a simplified model depends on the objective that the model sets itself, be it a communication model and dissemination of knowledge about the monument, or a model to be used for the management of the building and for the realization of restoration interventions. However, we must not forget that the BIM model is in any case an integrated model as it has a whole series of accompanying data within it, one of which is the point cloud, which provides an objective representation of the actual state of the object and can be investigated and inspected where the BIM model does not provide sufficiently detailed information; in the same way it is possible to use the information contained in the property sheets of the elements or to catalog the information deriving from diagnostic





Scheda per la determinazione del Level of Reliability degli oggetti digitali

Criteri per la catalogazione ▶ / Elementi ▼		GEOMETRIA	RILIEVO	INDAGINI	FONTI D'ARCHIVIO	CARATTERISTICHE FISICHE	DEFINIZIONE TECNOLOGIA	CONSERVAZIONE	VALIDAZIONE	FASE EDILIZIA	LOR ELEMENTO
		semplice (generale 1, puntuale 2); scultorea (generale 0, puntuale 1)	non disponibile 0; disponibile (semplice 1, integrato 2)	non disponibili 0; disponibili (generale 1, puntuale 2)	non disponibili 0; disponibili (generale 1, puntuale 2)	generiche o ipotetiche 0; specifiche ([illegible] 1, [illegible] 2)	incerta 0; verificata 2	non disponibile 0; disponibile (categoria 1, digitale 2)	non verificata 0; verificata ([illegible] 1, [illegible] 2)	non disponibile 0; disponibile (generale 1, puntuale 2)	
Famiglia	Descrizione										
pilastro	colonna pilastro ottagonale composita	2	1	0	2	1	2	0	2	2	6.6
muro	parete della facciata est	2	1	2	2	2	2	0	2	2	8.3
finestra	finestra architravata con timpano triangolare	2	1	0	2	1	2	0	2	2	6.6
porta	porta est detta del paradiso	2	1	0	2	1	2	0	2	2	6.6
tetto	tetto piramidale a falde piane	2	1	0	2	1	2	0	2	2	6.6
modello generico metrico	architrave del primo registro	2	1	0	2	2	2	0	1	2	6.6
											LOR MEDIO DEL MODELLO 6.8

Fig. 10 - Graphic expression of the Level of Reliability; below an example of a form developed for the numerical scale determination of the Level of Reliability of digital objects. On the right the model validation with Point Layout.

investigations which can also be connected to the model and accessible via external links. Among the numerous and multifaceted potentials, BIM therefore also includes the diachronic and multiscalar management of digital models.

Conclusions

Unlike geometric modeling, which produces anonymous modeling based only on the forms into which the architectural work can be broken down, the BIM paradigm leads us to consider the specificity of what is represented, where architecture is an organism composed of parts and elements organized according to precise rules. As we have seen, these systems require reliable documentary bases, capable of returning the metric and material information of the artefact. It therefore seems appropriate to use this type of three-dimensional representation for historical architecture, for the information potential that resides in it, being able to include historical data on transformations in a single digital environment, progressively recording the restoration and maintenance interventions, guaranteeing constant control of the ‘operates over time and setting up an updatable documentation database. However, it is always necessary to understand the objectives for which a survey is carried out and its representation. The latter in fact always constitutes the outcome of a program built with awareness and structured on a specific intention. The representation therefore has a consistent critical implication, as it investigates in the context of complex knowledge, providing interpretations according to different interpretations. If this can be traced back in its theoretical formulation to an operation of building a mental model, this is even more evident in BIM systems, where the clarity of the model is the result of analytical and intellectual precision (Di Luggo, A., Scandura, S., 2016). A process of simplification is necessary for the knowledge of the real, since it is only possible to know and represent it by bringing back the complexity of the real to a logical scheme; it is therefore necessary to find the right balance between mimetic representation of reality and its simplification. As Antonella Di Luggo points out, mimesis and descriptive richness do not always guarantee the transcription of the meanings of reality, but as a “slavish imitation”, they produce a copy by replicating the appearance and generating information that cannot be distinguished by cognitive levels. Instead, the goal of an intelligent representation must be pursued, capable of reading the formal structure of the architecture, its parts and the logical system that correlates them. One of the reflections that accompanied the research during the modeling and definition phase of the process, concerned the relationship between LOD and the graphic scale of representation that influence geometric modeling. This reflection arose during the modeling phase from a simple question: under what conditions can I consider all pillar columns to be the same? Obviously, the problem again falls within the field of simplifications that are carried out by the operator in the transition from the survey to the three-dimensional representation and implies a reasoning about the level of development of the column element, but more about the level of detail of the represented geometry. One of the assumptions that was applied in the research and modeling phase of the Baptistery is the possibility of compensating in some cases for the geometric simplification of the modeled element with the addition of LOI information attributes present in the property sheet. With regard to the question relating to the LOD and the graphical scale of representation that influence the modeling, the answer can only be affirmative, however it is believed that the latter should be defined a priori in the planning phase of the structuring of the model; the LODs present within the model will therefore be different as they are affected by the degree of knowledge of the operator about the LOI information attributes, but all included within a hypothetical range that is defined by the graphic scale chosen at the start. According to this assumption, the question about the possibility of considering and modeling the columns that are all the same finds direct response and correspondence with the graphical scale of representation that is defined[1]. We believe that the simplification of geometry is also allowed, and if necessary[2], it could be compensated by the addition of information describing the element (fig. 11). A brief reflection was also made on the possibilities of developing and implementing the model in the future. In fact, the Cultural Heritage has many models, which however, after their creation and dissemination, become obsolete and are condemned to be forgotten. In this sense, BIM offers us the possibility of continuously updating and improving the model over time, gradually adding

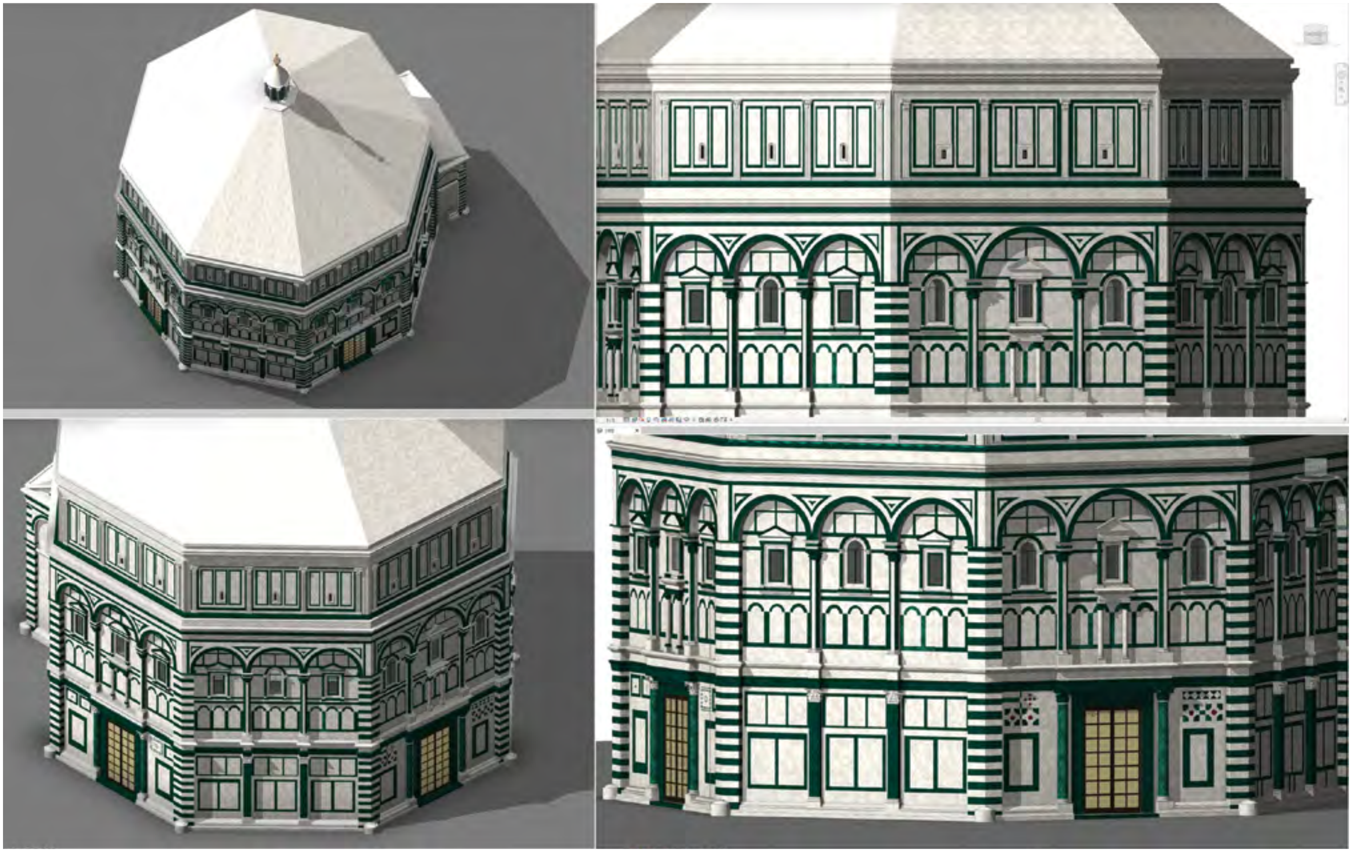


Fig. 11 - Perspective views of façade details of the Baptistery model and general views in a BIM environment; realistic mode with shadows.

information regarding the management of the building over the years, but also the addition of informative and geometric attributes deriving from new surveys. Not only, in fact, the HBIM model also adapts to a series of other developments, in other environments, collaborative with the platform, and of augmented reality (AR) which today is configured as one of the preferential avenues for viewing and communication of the historical heritage built. A constantly updated BIM model is not only useful for the management of the artefact but is configured as a unique database that includes all the updated information that you have on the monument, becoming a real database useful for documentation and scientific research.
With all the potential that platform expresses, the HBIM model is destined to play a fundamental role in the documentation of the historical heritage built, representing a valid substitute for other types of three-dimensional modeling, but also as a system for collecting and organizing data.

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Notes

[1] We believe that even in the case of the graphical scale of geometry representation the problem lies in the relationship, often incorrect, that is created between the Development Level, which includes both the geometric and the informative attributes, and the Level of detail that instead it only deals with the modeled geometry.

[2] The simplification of geometry is a natural, critical, and necessary operation in the creation of a model, especially when the geometry is particularly complex, or when detailed modeling is not necessary according to the objectives that the model proposes.

SESSION - II

Digitizazion of archival drawings

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Cettina Santagati, building engineer. She is associate professor at the Department of Civil Engineering and Architecture, University of Catania. In 2003 she got her PhD in Drawing and Surveying of Existing Heritage. She is a member of the Laboratory of Architectural Photogrammetry and Survey "Luigi Andreozzi" and head of the Laboratory of Digital Surveying, Representation and Reconstruction at Museum of Representation, University of Catania. She is responsible for the university of Catania of the Erasmus + Capacity Building project ARTEST (Enhancing Education Programs in Arts and Humanities via EU STEM Methods) coordinated by the university of Koln.
She is involved in several national project on 3D digitization and enhancement of Cultural Heritage and Museum Collections. Member of the Advisory Board of the project Erasmus + Cooperation partnerships in higher education 'CREAMS: Scaffolding Creativity of Arts Students: Framework, Toolchain, and Educational Material on how to Create their Own Virtual Exhibitions'. She is member of the commission Digital Technologies for Cultural Heritage of ICOM Italy and of the Drawing Archives Commission of the Italian drawing scientific association (UID). Her research interests are focused on: 3D acquisition, modelling and reconstruction from the urban to the architectural scale, H-BIM, Virtual Museums.

INTRODUCTION

The digitisation of archives is a system to ensure their preservation and to enable the dissemination and enhancement of their heritage. This process has already been affecting libraries and archives for several years and they are increasingly making their collections available to users in digital format, in online databases or on dedicated platforms, such as Google Arts & Culture, which organise virtual thematic exhibitions[1].

This effectively shortens distances and allows democratic dissemination and access to knowledge. The conditions imposed by the Covid-19 pandemic have taught us, after all, how important it is that the consultation of resources can also take place at a distance.

If digitising archive documents is always a delicate operation, making a faithful digital copy of an architectural drawing is an even more complex action. Those who study original architect's drawings from archives are well aware of how, at times, investigating the graphic sign, the nuance of colour, the intensity of the stroke used, the erasures, annotations and graphic constructions is (almost and with due differences) a task to be conducted with the same care as an archaeological investigation. In this meaning, the study of archive drawings can be likened to a survey operation, i.e. the reading and detection of traces that are also due to rethinking and corrections, or left by the tools used by the author.

The digitisation process of archive drawings, intended as a digital copy, must therefore not only avoid geometric deformations but also allow for the most faithful reproduction of the colour and physical characteristics of the original document. But the digitisation process does not end with the scanning of documents and the production of a digital copy. The possibility of accessing digital resources encourages the proliferation of studies on archival drawings, and interest in this heritage is now well established in the research field of digital representation of architecture. The extensive literature available concerns redrawing, graphic analysis and the creation of virtual models that are sometimes shared online[2].

The interpretation of signs and symbols, typical of the author's vocabulary, also requires knowledge of his graphic language, investigation of his architectural thinking and comparison with his realised architecture. This is even more important when the graphic documentation relating to a project and stored in the archives is incomplete. The graphic reading of archive drawings therefore becomes an opportunity to investigate the specifics of projects. The virtual models are the place where the interpretation of the project becomes shaped; furthermore, including all the knowledge that has been produced, they become new digital cultural products able to storytell the project.

The two presentations at the session cover both aspects discussed above: digitisation, as a process of digital reproduction, and some ongoing experiments in sharing digital models online derived from the study of archive drawings.

Sandra Mikolajewska's paper presents a speditive survey experimentation conducted on a collection of unpublished survey drawings by Giuseppe Cocconcelli made in the first half of the 19th century and conserved in the Historical City Archive of Parma. The method adopted is configured as a possible operative protocol that can be used for the digitisation of archive drawings and in those cases in which it is necessary to obtain a digital reproduction of documents free of geometric deformations.

Matteo Flavio Mancini presents some experiments, proposing a comparison between techniques for sharing online digital reconstructions of unrealised projects of contemporary architecture. His study invites a reflection on the need to define a protocol on the level of digital reconstruction of unrealised projects and the visualisation of the level of reliability of 3D models and spherical renderings.

Both papers propose methodologies for the analysis of archive documents and digital reproduction, which are also aimed at reproducing the structural qualities of a historical drawing. In both cases, the focus is on the importance of the faithful digital copy and the critical interpretation of the drawing, which is also based on the careful analysis of graphic signs.

Notes

[1] Google's platform allows users to explore artworks, places and collections from museums, archives and organisations in various countries that collaborate with the Google Cultural Institute. Artworks are shared through digital copies that can be explored and enlarged, maintaining high definition. See https://artsandculture.google.com/.

[2] Some disciplinary contributions are collected in the database created for the UID project: Il disegno negli Archivi di Architettura, available at https://www.unioneitalianadisegno.it/wp/archivi/. No. 10 of Diségno, the six- monthly journal of UID - Unione Italiana per il Disegno, soon to be published, is entirely dedicated to drawing in architecture archives. See https://disegno.unioneitalianadisegno.it/index.php/disegno.

Sandra Mikolajewska

University of Parma

Sandra Mikolajewska earned her Pd.D. from the University of Parma in May 2021 (supervisor: Prof. Andrea Zerbi). Her dissertation focuses on digital technologies for the documentation, conservation and valorization of Cultural Heritage, with an application to the Farnese Theatre in Parma. In September 2021, she received the "Gaspare de Fiore" 2021 UID Award, for the best ICAR-17's Ph.D. Thesis of the year.

Her research deals with Survey and Representation, with particular attention to the methodologies for the three-dimensional modeling of cultural assets and to the multimedia technologies for the valorization and communication of Cultural Heritage.

Currently, she is a short-term research fellow at the University of Parma (Department of Engineering and Architecture) and she is taking part in the "Existing Building Information Modeling for the management of existing building" research project.

SMART SURVEY METHODOLOGIES FOR THE DIGITIZATION OF ARCHITECTURAL DRAWINGS.

THE MAPS OF SOME CONVENTS LOCATED IN THE CITY OF PARMA, DRAWN BY GIUSEPPE COCCONCELLI IN 1811

Abstract

This paper regards the field of digitization of archival documentation, with particular attention to the historical iconographic apparatus related to the specific sector of architecture. The operation of dematerialization, essential for the preservation, protection, management, dissemination, and valorization of this heritage, plays a key role in the complex knowledge process of an architectural organism. By illustrating the experimentation carried out on an unpublished collection of survey drawings, drawn by Giuseppe Cocconcelli in 1811, related to some religious structures located in Parma, a reflection on the potential of survey methodologies for the digital documentation of graphic elaborates will be presented. The method adopted represents a possible solution for the digitization of documents that require a digital reproduction that is geometrically correct.

Il presente contributo si inserisce in un filone di ricerca relativo alla digitalizzazione della documentazione d'archivio, con particolare attenzione all'apparato documentario storico di carattere iconografico inerente allo specifico ambito dell'architettura. L'operazione di dematerializzazione di tale materiale, essenziale per la conservazione, tutela, gestione, divulgazione e valorizzazione del patrimonio cartaceo, riveste un ruolo fondamentale nell'ambito del complesso percorso di conoscenza di un organismo edilizio. Attraverso l'illustrazione di una sperimentazione condotta su un'inedita raccolta di disegni di rilievo realizzati da Giuseppe Cocconcelli nel 1811, relativi ad alcuni organismi religiosi ubicati a Parma, si vuole esprimere una riflessione sulle potenzialità delle metodologie di rilievo speditivo per la documentazione digitale dei disegni storici. Il metodo illustrato si configura come una possibile soluzione per la digitalizzazione di documenti d'archivio, per i quali sia necessaria una riproduzione digitale geometricamente corretta.

Introduction

The numerous projects carried out in recent years in the field of digitization of Cultural Heritage have shown that the operation of dematerialization may be considered an essential tool for the preservation, conservation and enhancement of heritage. At the same time, they demonstrated how this operation can support the dissemination of knowledge and research activities. It is easy to understand how, according to the type of document to be digitized and the purpose of the research, the necessary equipment and the operations to be carried out can be extremely different. When dealing with historical documents, it is also necessary to face some questions linked to their fragile nature, as they are frequently characterized by a poor state of preservation. In these cases, the digitization operation is particularly complex: it should be as less invasive as possible and should provide a faithful image of the document (both from a geometric and a colorimetric point of view).

Among the possible typologies of archival records, particular attention should be paid to the iconographic apparatus inherent to the specific field of architecture. The particularity of these documents (project, survey, or study drawings), often made on large paper supports, almost always folded repeatedly, causes their rapid deterioration. This material, which is also characterized by a poor manageability, is not always properly archived. The difficulty of managing architectural drawings was recognized as early as 2000, when the International Council on Archives[1] (one of the most important organizations dedicated to the conservation of the world's archival heritage), published specific guidelines for their preservation. Although they have not yet received the same attention or, more likely, the same economic resources as other types of documents, their digitization not only represents the first step to their safeguard, but also offers multiple possibilities for their use.

As these drawings are fundamental in the knowledge process of a building, their digital reproduction as geometrically correct as possible is essential.

In parallel with the rapid technological evolution that has led to the development of the most innovative image acquisition systems, specifically designed for historical documents such as books, maps, drawings, etc., the possible areas involved in the digitization operation have also grown exponentially. Among these, particular attention is given to projects related to heritage protection and dissemination (Apollonio et al. 2015), planning and territorial analysis (Bruno 2013), (Bianchi 2015), (Monaco 2014), historical and architectural analysis (Marani 2019), (Vitali et al. 2021), etc. The examples of digitization projects related to archival heritage and carried out with professional equipment could be numerous. However, they almost always refer to well-known historical records that are more easily funded by public or private funds. It is also true that the most significant percentage of the documentary heritage is less well known and is not involved in these projects. In these cases, or when it is not possible to use professional equipment, it is essential to seek alternative and more economical solutions.

This paper deals with the above-mentioned issues and is part of a wider research aimed at the study of the iconographic apparatus, drawn by Giuseppe Cocconcelli in 1811, concerning some religious architectures in Parma. This apparatus is composed of a collection of survey drawings available in two versions. The first, well-known and considered a definitive version of the collection, is kept in the National Archives of Paris. The second, unpublished and presumed a preliminary version, is preserved in the Parma Municipal Historical Archive. Since it has not yet been possible to digitize the Parisian collection, due to the ongoing pandemic situation, the focus of this paper is on the methodology adopted for the documentation of the drawings preserved in Parma.

Case study: the maps of some convents located in the city of Parma drawn by Giuseppe Cocconcelli in 1811.

The iconographic apparatus of G. Cocconcelli examined in this paper is linked to the phenomenon of the suppression of religious orders that took place during the Napoleonic government. In the specific case of the Duchy of Parma, Piacenza and Guastalla, the two decrees of 1805 and 1810 led to the suppression of numerous religious congregations present in the city. Not long before (in the second half of the eighteenth century), the city housed more than ninety religious structures (Giandebiaggi et al. 2019). These buildings are clearly documented, for example, in the Sardi Atlas, the first geometric-particle cadastre of the city, drawn in 1767 by Gian Pietro Sardi.

This particular phenomenon generated important effects on the urban fabric, leading to the reuse and demolition of many buildings (Pinon 2012). In this context, Cocconcelli was asked to survey some convents and to elaborate for each of them a project of possible new uses (Pederzani 1994). In the 1811 report sent to the mayor of the city, Mr. Ortalli, the engineer provided survey drawings of twenty structures (limited only to the ground floor plans of the buildings). Synthetic legends relating to the functions housed in the convents and some observations on their state of preservation are also present in the volume.

It is important to stress that the two versions of the collection are not identical and are characterized by an extremely different state of preservation. The Parisian version is almost intact and the collection kept in Parma is much more damaged. In particular, the binding of the volume is in poor condition; the pages have undulations, folds and cuts along the margins; there are widespread dark stains that in some cases compromise the readability of the documents; the ink color is non-uniformly weakened, etc. The fragile state of conservation of the collection highlights the need for its digitization. This operation is considered fundamental to avoid the risk of losing such a precious documentary heritage for the city of Parma.

An accurate examination of the version preserved in the National Archives in Paris, dated 1811 and entitled Atlas de vingt plans des couvents supprimés de la Ville de Parme[2], showed a rigorous organization of the volume. Its first pages are dedicated to a brief presentation of the contents, including tables showing the square footage and the estimated value of structures. In the following pages, there are survey drawings followed by a descriptive part.

Except for the plan of the Monastery of San Giovanni Evangelista, which is drawn on a larger sheet that is folded inside the volume, all the Parisian drawings are approximately 24 x 35 cm. Each plan is double squared and has a graphic scale in meters. These drawings are made with extreme accuracy: the principal lines are drawn with ink, while the exteriors of the structures and the sectioned parts are elegantly watercolored. To distinguish the green parts from the paved ones, Cocconcelli chose to use two colors: green and gray. The third color that characterizes the drawings is pink, used for the sectioned parts.

Comparing the Parisian version with the one preserved in the Parma Municipal Historical Archive, entitled Mappe con descrizioni della massima parte de' Conventi di frati e monache posti nella Città di Parma, il tutto fatto nel 1811 dal fu Capitano Ingegnere Giuseppe Cocconcelli[3], it is possible to notice that the structure of the collection is inverted. The first pages are dedicated to the survey drawings, followed by the textual part.

Although the textual part of the volume is equally important, in this context, the focus will be on the drawings. Differently from the Parisian version, the drawings of the Parma collection are not definitive and are not homogeneous. Some of them are watercolored, while others are clearly not finished (they

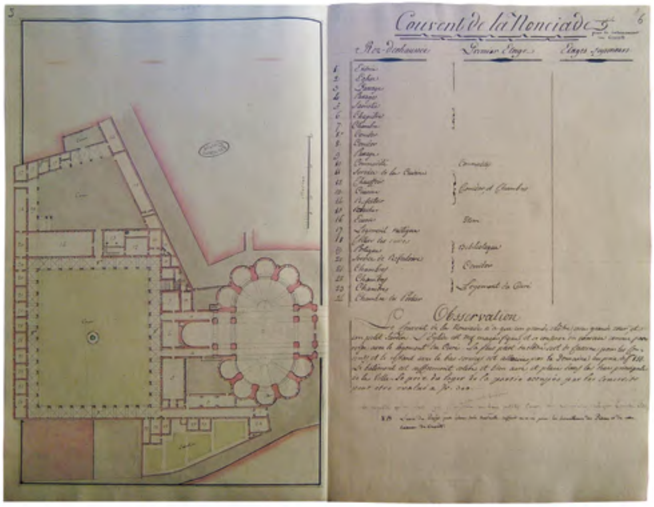

Fig. 1 - The Convent of Santissima Annunziata in the collection of drawings preserved in Paris.

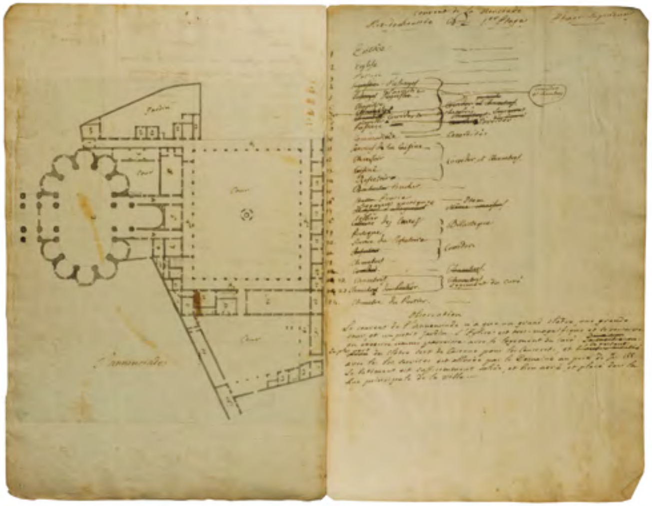

Fig. 2 - The Convent of Santissima Annunziata in the collection of drawings preserved in Parma.

are made with pencil or ink, have rich annotations and graphic constructions, are not always provided with a graphic scale, etc.). The preliminary nature of the volume is also evident by the fact that the drawings are made on different sheets, subsequently glued in the volume. The number, the orientation, and the order in which the complexes are illustrated are different from those followed in the Parisian version.

	Name of the structure	Name of the structure in the collection preserved in Paris	Drawing present in the collection preserved in Parma
1	Priory of San Francesco di Paola	Couvent des Minimes	
2	Convent of Santissima Annunziata	Couvent de la Nonciade	•
3	Monastery of Santa Maria della Neve	Couvent des Capucines de Ste. Marie de la Neige	•
4	Monastery of Sant'Uldarico	Couvent de St. Ulderic	
5	Convent of Santa Maria del Tempio	Couvent des Capucins	•
6	Convent of San Pietro d'Alcantara	Couvent des Reformés	•
7	Monastery of Immacolata Concezione	Couvent des Theatines	•
8	Monastery of San Salvatore	Couvent de St. Sauveur	
9	Monastery of Sant'Agostino	Couvent de St. Augustin	•
10	Convent of Santa Maria Bianca	Couvent des Carmelites Dechaussés	•
11	Monastery of San Quintino	Couvent de St. Quintin	
12	Convent of Santa Maria del Carmine	Couvent du Carme	•
13	Monastery of Santa Caterina	Couvent de Ste. Catherine	•
14	Monastery of Santa Chiara	Couvent des Clarisses	•
15	Monastery of San Domenico	Couvent des Dominiquaines	•
16	Monastery of San Basilide	Couvent de St. Basile	•
17	Convent of Santa Teresa	Couvent de Ste. Terese	•
18	Monastery of Santa Maria Maddalena Nuova	Couvent de Ste M. Magdalaine	•
19	Convent of Santa Cristina	Couvent de Ste. Cristine	•
20	Monastery of San Giovanni Evangelista	Couvent de St. Jean	•

Fig. 3 - Drawings of the structures surveyed by G. Cocconcelli present in the collection kept in Paris and the one preserved in Parma. Below: indication of the religious structures surveyed by G. Cocconcelli on the Sardi Atlas (1767).

Digitization process

Since the collection of drawings conserved in Parma is in a poor state of preservation, it was decided to carry out the photographic campaign in situ. This choice was supported by the desire to avoid transporting such fragile documents to other locations, which would have required a complex bureaucratic process. At the beginning of the digitization, all pages were carefully inspected. The main aim of this activity was to identify suitable procedures to minimize possible physical damage during the dematerialization of the manuscript. In order to guarantee a final result as uniform as possible, the same acquisition procedure was adopted for both the drawings and the textual parts. All pages were digitized separately, always maintaining the sequence and orientation of the originals. The photographic campaign, aimed mainly at the geometrically correct reproduction of documents, was performed with a Nikon D7200 (resolution of 6000x4000 pixel). The camera was placed on a rigid rod, placed with the optical axis as perpendicular as possible to the document to be photographed and finally, it was leveled. The height of the camera was chosen in order to ensure the framing of the entire sheet. To this aim, a 35 mm optics (52 mm equivalent focal length) was used. To ensure maximum stability for the camera, all frames were taken using an infrared remote control. The entire campaign was performed using artificial light conditions, with two light sources (one zenithal and one lateral).

Two frames were taken for each page of the manuscript: one with a grid overlaid on the page and one without. The grid (with a pitch of 5 mm) was used in order to facilitate and have more control over the subsequent rectification operations and was made on a transparent acetate in A3 format. All frames were acquired in two formats (JPG and NEF), characterized by an average weight of about 15 Mb (JPG) and 28 Mb (NEF) and a color depth of 24 bits.

At the end of the photographic campaign, all the images were examined in order to verify their quality. Next, they were cataloged, and the entire process and all the methodological choices were documented. As specified in the Guidelines for Planning the Digitization of Rare Book and Manuscript Collections[4], this approach helps to make operations more scientifically transparent, reducing the risk of possible misinterpretations.

Once the photographic campaign was completed, it was possible to proceed with the rectification of the images. This operation was carried out by using software that allows to eliminate the perspective effect of photographs of flat objects, RRR[5]. In the case of drawings examined in this study, made on sheets that can be considered flat (the small deformations that inevitably characterize historical documents are less than a few mm), this software seemed particularly suitable. The experimentation carried out included two phases: the first related to photographs with the grid overlapped on the drawings, the second to photos without the grid.

The first operation concerned the identification on the photograph with the grid of the area for which it was necessary to eliminate the perspective effect (the area was defined considering the page sizes). Within this area, 4 points were then identified and collimated. These points were chosen as much as possible at the edges of the sheet, in correspondence with the intersection points of the grid (in order to have their coordinates). Once the projection plane and its characteristics were defined, it was possible to generate the photoplans of the drawings, in png format and with a resolution of 10 pixels per mm.

Next, the obtained photoplans were imported within the AutoCAD software. In order to verify the correctness of the rectification operation, it was decided to compare the photoplane grid with a vector-drawn one (drawn with the same pitch used on the acetate, equal to 5 mm). By superimposing the grid on the image, it was possible to identify areas of deviation between the vector grid and the

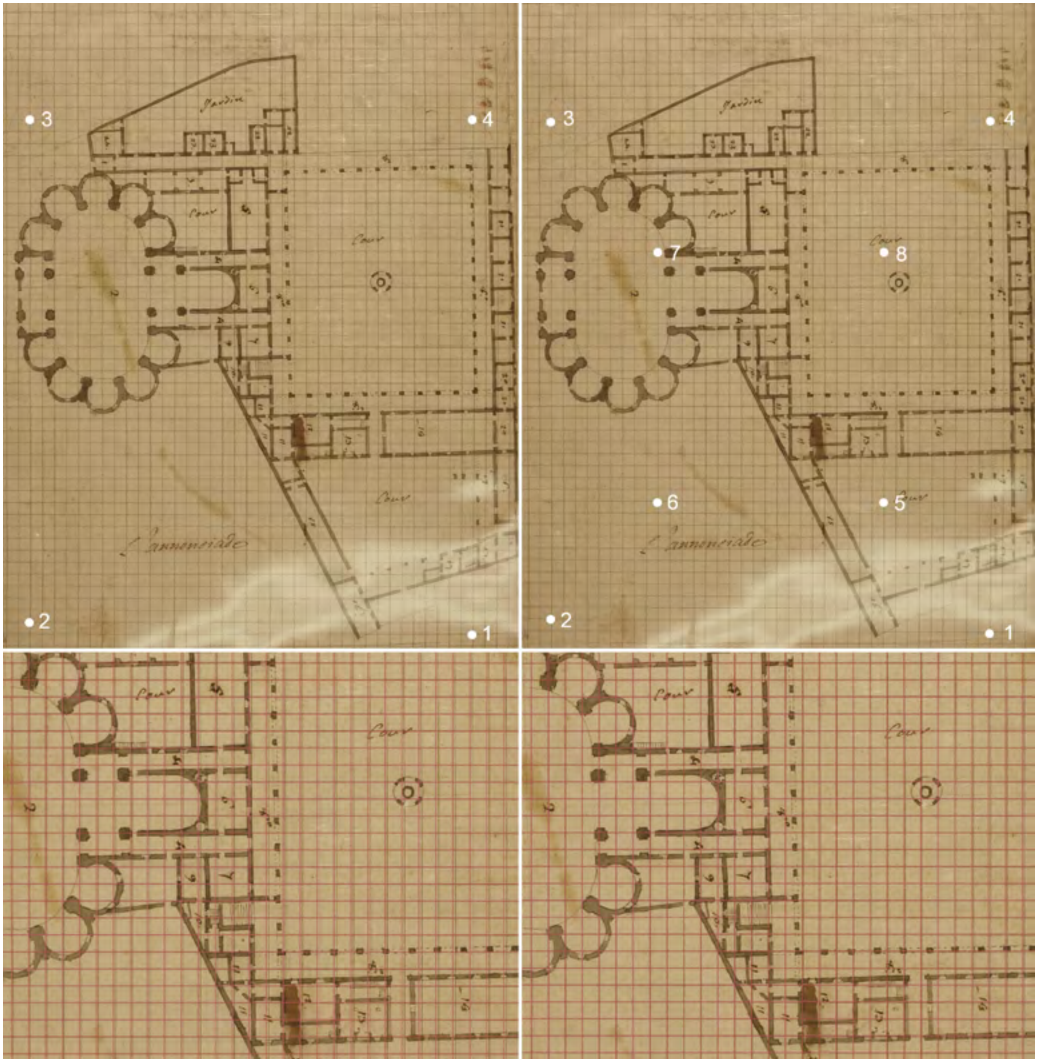

Fig. 4 - On the left: photoplane of the drawing of the Convent of the Santissima Annunziata obtained using 4 points. On the right: photoplane of the same document obtained using 8 points. Below: particulars of the comparison between the photoplane grid with a vector-drawn one.

one present in the photoplane.
For example, in the case of the drawing relative to the Convent of Santissima Annunziata, the maximum deviation was measured in the lower part of the photoplane. With the aim of minimizing this error, the same rectification operation was carried out a second time, using another 4 points (for a total of 8 points). Then, in the most critical areas, the distance between the two grids was measured. In the first case, the maximum error was 0.55 mm, in the second 0.32 mm. The rectification of the image with 8 points has therefore allowed to obtain a photoplane with a lower error and more equally distributed.
The second phase of the entire process regarded the rectification of the photographs in which the grid was not

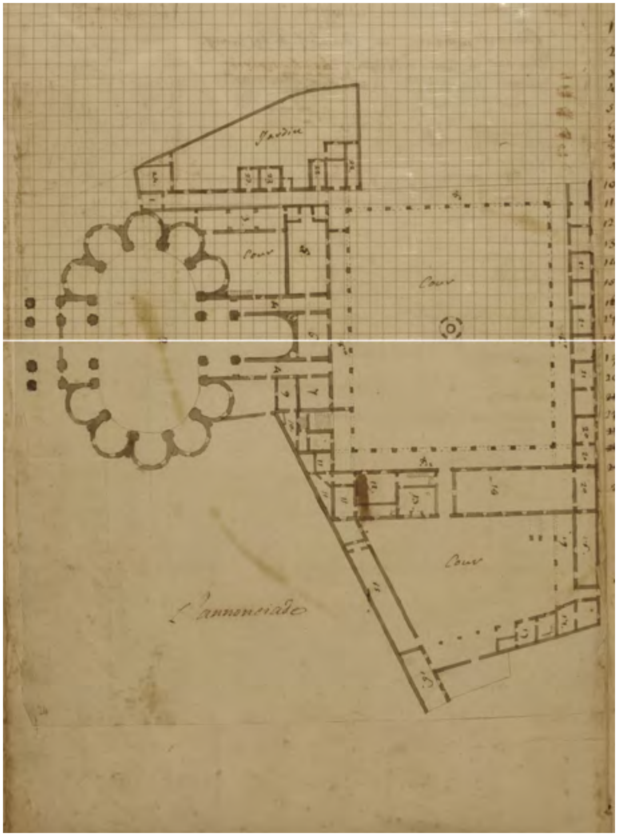

Fig. 5 - Overlapping of the photoplans obtained using two different methods.

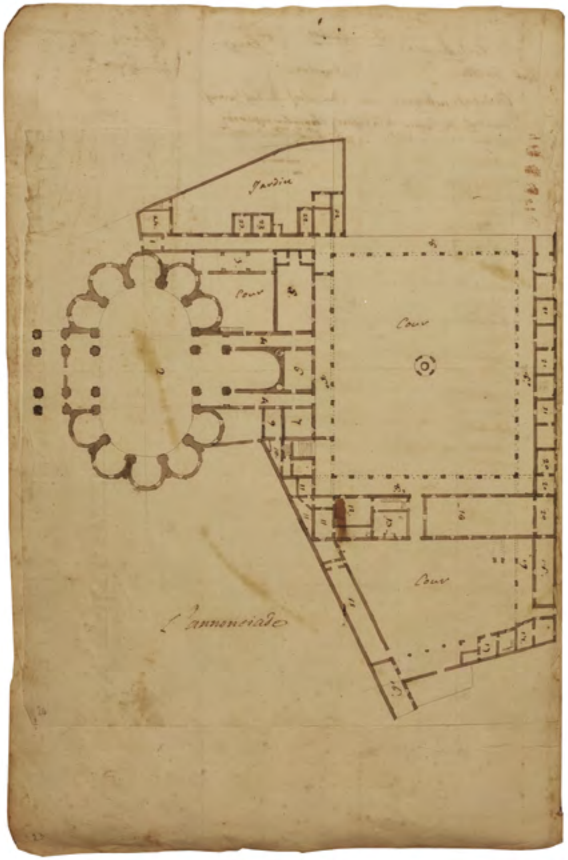

Fig. 6 - Definitive photoplane of the page related to the Convent of the Santissima Annunziata, ready to be digitally archived.

present. Two different methods were experimented. The first method was based on the application of the same distortion parameters used for photos with the grid. It is important to stress that this method makes the whole process extremely faster. The second method was based on the rectification of the image using points in common between the photoplane of the image with the grid and the photograph without it. In this case, 4 other easily recognizable points were then identified. This time, however, reference was made to the drawing lines and not to the grid (the points were identified, for example, at the intersection of the walls). Once the coordinates of these points were identified (from the photoplans imported into AutoCAD), it was possible to repeat the operations illustrated previously for the images rectification.
Finally, in order to verify that the photoplane relative to the frame without the grid was geometrically correct, it was decided to compare the two photoplans (with and without the grid) within the software Adobe Photoshop CC 2017. The two images were overlapped and the comparison showed that they coincide perfectly. This operation allowed to verify that, for the purposes of this research, the first method was faster and equally valid.

Conclusions

The digitization of the collection preserved in Parma represents the first step towards the preservation of a little-known but extremely significant historical documentation for the knowledge of the city. This operation, in addition to the valorization of the manuscript, may have implications in several areas of research.
One of the next aims to be achieved concerns the digitization of the collection preserved in Paris. This activity, made impossible by the ongoing pandemic situation since 2020, would allow accurate metric comparisons between the two versions of the drawings.
Secondly, the drawings of the structures still present in Parma could be compared with the plans obtained from the most recent surveys. This comparison would allow to analyze in detail the transformations that the complexes have undergone in the course of time.
Finally, the dissemination of the material on online databases would be particularly useful. To this end, it would be necessary to complete the compilation of all the metadata, proceed with the transcription of the textual parts of the documents and select appropriate solutions for the visualization and consultation of the contents. On the one hand, this would facilitate study and research activities, as well as the dissemination of knowledge; on the other hand, it would also contribute to the protection of the documents. At the same time, the dissemination of this material could become a solution aimed at collecting funds that are needed to further investigations and restoration activities, essential to ensure the conservation of the documents over time.

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Notes

[1] International Council on Archives, Section on Architectural Records (2000). *Guide to the Archival Care of Architectural Records, 19th-20th Centuries*.
[2] Paris National Archives. N/IV/Taro/1.
[3] Parma Municipal Historical Archive. Maps and Drawings Fund. Thanks to arch. Enrica Caffarra for collaboration.
[4] IFLA Rare Book and Special Collections Section (2015). *Linee guida per pianificare la digitalizzazione di collezioni di libri rari e manoscritti*.
[5] The RRR software was developed within the DIA of the University of Parma by Prof. R. Roncella.

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DIGITAL MODELS FOR HISTORICAL AND CONTEMPORARY ARCHITECTURAL ARCHIVES: EXPERIMENTS AND REFLECTIONS

Abstract

The sensitivity of institutions that manage archives of architectural drawings towards digitisation
has significantly been accelerated due to the conditions imposed by the pandemic. The increased accessibility of resources has promoted research in different directions, from analysing historical architectural drawings to the three-dimensional reconstruction of unrealised projects of contemporary Italian architecture. At the same time, these researches have stimulated reflections on specific issues: the suitability of digital archives as research and dissemination tools for cultural assets with particular qualities such as historical architectural drawings; the need for a higher level of transparency of the methods adopted for 3D reconstructions of contemporary architecture and the importance of clearly communicating their reliability, similar to what has been pursued for some time in the field of archaeology. Furthermore, some experiments on the online sharing of results through spherical renderings and 3D models are presented, considering the potential of the different techniques in terms of visualisation, implementation complexity and interaction.

La sensibilità delle istituzioni che gestiscono archivi di disegni d'architettura verso il tema della digitalizzazione ha subito una notevole accelerazione a seguito delle condizioni imposte dalla pandemia. L'accresciuta possibilità di accesso alle risorse ha promosso ricerche in diverse direzioni, dall'analisi dei disegni di architettura storica, alla ricostruzione tridimensionale di progetti non realizzati di architettura contemporanea italiana. Al contempo, queste ricerche hanno stimolato riflessioni su temi specifici: l'adeguatezza degli archivi digitali come strumenti di ricerca e divulgazione di beni culturali dalle particolari qualità come i disegni di architettura storica; la necessità di un maggiore livello di trasparenza dei metodi adottati per le ricostruzioni 3D di architetture contemporanee e l'importanza di comunicare chiaramente la loro attendibilità, similmente a quanto perseguito da tempo in ambito archeologico. Inoltre, vengono presentate alcune sperimentazioni sulla condivisione on-line dei risultati attraverso rendering sferici e modelli 3D con considerazioni riguardo le potenzialità delle diverse tecniche in tema di visualizzazione, complessità di implementazione e interazione.

Introduction

The paper presents some experiments conducted on historical and contemporary architectural drawings by Italian authors, some accessible online, preserved in important Italian institutions. The first part of the paper is based on the experience of research and analysis performed on the project drawings of Ottaviano Mascherino (Bologna 1536 - Rome 1606) for the foundation of the town of Manziana (1589-1590), on the reflections about the characteristics of the historical architectural drawing and a proposal of contents for the historical architectural archives, aimed at a correct reading of the peculiarities of these cultural assets. The second part refers to the experiments developed on the three-dimensional reconstruction of unrealised projects of the architect Francesco Cellini (1944), on the necessity to define a protocol regarding the level of reconstruction and on the visualisation of their level of reliability. Finally, the third part presents the ongoing experiments on the tools for the online sharing of three-dimensional reconstructions of unrealised projects by the ABDR architectural firm.

Historical architecture drawings: digital contributions to the reading of an analogue language

The project drawings for the foundation of the village of Manziana (RM) made by Ottaviano Mascherino on behalf of the Ospedale del S. Spirito between 1589 and 1590 are preserved in Mascarino Fund at the Accademia Nazionale di San Luca in Rome. The fund consists of about 250 drawings, primarily autographs of the Bolognese architect, and is an essential testimony of the graphic conventions of architectural drawing between the end of the 16th and the beginning of the 17th century . By Mascherino's time, architectural drawing had reached a stage where methods and conventions had been formally established, and the tension between the orthographic and perspective representation of the project had been overcome in favour of the former . There are nine drawings of the Manziana project, all drawn in orthographic projection (plan and elevation) at different representation scales. The drawings in the Mascarino Fund have all been digitised and can be accessed in high resolution through the Lineamenta database, developed by the Hertziana Library - Max Planck Institute for Art History in Rome .

The study of the drawings for Manziana was performed based on the available digital reproductions, according to a philological analysis methodology based on a double transcription of each drawing: the first is aimed at analysing the drawing as a set of graphic signs and therefore considers the actual dimensions of the support, the tools and techniques used; the second is aimed at the critical interpretation of the drawing as a two-dimensional representation of architecture and therefore normalises the drawing, eliminating errors and integrating any lacunae in order to obtain a set of drawings as complete and coherent as possible (Fig. 1).

The analysis methodology briefly presented above has led to the formulation of some reflections on the characteristics of analogue drawing and historical drawing specifically, in relation to its digitisation. It is, in fact, a widespread opinion among those who have dealt with digital culture that the digitisation process produces, besides significant advantages, always a loss of some kind .

Therefore, it is legitimate to wonder what is lost in the digitisation process of an analogue original and, then, what new digital content can restore this loss. Assuming that the digital reproduction of drawings is of high quality in terms of resolution and colour fidelity, we can exclude that the loss concerns the aesthetic aspect of the analogue original. At the same time, it is appropriate to focus on its structural aspects. The drawing as a material object is always characterised by

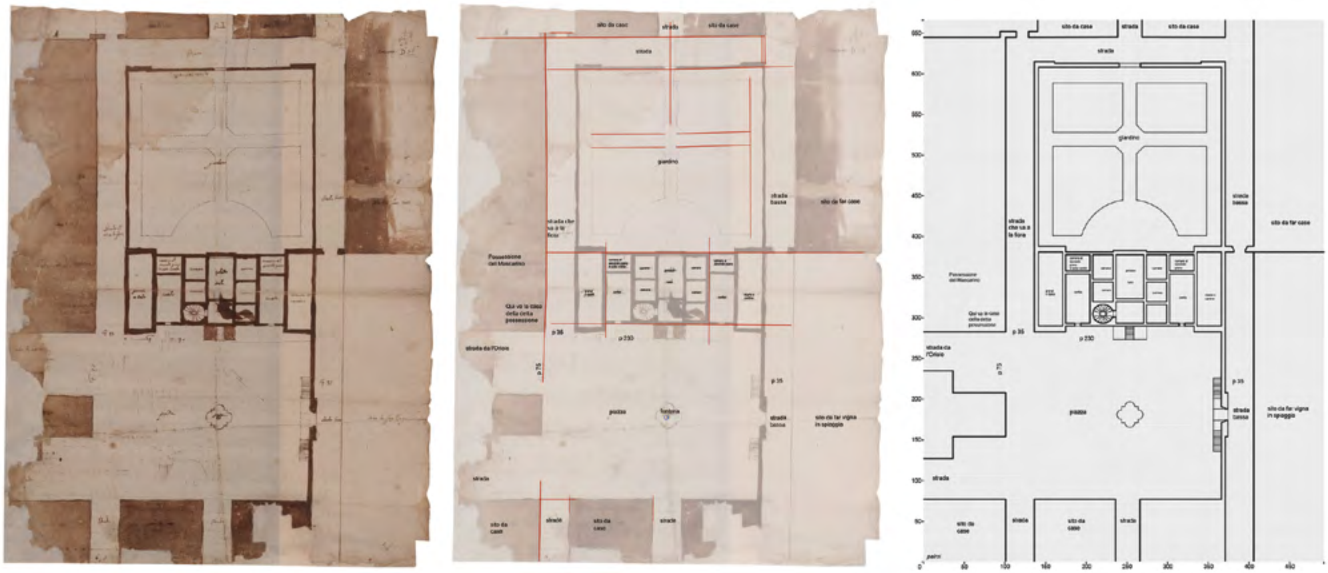

Fig. 1 - An example of the analysis of Ottaviano Mascherino's drawings for Manziana (Drawing ASL 2553, Fondo Mascarino, Accademia Nazionale di San Luca).

a support, with specific dimensions and characteristics, by graphic signs and texts constituted by traces of pigments and by 'mute' signs, engraved by the tools used by the author. These elements are organised through a topography, intended as the distribution of signs on the support, and stratigraphy that, although condensed in an infinitesimal thickness, testifies the chronology of the creation of the drawing itself. This last aspect is lost the most in the digitisation process since it condenses the drawing's stratigraphy into a pixel whose colour represents the sum of all the elements present at that point. Further confirmation of this reflection can be found in the experience of consulting the Lineamenta database, which, despite being built on rigorously scientific criteria, treats the drawing as a unitary whole, neglecting the topographical aspect of the signs that compose it. (Fig. 2).

In order to restore the structural qualities of a historical

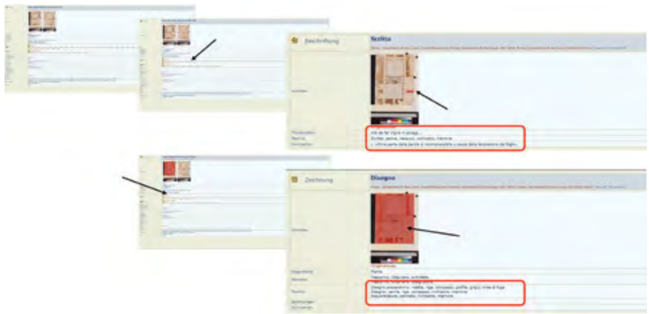

Fig. 2 - Screenshot of the Lineamenta database interface. Above, information relating to a text; below, information relating to a drawing.

drawing (topography and stratigraphy), it is therefore appropriate to imagine the enrichment of digital archives with new elaborations, such as those obtained through the analysis methodology described above, which can be inserted into a structure consisting of four levels (Fig. 3):

a) The digital image of the analogue source;
b) A layer that reveals the presence and distribution of the signs that constitute the drawing, paying particular attention to those that are part of the preparatory drawing and constitute the palimpsest of the final drawing.;
c) A layer that shows the critical transcription of the source;
d) When enough data are available, a three-dimensional reconstruction is obtained from the critical transcriptions, representing a proposed synthesis of the original sources.

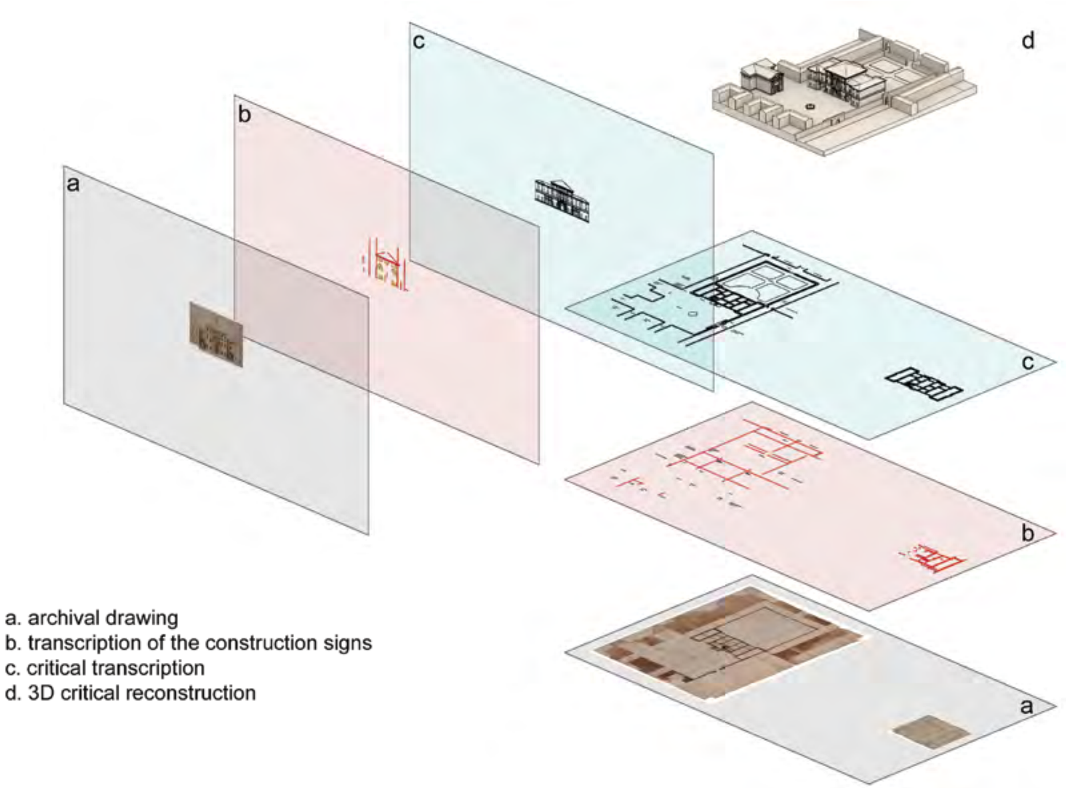

Fig. 3 - Diagram of the proposed layer structure for digital content to be related to archive drawings.

Contemporary architectural drawings: 3D reconstructions and reliability visualisation

The archive of Francesco Cellini's drawings is kept in the Archivio Progetti of the IUAV in Venice and the architect's studio and includes works that span his entire career as a designer, from the beginning to the present day. The projects chosen for experimentation with three-dimensional reconstructions were mainly prepared for competitions and covered the early 1980s to the 1990s, when the design was still based on analogical logic and techniques.

The first phase of the research concerned the study of the drawings and led to their classification according to the phase of the design process in which they fell: preparatory, preliminary, definitive and executive. (Fig. 4).

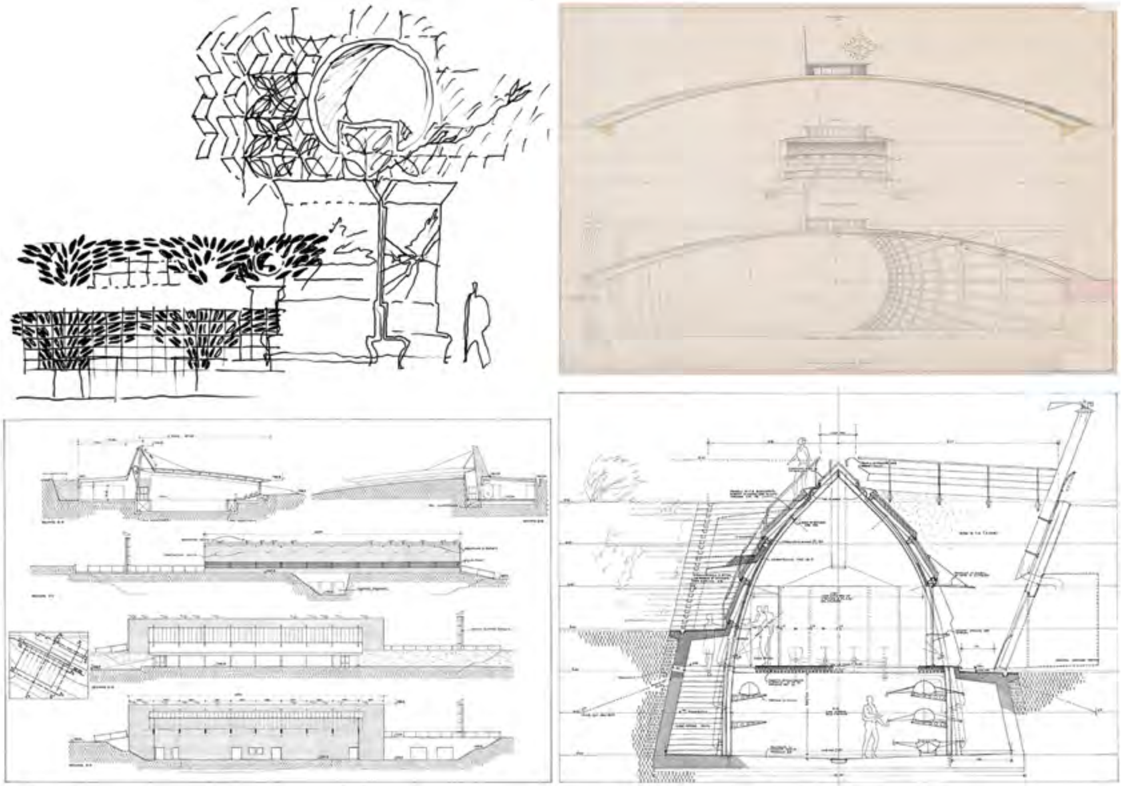

Fig. 3 - Drawings by Fracesco Cellini: top left, preparatory drawing for the rehabilitation of Piazza dei Cinquecento (Rome, 1981-82); top right, preliminary drawing for the Accademia Bridge (Venice, 1985); bottom left, definitive drawing for the indoor swimming pool in Baschi (1995); bottom right, executive drawing for the Baschi rowing club (1993-95). Thanks are due to Francesco Cellini for allowing experimentation on his drawings.

The systematic classification of the drawings showed that not all of the selected projects were fully described by the archival documents, so it was decided to consider the archival sources as 'incomplete witnesses' of the projects. It was decided that the architectural restoration theory should be considered to draw guidelines for what is configured as a phase of interpretation and integration necessary to arrive at the three-dimensional reconstruction and, therefore, the proposal of a 'complete witness' of the project. In particular, the concepts of "potential unity" of the work, of "reintegration of form" , and of "deferred execution" of the project were considered, adopting, in general, the choice never to exceed the level of information contained in the project drawings.
Digital modelling was therefore adopted as a virtual workshop where continuous models (NURBS) were chosen for the analysis and reconstruction phase of the project geometries

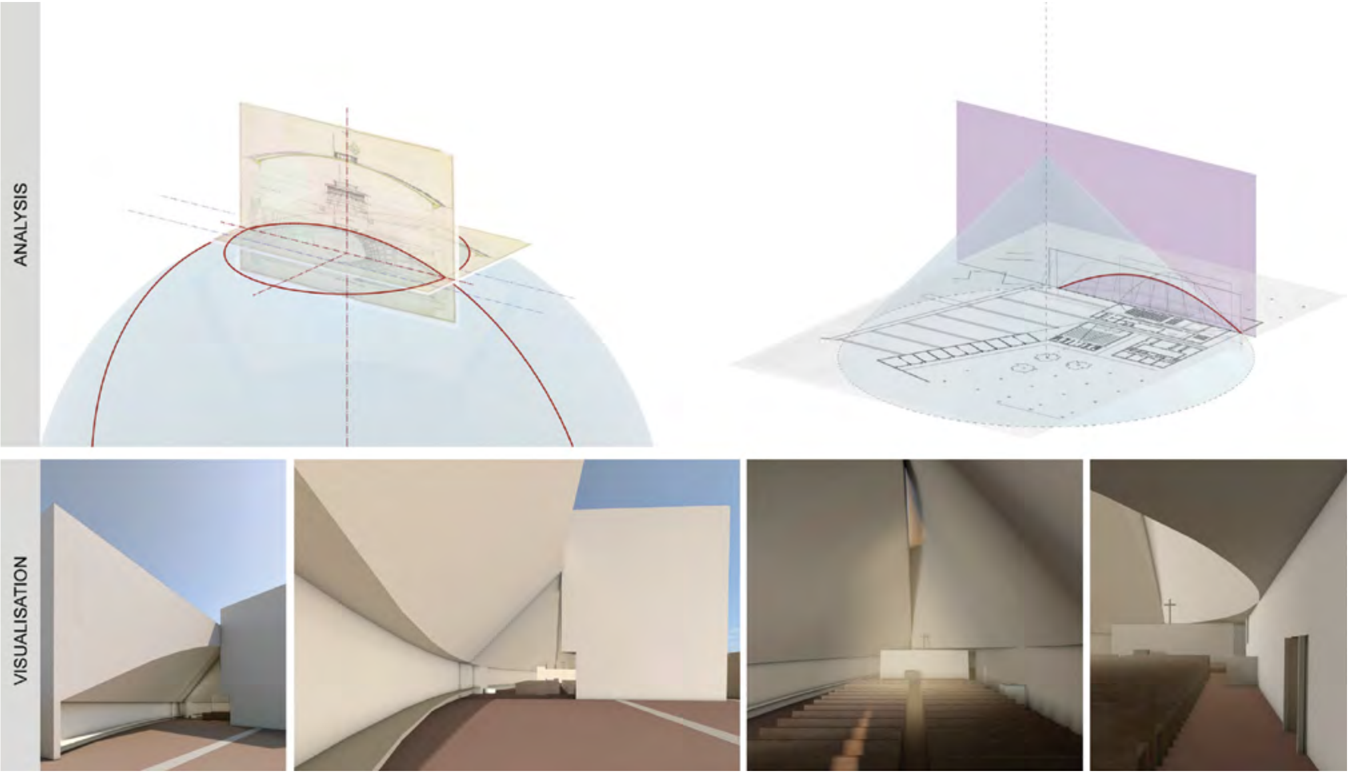

Fig. 5 - Above, analysis and modelling of two projects by Francesco Cellini (Accademia Bridge, Venice, 1985; church of San Giovanni Battista, Lecce, 1998-99); below, visualisation of the project for the church of San Giovanni Battista, Lecce, 1998-99. Roma Tre University, Department of Architecture, Corso di Tecniche di Rappresentazione, Prof. L. Farroni.

and discrete models (Mesh) for the visualisation phase of the proposed reconstruction (Fig. 5).

The development of the reconstructions highlighted the need to integrate a criterion into the method that would allow an assessment of the degree of depth, accuracy and reliability of the reconstruction. To this end, both the London Charter and the Seville Principles were considered, which, developed in an archaeological context, emphasise the importance of communicating these aspects of reconstructions through visualisation . Therefore, it was decided to propose a classification criterion for reconstructions linked to the design phase documented by the archive drawings since this influences both the depth and metric accuracy of the three-dimensional reconstruction (Fig. 6). In defining the graphic codes to be attributed to the different levels identified, reference was made to the concept of iconicity of the representation to communicate the general degree of reliability of the reconstruction through visualisation styles with different levels of verisimilitude. The Level of Reconstruction (LOR) that derives from these considerations is articulated on four levels (A, B, C,
D), corresponding to the phases of the building process, and adopts for each category two graphic codes, one for the parts of the model based on the data present in the drawings and one for the hypothetical parts. The four levels of the data-based parts are distinguished by the treatment of the materials adopted: a single neutral colour for the whole model (A); shades of grey, or at least a single colour, to distinguish the families of component elements (B); polychromy assigned alluding to the assumed materials (C); textures and physical properties of the materials (D). The hypothesised parts of the models assume the graphic code of the lower level with the addition of the geometry wireframe. The ultimate aim is to obtain models with an increasing level of verisimilitude as the LOR increases (Fig. 7), thus differing from other currently proposed methods that adopt highly symbolic or numerical visualisations.

	A - Preparatory	B - Preliminary	C - Definitive	D - Executive
Geometry	Proportionate volumes	Volumes measured	Volumes measured	Volumes measured
			Wall thickness	Wall thickness
				Stratigraphy
				Technological details
Information		Functions	Functions	Functions
			Materials	Materials

Fig. 6 - Diagram of the geometric qualities and information extracted from the drawings in the different design phases.

The projects by Francesco Cellini that have been investigated are the renovation of Piazza dei Cinquecento (Rome, 1981-82), the indoor swimming pool (Baschi, 1995) and the rowing club (Baschi, 1993-95) and have allowed the adoption of all four levels of LOR. In the case of the renovation of Piazza dei Cinquecento, attested by both preparatory drawings (sketches) and preliminary drawings, it was possible to develop two different reconstructions to which the respective graphic codes were assigned (Figg. 8/9).

Online accessibility: spherical panoramas and three-dimensional models

The last experience concerned the reconstruction of unbuilt projects by the Roman studio ABDR. In this context, the elaborations presented concern the project for the requalification of the Crypta Balbi area (Rome, 1985) and have been declined to experiment with different techniques of online sharing of the reconstruction results. The drawings describing the project were produced for a competition and therefore did not go beyond the preliminary design level (Fig.10), which is why a LOR A was chosen for visualisation. The techniques experimented for the publication of the reconstructions were the creation of spherical panoramas and their sharing through the Momento360

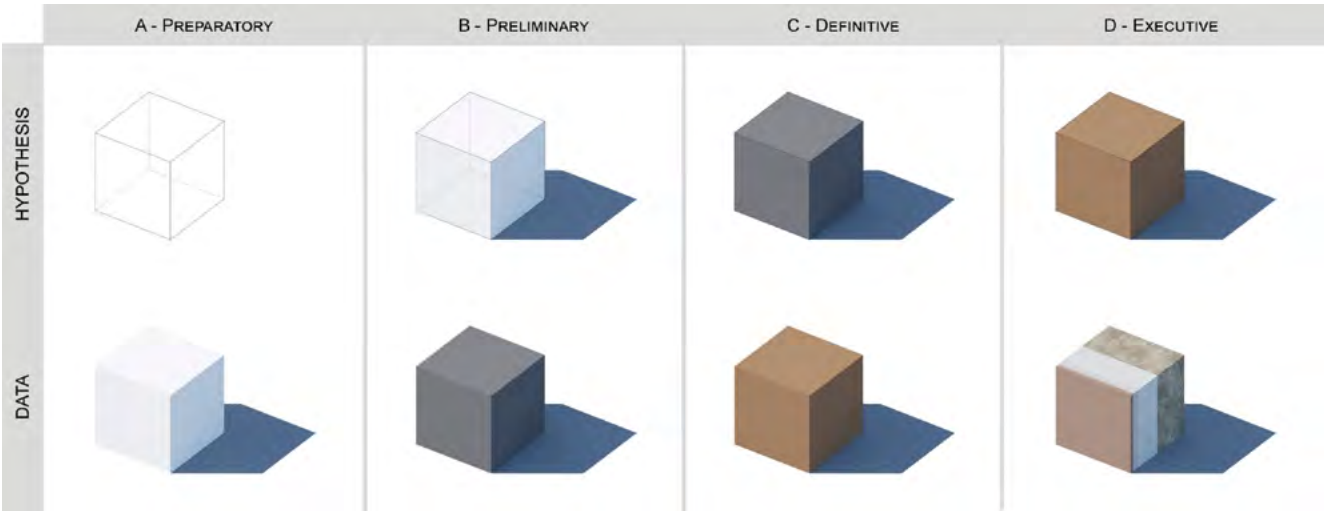

Fig. 7 - Diagram of the graphic codes adopted for the four levels of the Level of Reconstruction (LOR).

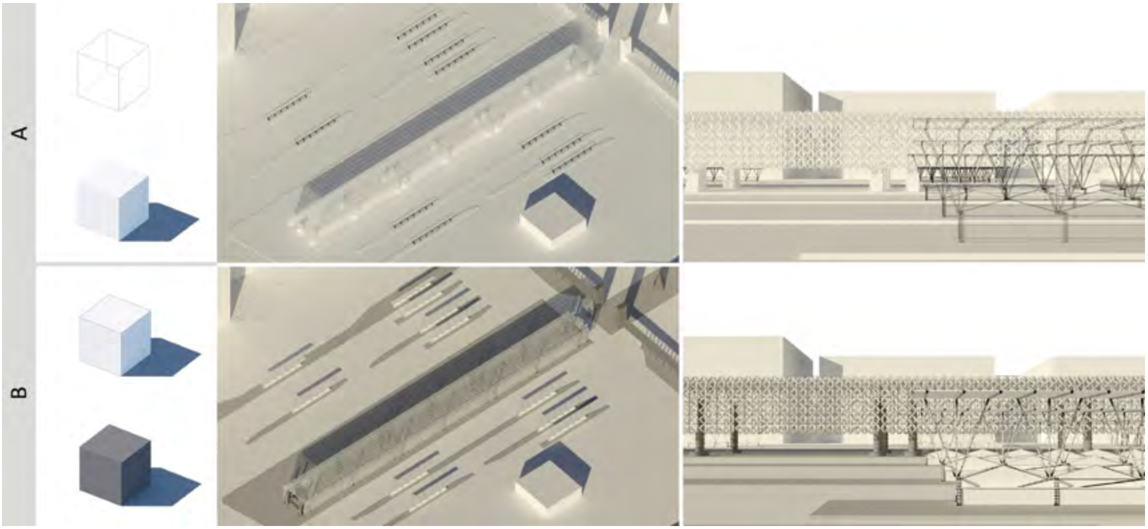

Fig. 8 - Examples of the application of the LOR (A, B) on Francesco Cellini's Piazza dei Cinquecento rehabilitation project.

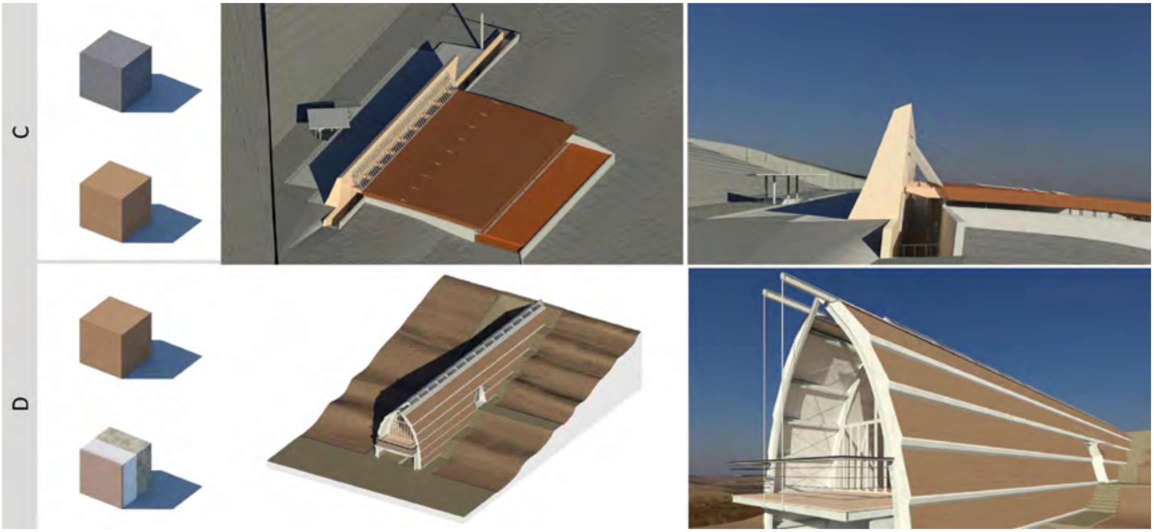

Fig. 9 - DExamples of the application of the LOR (C, D): top, project for the indoor swimming pool in Baschi by Francesco Cellini; bottom, project for the rowing club in Baschi by Francesco Cellini.

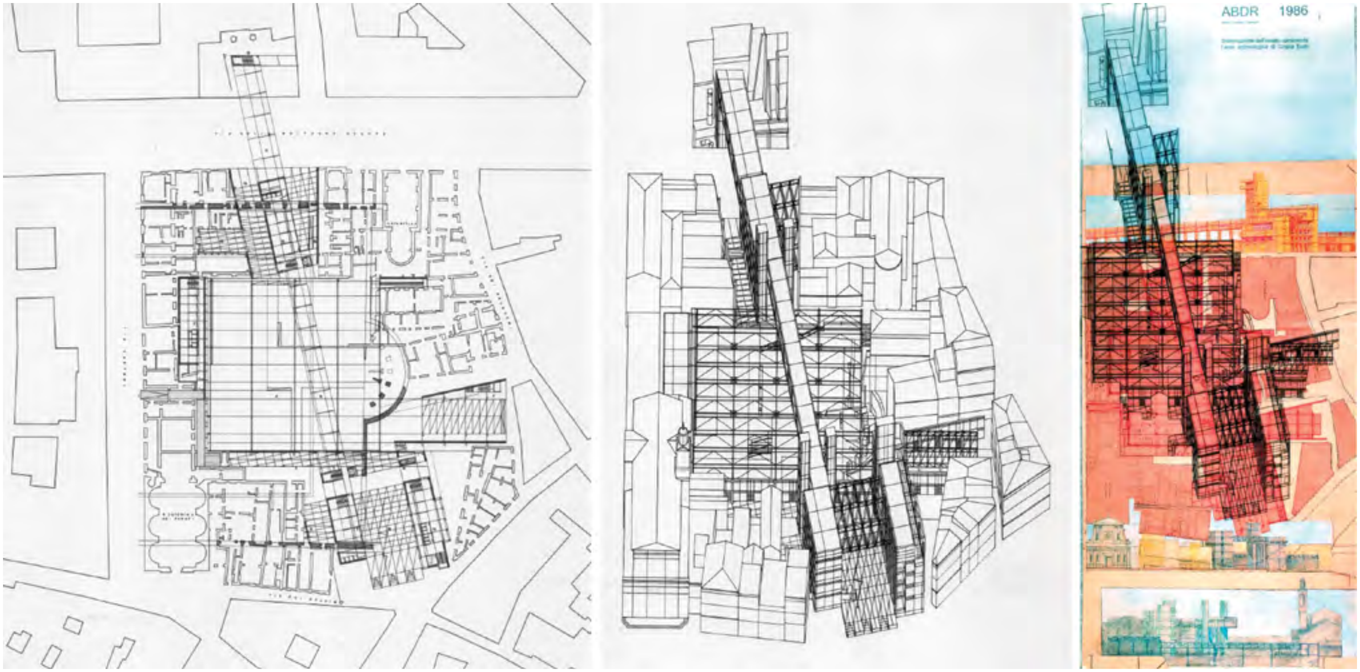

Fig. 10 - Project drawings for the Crypta Balbi rehabilitation project (Rome, 1985) by the ABDR office. Thanks are due to Michele Beccu for allowing experimentation on these drawings.

	Spherical panorama / Momento 360	3D model / 3DHOP	3D model / Sketchfab
PROS	1.High quality display (framing and chiaroscuro)	1.Mid-level interaction with the model	1.Mid-level interaction with the model
	2.Sharing platform (simple and free)	2.Model query tools suitable for cultural heritage	2.Medium-high quality visualisation (framing and chiaroscuro)
	3.Low hardware requirements for consultation	3.High level of customisation of the interface	3.Low hardware requirements for consultation
CONS	1.Low level of interaction with the reconstruction	1.Low quality chiaroscuro	1.Low level of interface customisation
	2.Low level of interface customisation	2.Requires programming skills for customisation and sharing	2.Not designed for cultural heritage

Fig. 11 - Comparative diagram of the pros and cons of the different techniques tested.

platform and the online sharing of the three-dimensional models through the commercial platform Sketchfab and the 3DHOP application developed by the Visual Computing Lab of the CNR-ISTI in Pisa (Fig. 11). The comparison between the different techniques highlighted the pros and cons of each tool: spherical panoramas have the advantage of being realised with traditional rendering software, which allows for a high quality of visualisation and the adoption of advanced graphic codes, while they have a low level of interaction due to the fixity of the viewpoints (Fig. 12); three-dimensional model publishing platforms, on the other hand, are characterised by generally lower visualisation potentials, better in the case of Sketchfab, but provide a more advanced interaction and, in the case of 3DHOP, the possibility to interrogate (measure) and perform geometric operations (sectioning) on models (Fig. 13).

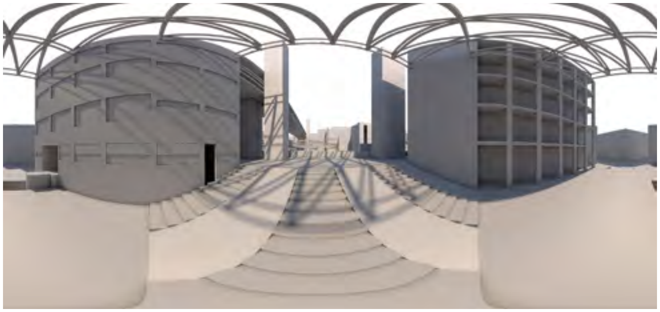

Fig. 12 - Spherical rendering (equirectangular projection) of the three-dimensional reconstruction of the Crypta Balbi rehabilitation project by the ABDR studio.

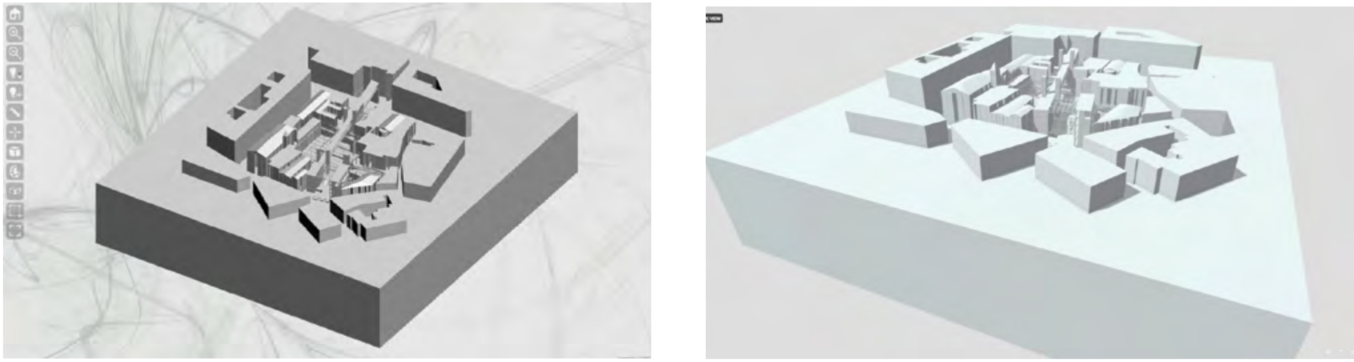

Fig. 13 - SModel of the three-dimensional reconstruction of the Crypta Balbi rehabilitation project by the ABDR studio. Left, in the 3DHOP platform; right, in the Sketchfab platform. 3D model developed at Roma Tre University, Department of Architecture, Corso di Tecniche di Rappresentazione, Prof. L. Farroni.

Conclusions

The experiments presented cover a wide range of issues related to the digitisation of cultural heritage in the broadest sense and, in particular, the creation of digital content for the enhancement, dissemination and accessibility of the heritage preserved in architectural archives, both historical and contemporary. The three fields concern the creation of contents that allow the complete understanding of the qualities of historical architectural design, the development of three- dimensional reconstructions philologically faithful to the archival sources and with a high level of transparency towards the user, both expert and general, and finally the identification of tools for the publication of the same reconstructions that allow to increase their accessibility and maintain a high level of scientific fidelity.
The developments of these experiments will be directed towards extending the experiments to other case studies and exploring the possible interactions between the three themes to propose a methodological prototype.

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SESSION - III

Parametric modelling and Video mapping

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Francesco Di Paola is Associate Professor at University of Palermo within the Department of Architecture. Graduated cum laude in Building Engineering-Architecture at University of Palermo, 2003. Ph.D in "Representation and Surveying of Architecture and Environment" at University of Palermo in 2007. He is a member of the Scientific Board in the Interdepartmental Research Center "Coscienza" of the University of Palermo. His research mainly topics are in the field of Architectural Geometry, Algorithms Aided Design, Survey, Cultural Heritage Fruition in VR/AR. He is a member of several area research associations, he is member of scientific/technical committees of international conferences, he is reviewer member in several International Journals and guest editor of a special issue in MDPI Journal. He has been involved in several international and national projects. He is actually the author of more than 110 publications in scientific journals, proceedings of national/international scientific papers and monographs. He won a best paper award and, in 2007, he was awarded the UID Silver Targa by the Association of Italian Unity of Design (UID)

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Graziano Mario Valenti is an associate professor, afferent to the Department of History, Design and Restoration of Architecture at the University of Rome "La Sapienza".
In 2014, he was awarded the national scientific qualification for the role of full professor. His research activity - articulated in the study and development of theory, conception, realization and testing of experimental models - is focused on the application of new digital technologies to support the design, construction, knowledge and communication of industrial and architectural products, with particular regard to cultural heritage and with the specific objective of anticipating future operational scenarios and solving current application problems. An expert in computer science, since the origins of his research activity, he has directly designed and implemented, using multiple programming languages, numerous procedures and applications for sharing, integrating and representing data of a heterogeneous nature distributed over a geographic network. A particular object of study that cuts across all of his research is the definition and representation of integrated and dynamic digital models that take on the role of both a container and a processing unit for heterogeneous information.
From 2000 to the present, he has participated in numerous university research projects funded by "La Sapienza" University and MIUR, frequently assuming the role of scientific coordinator.
Author of monographs and numerous scientific papers, he has spoken as a speaker or reviewer at international congresses and conferences.

INTRODUCTION

Virtual representation, free-form surface modelling techniques and numerical control manufacturing, with their intrinsic dynamic and interactive capabilities, have profoundly expanded and enriched the repertoire of geometric shapes, generating innovative design skills and creative languages.
There is no doubt about the opportunities for exploration, contamination, relationships and overlapping of ideas, measurements and information, which the continuous evolution of expeditious, parametric and automatic procedures brings to the use of the many products of the information age.
Adopting computation as a form of design is profoundly different from simply using tools geared toward increasing the productive capabilities of the designer. This approach implies first of all an extension of design actions to techniques and strategies, whose main strength is measured in the ability to promote new and different ways of thinking.
The added value of digital culture is rooted in the complementarity and synergy of all graphical and expressive methods of architectural language, hinging on the foundations of Scientific Representation. The latter play a basic role for infographics, constitute an essential cultural baggage and enrich the researcher with the awareness of possessing the tools of knowledge and governance of the geometric properties that regulate space, in order to be able to both read and communicate the design.
In computational design, the programming and the design domains come together to identify a form of creativity capable of interpreting information into procedures and rules for the project. In this field, new research perspectives declined in the specific contexts of the project (architecture, design, representation, territory, technologies, communication interfaces) integrate digital and emerging technologies in the elaboration of a product. The computation is seen as the process that regulates the information and the interactions between the elements involved in the definition of the design of the form, its responsive reactions to the context and the application of the same digital technologies to the production.
The emerging techniques of parametric and generative modeling, algorithmic-visual and computational programming, the methodology of "form-finding" and optimization processes with genetic algorithms constitute the tools of geometric-formal control that, in addition to bringing a methodological and applicative renewal, connects and hybridizes fields, processes and disciplines.
In Industrial Design, as in multi-scale architectural design, the explication of algorithmic thinking promotes research directions based on the centrality of the concept of code-procedure for building geometric- informative models. The parametric and semantic digital three-dimensional model simulates, collects and manages not only geometric data, but also structural, energy related and construction aspects of the work, putting them in relation with each other and thus

improving the interaction and dialogue between the design figures involved in the process. Furthermore, in the field of Design, generative and pre-figurative systems are now often associated with new production processes that are no longer of a “mechanical” type (cutting, turning, milling) but “plastic”, linked to the additive modes of digital fabrication. In the near future, most industrial processes will have a digital matrix as a generator of governance and production control. The generative approach is useful for the designer to translate even the most complex visions into tangible signs, conceiving objects that can significantly adhere to the specific needs of people, contributing to the construction of unprecedented and fruitful design paths.

The contributions explore the themes of digital design and, specifically, the systematic aspects central to the relationship between computation and design.

The researches of Giorgio Buratti, Domenico D’uva, Marco Filippucci and Mirco Cannella provide a significant contribution to this scenario, describing a vast applicative and theoretical panorama, which ranges from the small scale of the industrial product to the large scale of territorial analysis, at the same time offering useful conceptual connections, which consolidate the general and increasingly shared theoretical apparatus of digital work, both for research and for the project.

Giorgio Buratti experimentally demonstrates how, through the coding of generative procedures, it is possible to investigate and use morphologies typical of the natural world for design, functional and manufacturing optimization purposes. His applications concern articulations of minimal surfaces and fractal geometries, whose parametric and generative definition must necessarily find its foundation in theoretical knowledge and critical capacity, useful for identifying and describing its formal genesis step by step.

Domenico D’Uva’s research concerns the territorial scale, addressing those situations defined as “fragile”, whose analysis and mapping, due to the complexity of the landscape and the scarcity of pre-existing information, require an unconventional approach based on integration of heterogeneous sources. The problem highlighted in the illustrated case study finds a solution in the definition of an optimized workflow that systemize various digital technologies.

Marco Filippucci, retracing a vast repertoire of exemplary case studies, emphasizes some critical issues and solutions that have profoundly transformed the meaning of design and model; focusing in particular on the problem of the explication of the process of representation, he emphasizes the temporal separation - postponement - of the representative result with respect to the act of drawing, which he pertinently associates with the renewal of the ancient discipline of descriptive geometry.

Finally, Mirco Cannella, delves into aspects that are different in type to the previous ones. The researcher discusses the potential and criticalities of augmented reality systems used for fruition purposes in architectural and archaeological contexts. In particular, his contribution focuses on procedures for georeferencing digital models in the real context, determining solutions that overcome the operational difficulties of current systems on the market.

The researches illustrated here, in their diversity and in some ways complementarity, are indicative of a mature thematic area, of great potential and rapidly developing: a resource of opportunities that will certainly be able to inspire and motivate future young researchers.

Marco Filippucci

Università degli studi di Perugia

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GENERATIVE REVOLUTION:

REPRESENTATIVE EXPERIMENTATIONS AT THE FRONTIERS OF COMPUTATIONAL DESIGN

Abstract

The paper aims to outline a critical path between the protracted experimentations through parametric
representation, with the aim of showing the increasingly central role of the discipline as a place for the model. In the increasingly mixed relationship between medium and message, the explication of the underlying logic in modeling opens up the value of computational design, with its ability to exploit the main ability of the computer to make calculations. The postponement of the representative result with respect to the act of drawing is the sign of a first contamination of artificial intelligence in the drawing, which already now finds its dimension in augmented intelligence, an important milestones in the renewal of descriptive geometry.

L'intervento si propone di delineare un percorso critico fra le sperimentazioni protratte attraverso la rappresentazione generativa, con il fine di mostrare il ruolo sempre più centrale della disciplina come luogo del modello. Nel rapporto sempre più commistionato fra mezzo e messaggio, l'esplicitazione delle logiche sottese nel modellare apre al valore del computational design, con la sua possibilità di sfruttare la principale capacità del computer di fare calcoli. La posticipazione del risultato rappresentativo rispetto all'atto del disegnare è il segnale di una prima contaminazione dell'intelligenza artificiale nel disegno, che già ora trova una sua dimensione nell'intelligenza aumentata, che si presenta quindi come un importante passo nel rinnovamento della geometria descrittiva.

Introduction

This research reports the critical considerations born within the research group of the University of Perugia in the Drawing topics (ICAR / 17), coordinated by prof. Fabio Bianconi, who for the past 15 years has been involved in experimenting with the value of generative representation in the field of research and teaching. This path stems from the assumption that the representation is always the expression of an "algorithm", absolutely complex, which transforms the experienced and understood reality in the abstract plane of the model. And, vice versa, any "algorithm" that transforms the input captured from the real into an output inscribed in some way in the sphere of ideality must be considered a result proper to the sphere of representation. Taking up the role of the digital in the renewal of descriptive geometry [Migliari, 2003, 2012], it could be interesting to analyze how the new representative transcriptions, understood as new ways of drawing, are an harbinger means of a language and tendentious paths that in some way want to be analyzed to provide, to who uses them, with an awareness of their values.

The representation, therefore understood as the place of the model, as the field of existence of the interpretation of reality, is proposed in its transdisciplinary value, which finds in the form an essential element for all the different scientific issues that cannot ignore the aspects related to materiality. Despite what is underlying and immaterial, the relationships are what science must be able to "make visible": the models simulate behaviors and performances, therefore reactions inherent in the systemic set of relationships underlying the project.

The new challenges of generative representation

Representation in the digital world always implies figurative actions transcribed in algorithms: to draw an output, such as a circumference, it is necessary to recall a command that requires input (center and radius), according to a process that is not that dissimilar to use of a compass. As in the classical design these primitives are composed in procedures, so also in the digital the algorithmic sequence leads to the construction of the representative model, with all the advantages that the digital entails in the ability to converge data, interactivity, multimedia and manipulability (Bianconi, 2005).

In reality, this path remains underlying and those qualities of digital lose their efficiency, reduced operationally by a complexity that causes the loss of multiple values. Visual aids for scripting of commercial software are thus establishing themselves, interfaces that make explicit the relationships underlying the form, making the interconnections and dependence on parameters emerge (Jabi, 2013): input values are required, potentially variable, and the result of the algorithmic path is an output of solutions, generically usable as input data for further commands, so as to form a network, an ideogrammatic morpheme of contemporary hypertextual communication. The elements drawn in the generative modeler enhance the concept of virtuality, appearing in an ethereal way in the visual interface, registered as geometries only at the end of the path. The created interconnected structure clarifies the mutual positions of the algorithms which, by composing themselves, becoming procedures (Migliari, 2000, p. 6), to be read as the true text of the scientific representation (Bedoni et al., 1989). This finds a clearer correspondence between the formulation of the interpretative hypothesis of the model and the identification of its representations (de Rubertis, 1994).

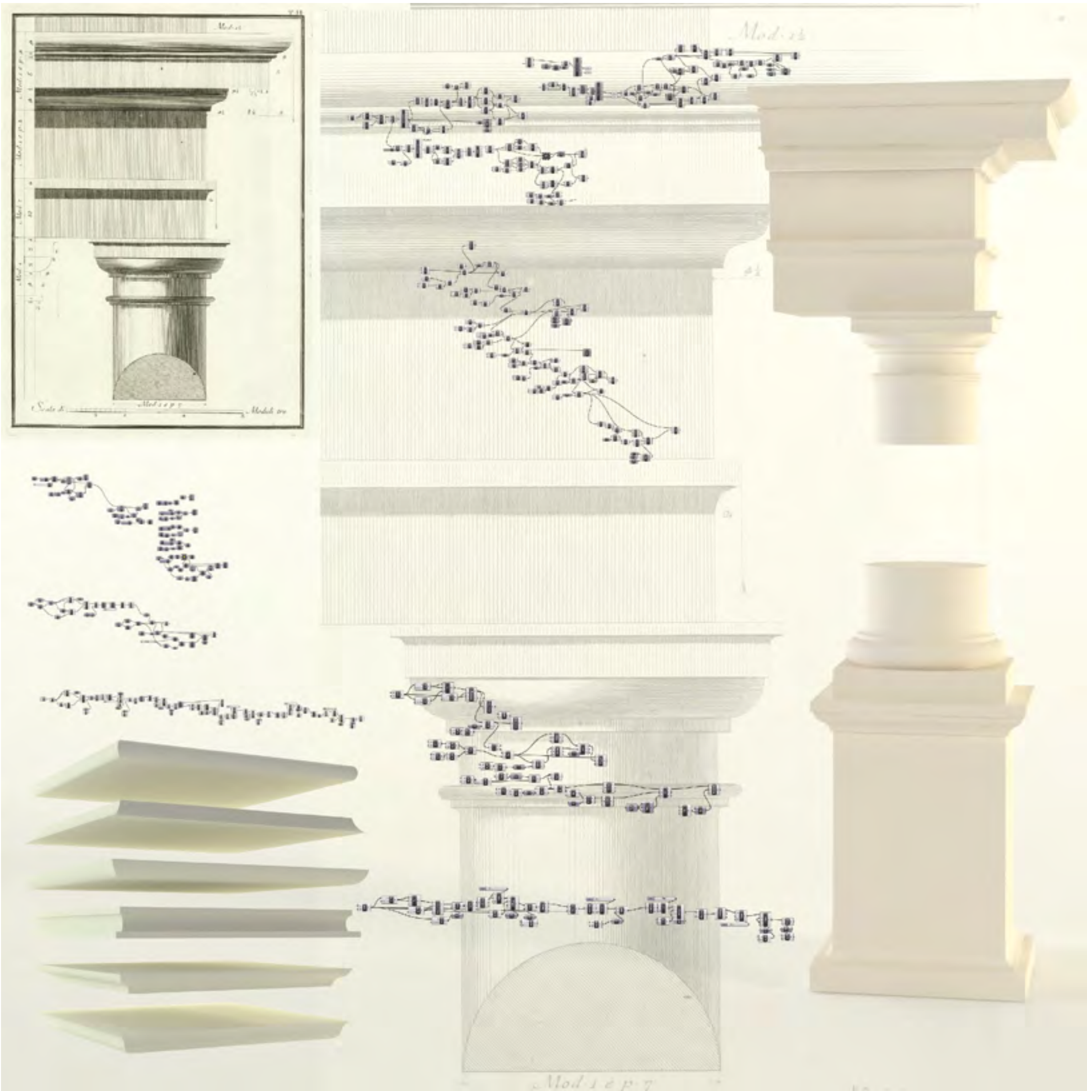

Fig. 1 - Generative design as research field of the procedurality approach in the didactic verified in the transcription of treatises the Classical Order (Academic drawing by F. Magi Meconi).

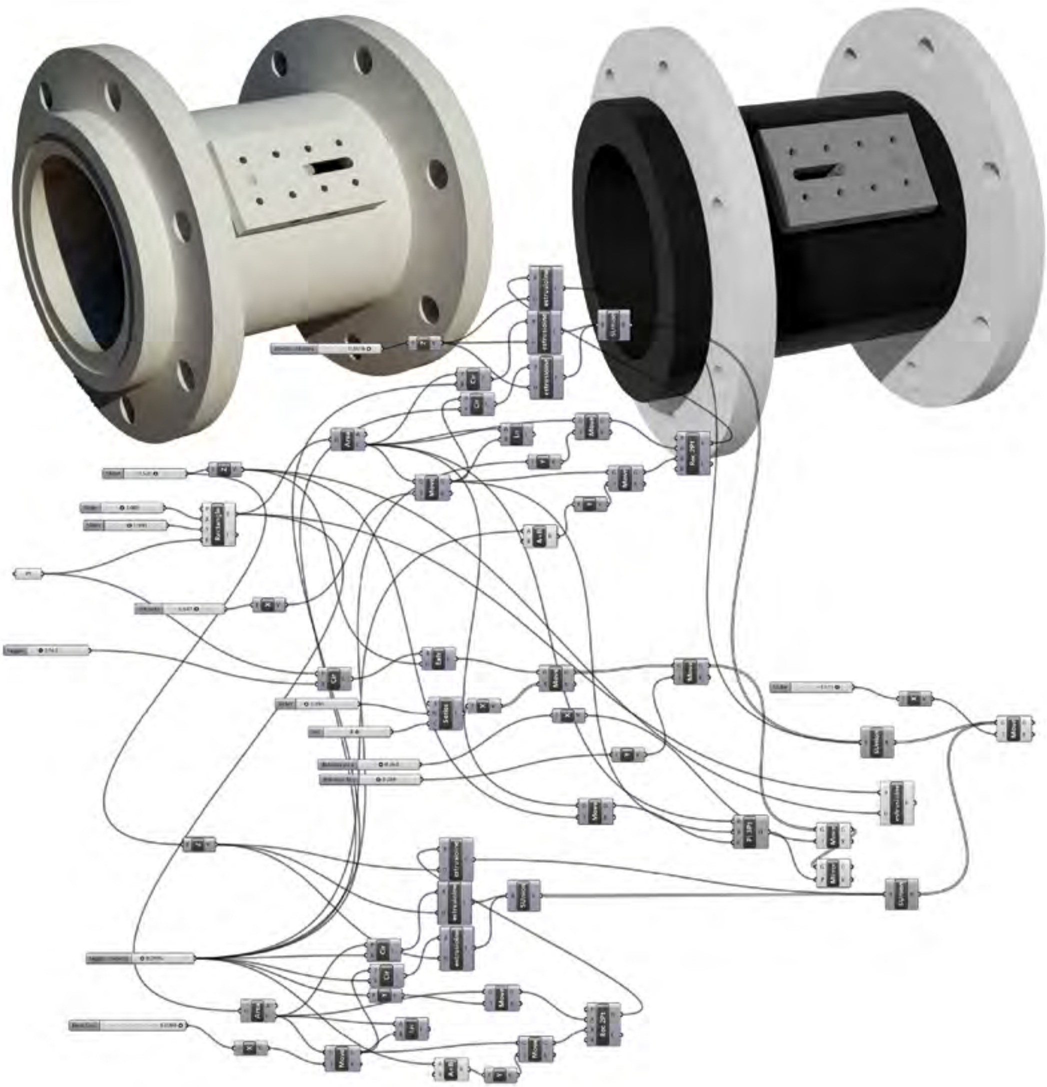

Fig. 2 - Generative design as research field of parametricism in the representation of technical connections for variables for hydraulic infrastructures.

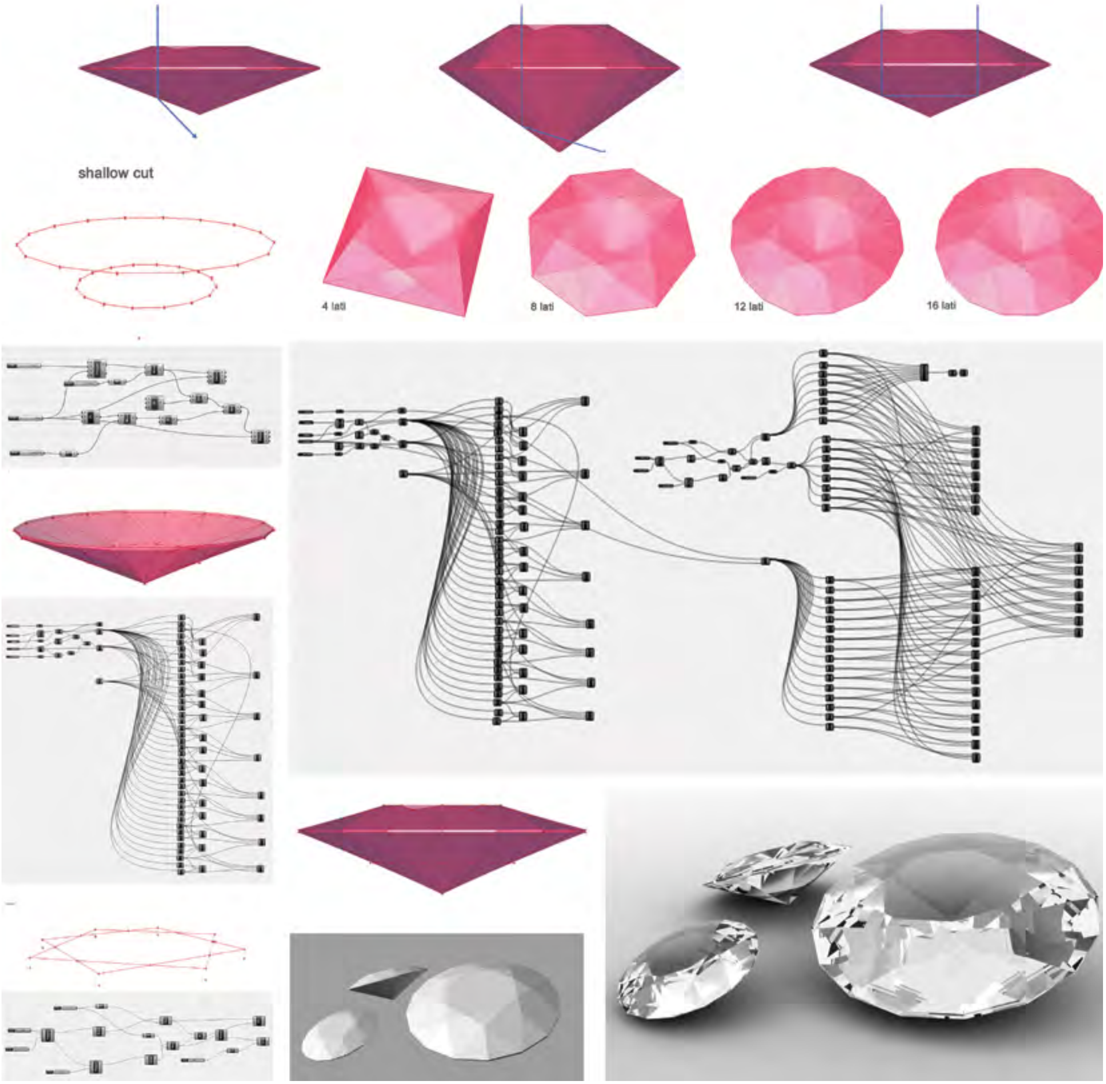

Fig. 3 - Generative design as research field of morphological relationships in the cut of the perfect diamond (Academic drawing by N. Briganti).

Among the tools used, of particular interest is the use of Grasshopper by Rhinoceros, a tool widely used internationally and enriched by a series of add-on that make it a system capable of responding to the many issues inherent in the need for integrated design. The same tool is finding an additional value in interoperability with other programs, which clearly reflects the NURBS logic of the digital
environment it represents, a geometric interpretation that guarantees a wide freedom of representation of complex surfaces. However, it is at least an integrative approach conquering many modeling software (e.g. Dynamo for Revit, Unreal, 3DStudio ...), as demonstrating the revolution in place in the approach to modeling, of which Grasshopper can become a useful paradigm for understanding logics that can be transferred and replicated in other environments.

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The transcription, of which this new approach to drawing is a harbinger, lives on the paradox of being on the one hand a representation that does not represent, as the command is drawn and not the form. However, this absence, reference and implication, are the result of a "representation of representation", a "squared representation", able to amplify the logic of the model in an "exponential" form, correlating geometry and computer syntax in an image of its process. This representative deconstruction of the elements opens up to parameterization, creating a real current of thought (Schumacher, 2008, 2011, 2015) harbinger of its clear aesthetic (Schumacher, 2009, 2010), which enhances this approach, defining a morphological language. This, however, must be read as the hyperbolic expression of the revolution of a representative culture that does not necessarily have to be linked to these expressions, also determining solutions that may appear more "normal". In representing a logical network, the parameterization of the elements is a consequence, an opportunity of the digital descriptive text to reclaim its infinite potential and the heuristic dynamics that are typical of every form of drawing, and not the purpose. The centrality of the model as an organic system of relations defines its variation as a result, according to the question that "difference is not diversity. Diversity is given, but the difference is that for which the data is given ... the difference it is not a phenomenon but the closest noumenon to the phenomenon" (Deleuze, 1994). Perhaps an expression of social and cultural fluidity (Bauman, 2000), the stylistic phenomenon nevertheless tells how the medium is the message (McLuhan, 1967) and any related transcription to the tools it also involves variations of meanings, tendentiously directing the impact of the solutions. In this way we arrive at transforming the very value of representative morphogenesis, living those processes of construction of the model differently, passing from "designing the form" to "designing as it is shaped".

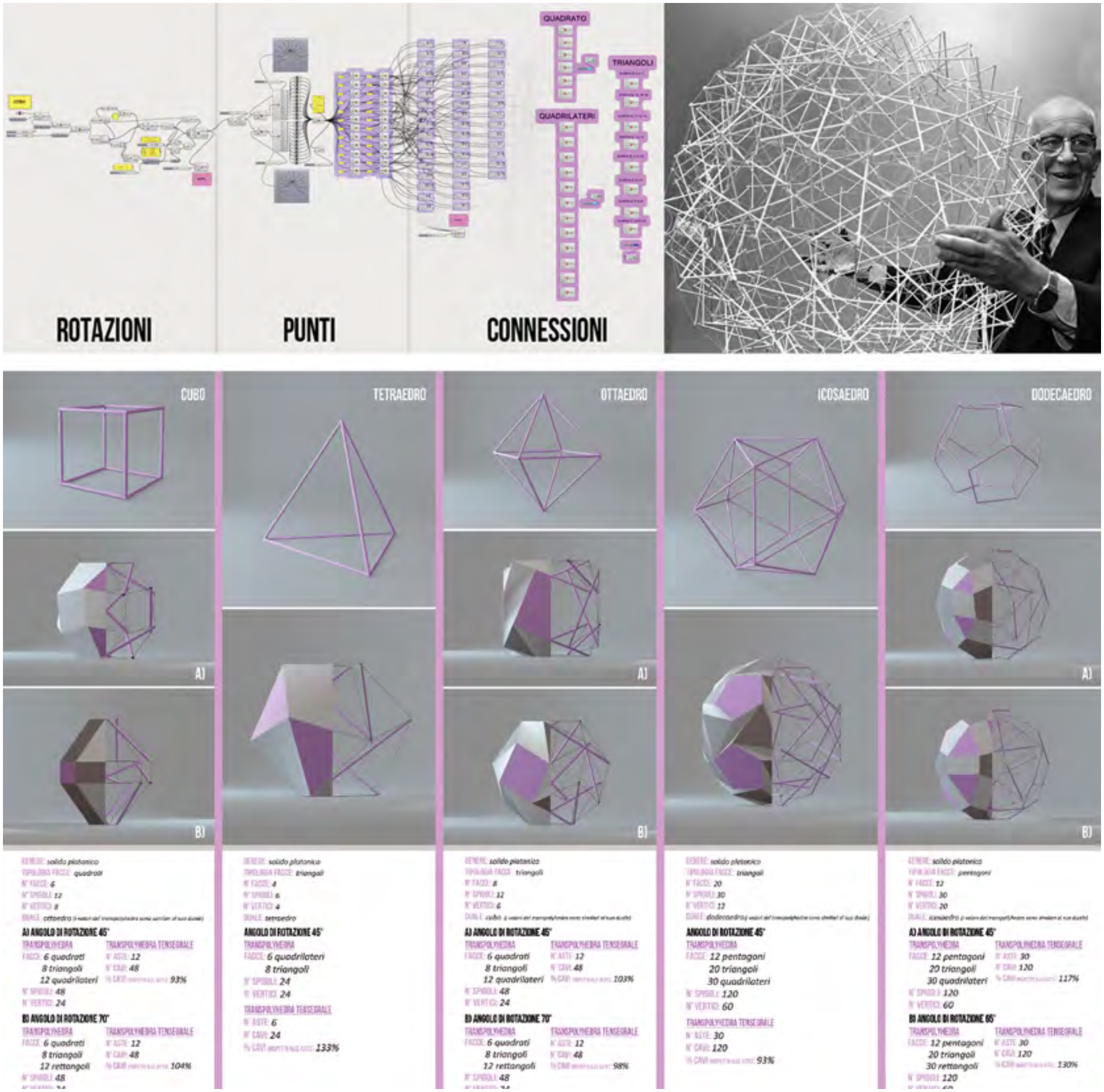

Fig. 4 - Generative design as research field of geometric relationships in the morphogenetic processes of tensegrities (Academic drawing by M. Stramaccia, M. Margutti).

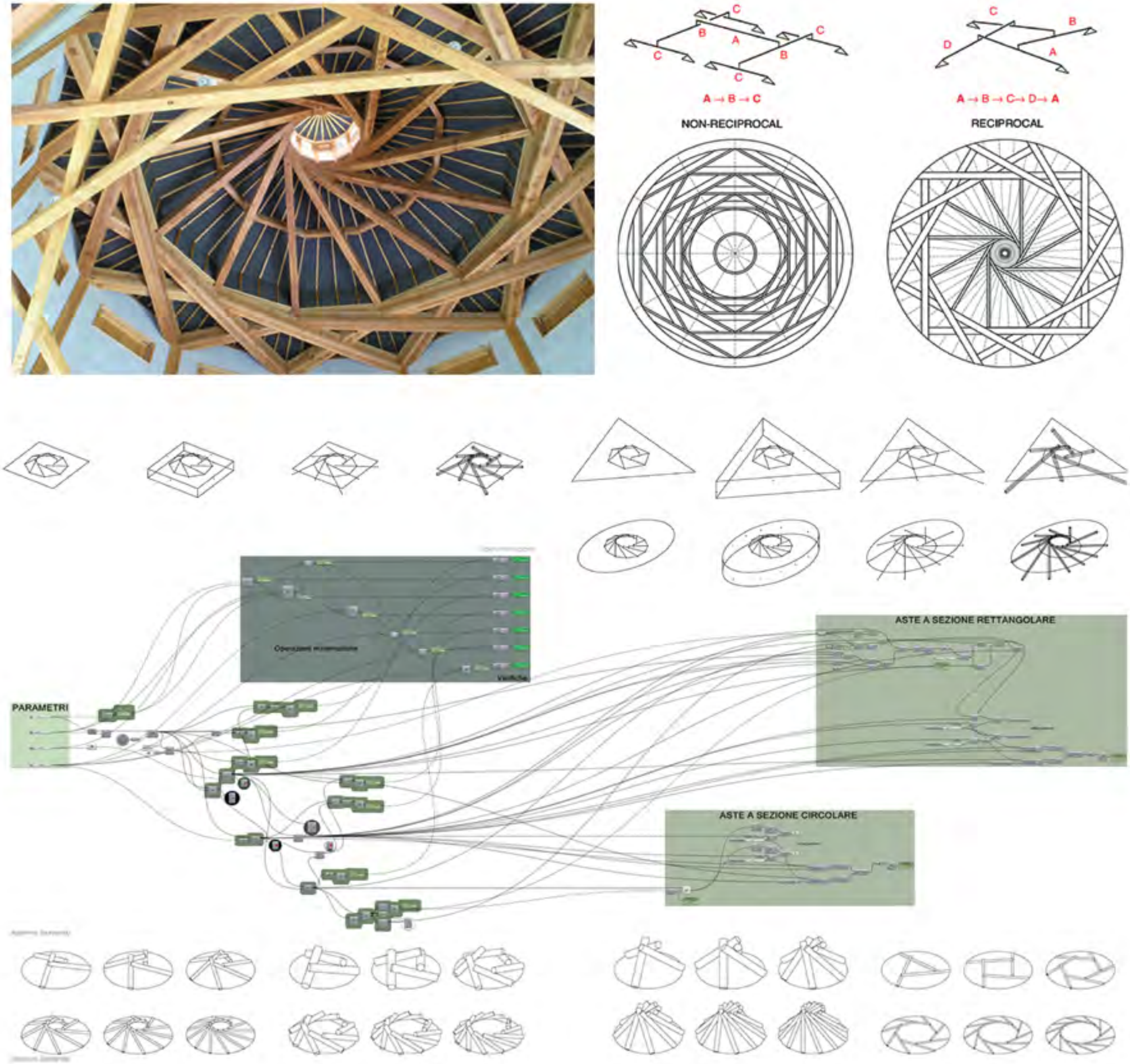

Fig. 5 - Generative design as research field of load balances in reciprocal frame structures (Academic drawing by V. Fortunelli).

The renewal of descriptive geometry

The generative approach responds perfectly to the modern request, proposed by the father of descriptive geometry, Gaspard Monge, when he writes of his objectives *"Le premier est de représenter con esattezza, sur des dessins qui n'ont que deux size, les objets qui en ont trois, et qui sont suscettibili di definizione rigoureuse.… Il secondo objet de la géométrie descriptive est de déduire de la description exacte des corps tout ce qui suit nécessairement de leurs formes et de leurs position respectives. Dans ce sens, c'est un moyen de rechercher la vérité; elle offre des examples perpétuels du crossing du connu à l'inconnu"* (Monge, 1789).

The first question raised at the foundation of descriptive geometry is the reduction of three- dimensionality in the language of drawing: it is certain that Gaspard Monge did not remotely think of such algorithmic logics, but the algorithmic interconnections do not however lose the ability to accurately represent "what has three dimensions", then reaching the second request, rigor, through that abstraction from the dependence of the parameter that reflects and enhances the underlying geometric need. Although the computer revolution in the field of design has succeeded in the difficult task of shifting the emphasis from visualization to modeling (Migliari, 2003), in design practice today one can see the inevitable limits of a representative action focused on the result rather than on the process: the digital model, the result of a series of elaborations, becomes generically hardly verifiable in the process that leads to its form and difficult to manipulate with respect to the assumptions imposed. The purely dynamic ability of geometry but also of the digital to describe virtually abstract forms is therefore limited by a concretization that weighs on the ability of drawing, always called to the paradox and compromise of abstraction and concretization. The morphological representation of algorithmic interconnections then responds to the second question raised by Gaspard Monge, the centrality of the deduction that is proper to science, its starting from the exact description of bodies to understand the relationships between forms and positions with all its morphic, morphological and morphogenetic questions. In this sense, it is understood how with this representative transcription it is possible to bring out the parametric variation as an explicit deduction of what the mind intended to analyze in an abstract way. The parametric logics, after the considerable effort of conceptualization, simplify the verification of the multiple boundary conditions imposed by the variation of the parameters, placing at the very center the relationship between forms and positions, the true object of representation. If descriptive geometry teaches procedures and logics, these tools likewise present themselves with similar graphic logics, thus proposing themselves as a key tool for defining procedures and for representing the design substance of architecture. These are the "*lineamenta*", the set of signs and procedures (Bianconi et al., 2020), to which Alberti refers when he states that *"Tota res ædificatoria lineamentis et structura constituta est"* (Alberti, 1443): in the center of the architectural question is its representation, understood, however, not as a description of the image, but as a procedural process that is concretized in architecture and that goes beyond appearance. This t is that "search for truth", the overcoming of apparent knowledge (Docci, 1996), the search for processes and relationships between the value of the signs that are recomposed in a project, a model. Thus the characteristic of these tools emerges to guarantee that passage from "what is known to what is unknown", the transformation from logics structured according to multiple parameters, to new combinations that create forms that sometimes could not be imagined, but which in general could not be fully assessed due to the multiplicity of implications put in place.

For these reasons, it is considered fundamental to describe this approach as "generative representation", due to its ability to originate solutions that go beyond previous knowledge. This

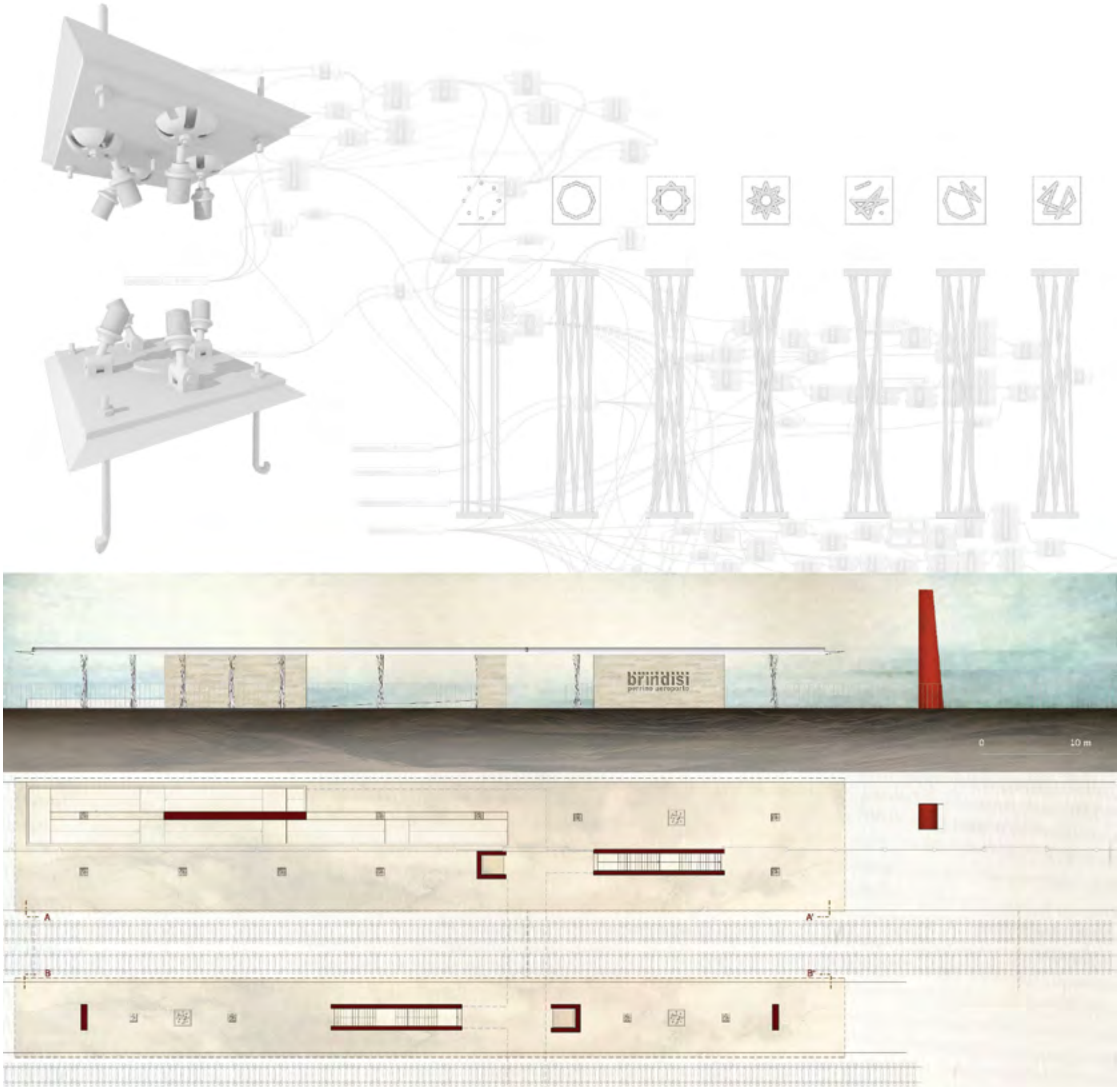

Fig. 6 - Generative design as research field in the architectural design regarding the preliminary design of the Brindisi stations' generative optimized columns.

Fig. 7 - Generative design as research field of the relationships between form and energy in didactic studies (Academic drawing by V. Tomassini).

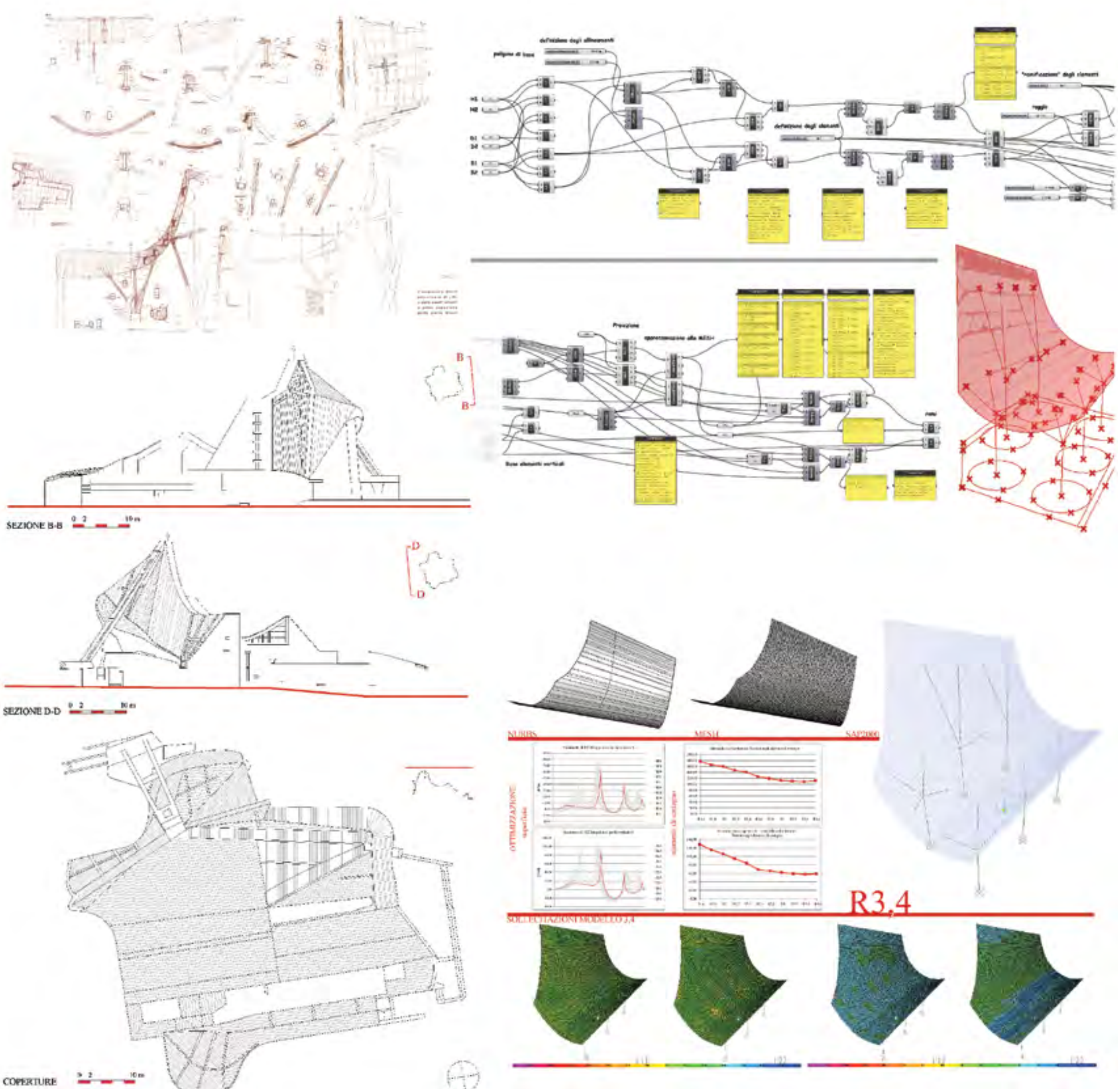

Fig. 8 - Generative design as research field of the relationship between architecture and structure in the reconstruction of the roof of the "Church of the Highway" by Giovanni Michelucci (Academic drawing by L. Armino).

definition appears more adequate than the term parametric representation, which expresses the condition of dependence on the variation of inputs and outputs, but also on the terms of “algorithmic”, “nodal”, “interconnective” representation. In these terms the emphasis is rather placed on the “finger” and not on the moon it points to, on the interconnection between digital segments, on the graphics with which they are explained. If the term “representation” centers the field of action in the field of drawing, expanding its field of action but specifying its value with respect to the more vague theme of “modeling”, the term “generative” underlines the close relationship that these tools are providing today to renewal of descriptive geometry, equally marked by procedural logics similar to this “square representation” which makes explicit the logic to guarantee verification, interactions and repeatability.

The revolution of artificial intelligence in representation for the project

The generative approach responds perfectly to the modern The computer is a “silly” machine, able “only” to do the calculations, but not for this, as today it is more than pleonastic, it is not something that binds creativity, however essential in the visceral relationship between representation and design. The parametric revolution (Schumacher, 2012) presents itself as a fertile ground capable of generating innovation, and this appears as a paradox, but only up to a certain point since, in general, any technology that affects the processes has an impact on the life of the man (from the plow to the smartphone). The generative representation is nothing “extraordinary”, it is just a different way of “reading” what is underlying the modeling. But, in this transcription we follow that rule according to which many discoveries arise from changing the point of view, from that transformation of processes that involves thinking and doing architecture (Oxman et al., 2010), increasingly digitized in its soul and its materiality (Burry et al., 2012). In a new dominance of performance (Turrin et al., 2011; Bergin et al., 2012), the complexity of the multiple factors that combine in a number of solutions that cannot be imagined without digital tools, is projected into a process that must necessarily evaluate multiple configurations. The possible cases that arise from the multiple variables of a complex project, however, are unimaginable, certainly incalculable to the human mind, limited in the domain, in the range of input solutions, which often matter less than the output value, of the solutions that are sought. Once the logic has been made explicit, the relationship between parameters and procedures, between admissible conditions and solutions defined, it is possible to leave it to the computer to do the math, to find the researched solutions. The representative revolution leads to concentrating the efforts on the research of the underlying logics in the model, in which the boundary conditions and the objectives are then to be established. It takes place the great transition from the usual form-checking, where the model wants to “verify” the proposed solutions, to the new logic of form-finding, based on the ability of the computer to test and calculate solutions beyond the functions (Menges, 2012; Adriaenssens et al., 2014), highlighting the multiple interactions between form and function (Greenough, 1947). The explication of the morphogenetic logic, which is connected to the parameterization of the multiple elements that contribute to the form, becomes a condition of clear facilitation of the form-finding approach, where the digital process is required to find those combinations that minimize or maximize certain objectives, processes that lead to the enhancement of generative logics (Renner et al., 2003) for their ability to lead to the definition of unthinkable and performative solutions also in the architectural field (Menges, 2009). In this simulation it is possible to exploit the computational capabilities of digital tools and explore the possible combinations, with the aim of improving not a single aspect (Jones, 2009), but several issues at the same time in an organicist vision integrated by the project (Gruber et al., 2012). The development of evolutionary strategies for construction problems (Kicinger et al., 2005), is one of the greatest (invisible) innovations of design, which in an increasingly explicit way no longer makes use of "hands", it does not project itself to the direct representation of lines and points, but puts the desired performance and the constraints imposed on the representation of the form, even temporally misaligned with respect to the representative act.

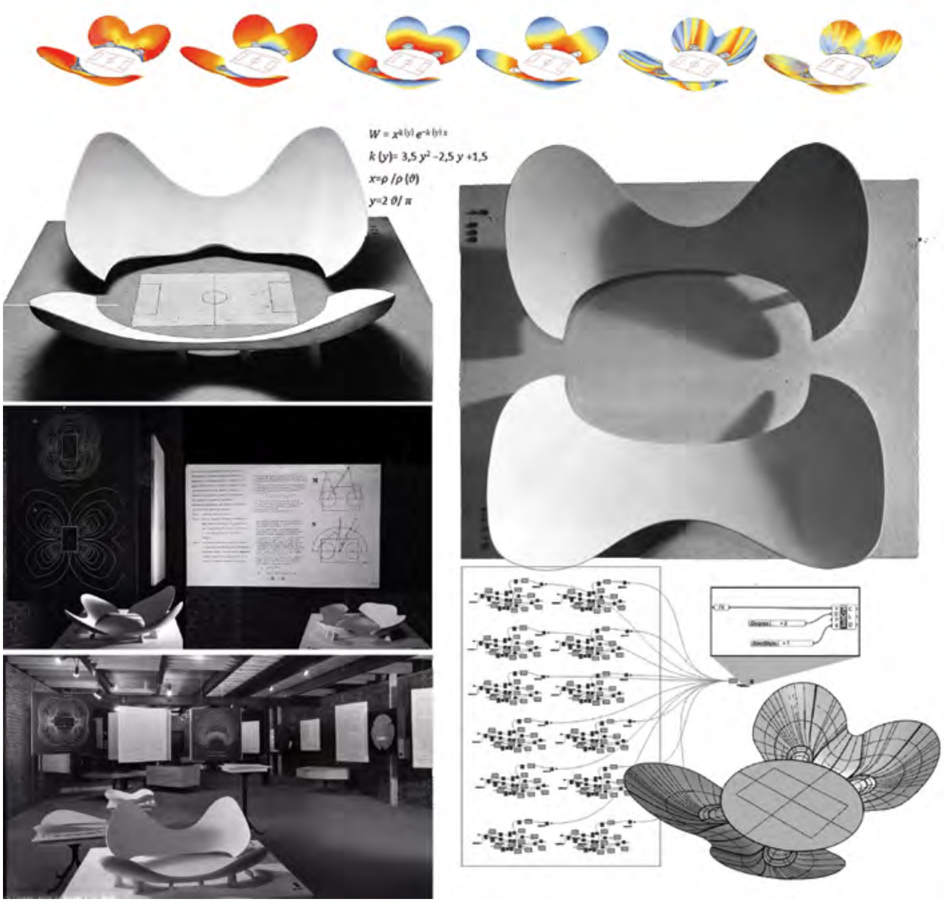

Fig. 9 - Generative design as research field of the relationships between mathematics and form in the reconstruction and reinterpretation of Luigi Moretti's "Parametric Architecture" (Academic drawing by L. Vitale).

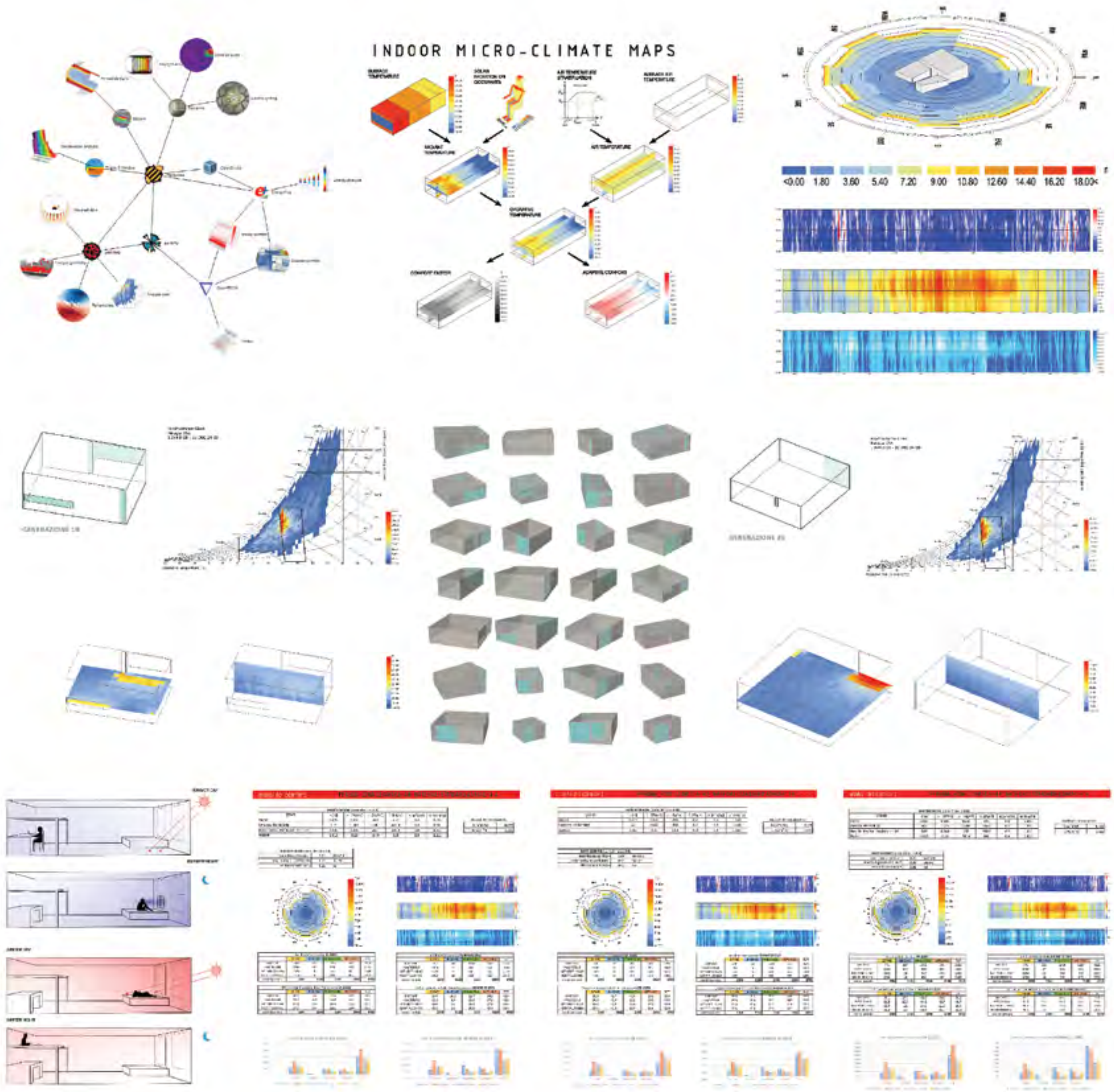

Fig. 10 - Generative design as research field of architectural form finding in the optimization of natural ventilation (Academic drawing by M. Governatori).

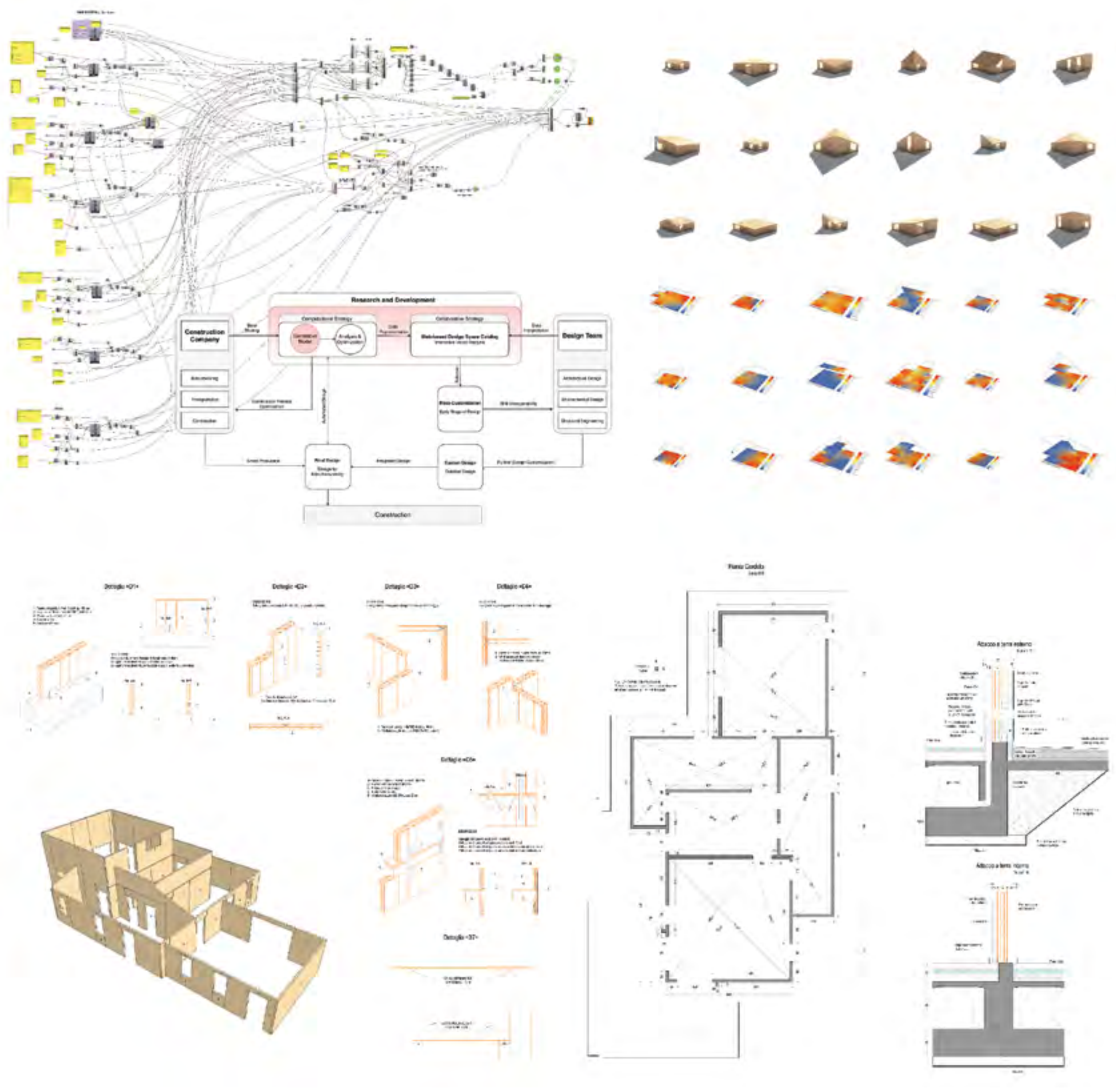

Fig. 11 - Generative design as research field of mass customization processes for wooden houses.

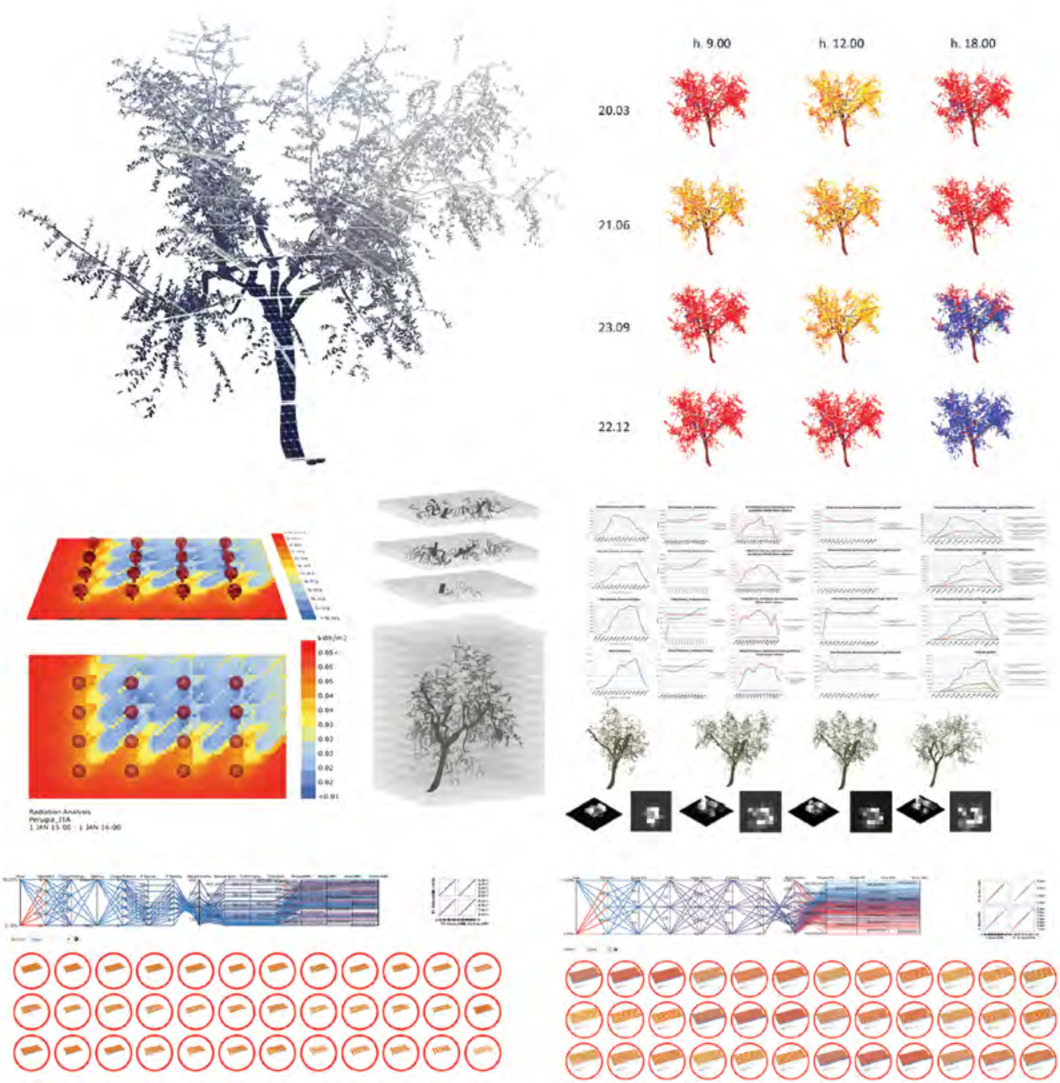

Fig. 9 - Generative design as research field of relationships between form and energy in the analysis of olive trees and in the optimization of "for the best" solutions in new planting layouts.

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PARAMETRIC MAPPING AND MACHINE LEARNING.
EXPERIMENTAL TOOL TO ANALYSE LANDSCAPE IN SLOW MOBILITY PATHS.

Abstract

The bottom-up research developed has led to an evolution in terms of tools and methodologies for
spatial representation, divided into three classes. The first one implements the GIS digital ecosystem for spatial data provision. The first is inherent in the parametric precision landscape modeling using NURBS technology in synergy with parametric platforms. The multiscalar flexibility of the ad hoc developed workflow was applied both to manage soft mobility nodes and to define energy flows in built-up areas of fragile territories. The second concerns the quantitative analysis of the quality of slow routes through programming codes that guide artificial intelligence platforms such as Mapillary and Google TensorFlow. At present, research is directed towards the synergic fusion of the two classes to have increasingly precise representation and analysis tools.

La ricerca bottom-up che è stata sviluppata ha portato una evoluzione in termini di strumenti e metodologie per la rappresentazione del territorio, suddivisa in tre classi. La prima implementa l'ecosistema digitale GIS per l'approvvigionamento dei dati territoriali. La prima è inerente la modellazione parametrica del paesaggio di precisione mediante la tecnologia NURBS in sinergia con piattaforme parametriche. La flessibilità multiscalare del workflow sviluppato ad hoc è stata applicata sia per la gestione di nodi della mobilità dolce, sia per la definizione dei flussi di energia in centri abitati dei territori fragili. La seconda riguarda l'analisi quantitativa della qualità dei percorsi lenti per mezzo di codici di programmazione che guidano piattaforme di intelligenza artificiale come Mapillary e Google TensorFlow. Attualmente la ricerca è direzionata verso la fusione sinergica delle due classi per avere strumenti di rappresentazione ed analisi sempre più precisi.

Introduction

The research work on parametric mapping was carried out through the development of methodologies for the optimization of sustainable mobility in fragile areas. These procedures have been applied in the Via Verde of the Costa dei Trabucchi(Luigi et al., 2018) in Abruzzo, a greenway created from the void generated by the inland retreat of the Adriatic railway. This vital artery of slow mobility is inserted in a territory characterized by long, fast, and longitudinal networks such as the Adriatic railway, the A14 motorway, the SS16, and short, slow, and transversal networks connecting the hilly territories left out of the coastal development. This work aims to create and optimize connections in this territory between longitudinal and transversal networks. The latter can be the object of redevelopment because there are railway tracks characterized by different degrees of abandonment or degradation that could be developed, just as happened to the greenway on the coast. This hilly hinterland is also crossed by historical networks, which, although partially disused, constitute routes of considerable historical and cultural importance both longitudinally and transversally to the coast. The "Cammino di San Tommaso," linked to the Christian faith, connects Ortona with Rome, and the Gustav Line, representing a World War II front located along the Sangro River, connects with Cassino. These paths both run transversally. Instead, longitudinally runs the "Tratturo Magno," an old sheep track linked Abruzzo with Puglia, but it runs diagonally connecting inland with the coast (Pescara, 2020). The process of recognizing and enhancing the mentioned towns and routes is carried out with digital instruments using programming codes designed ad hoc to solve the various problems encountered. It is possible to categorize this process by classifying the two families of landscape elements that are analyzed, the nodes and the networks. Digital ecosystems, as GIS procedures and NURBS spatial modeling, are used both for network and path analysis. Machine Learning methodology for evaluating the landscape crossed by routes is used for the analysis of networks only.

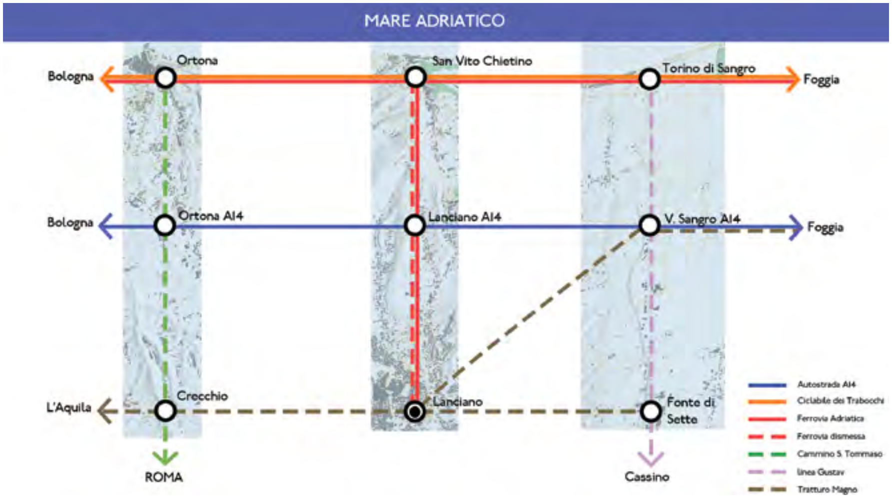

Fig. 1 - The network of longitudinal and transversal connections.

The GIS method

The use of digital tools belonging to the GIS family is the first step in managing the mapping of a territory, and the in-depth study of the fundamental technologies has led to further developments in research. Initially, the software ArcGIS - an unavoidable de facto standard - and QGIS, which represents its opensource alter ego, were used in parallel; the latter was preferred for its ease of use and for a general approach to problems based on the sharing of users' experiences aimed at solving problems, as opposed to the proprietary approach of ArcGIS. QGIS, furthermore, incorporates a Python interpreter, an essential part of the research work. Several plugins connected to QGIS for travel time analysis were tested, such as Qneat3, TravelTime, ORS, Iso4App. These tools have been essential to map the reachable road network with predefined cycle times starting from the Adriatic route's railway stations. Eventually, a network analysis QGIS function has been used by calculating and representing the catch area with its origin in the station. The test was completed within the Vasto area in Abruzzo, Italy, using the 15-, 25- and 35-minute cycling range. (Bianchi et al., 2020) The issue with this kind of analysis is the simplification of the road's flatness. This generalization may be acceptable if automobile mobility is considered. As slow mobility is the foundation of the research, it is essential to consider the motion direction, making a path a completely different bikeability if it is taken upwards or downwards. Therefore, a method has been developed that considers even the territory morphology, the Nurbs Methodology.

The Nurbs method

The NURBS spatial modeling was developed from obtaining precision and flexibility of valuable modification for the definition of slow mobility routes. This precision is difficult to achieve with geometric data on a territorial scale, including vast areas whose precision is limited for computational reasons. Therefore, an innovative methodology has been developed to manage these data with a technology that works with mathematical models and significantly increases precision and flexibility. Introducing an innovative digital mapping device, namely NURBS technology, was necessary to include morphology features. Spatial modeling is conventionally carried out with Mesh technology - mainly based on triangular cells - which have an excellent capacity to visualize large amounts of data but possess modest possibilities of manipulation. On the other side, the NURBS architecture allows precise and refined representation models because it is based on mathematical equations and works independently of the scale of representation. NURBS are used to model all kinds of objects, such from jewelry up to territories, as they have a greater capacity for synthesizing information than meshes. Mesh triangular geometry does not allow the precise modeling of organic landforms, which is paramount for managing bicycle networks' paths.

Further research has shown that these considerations are correct when applied at a territorial scale because two- and three-dimensional representations have adequate accuracy and a manageable use of machine resources in computational time. As the scale increases, however, the increase in accuracy becomes negligible, and the calculation time increases dramatically, making mesh computation the most suitable, especially when no landscape modification operations are required. (D'uva & Eugeni, 2021) The same approach can be intuitively applied with the DTM accuracy parameter. The grid pitch of DTM is the level of detail of the data and conditions both the calculation time and the refinement of representation. Many experiments have been carried out which have highlighted the DTM pitch of 20 x 20 meters, beyond which the difference between NURBS and Mesh representation is no longer significant. It is also possible that the two representation methods coexist to represent different data in the same area. Analyses of climatic data, for example, are carried out in terms of incidence calculated on a typical cell, equivalent to a quadrangular mesh cell. Such analyses can be represented by overlaying them in Nurbs models with an appropriate level of accuracy. Rhinoceros, a standard for NURBS geometric entities, has been experimented with as a bridge with forms typical of territorial mapping such as shapefiles. The connection is made through a visual programming language within Rhinoceros, called Grasshopper. This language allows the insertion of further applications within Grasshopper itself, such as Merkaat and @it, which allow the import of shapefiles into Rhinoceros.

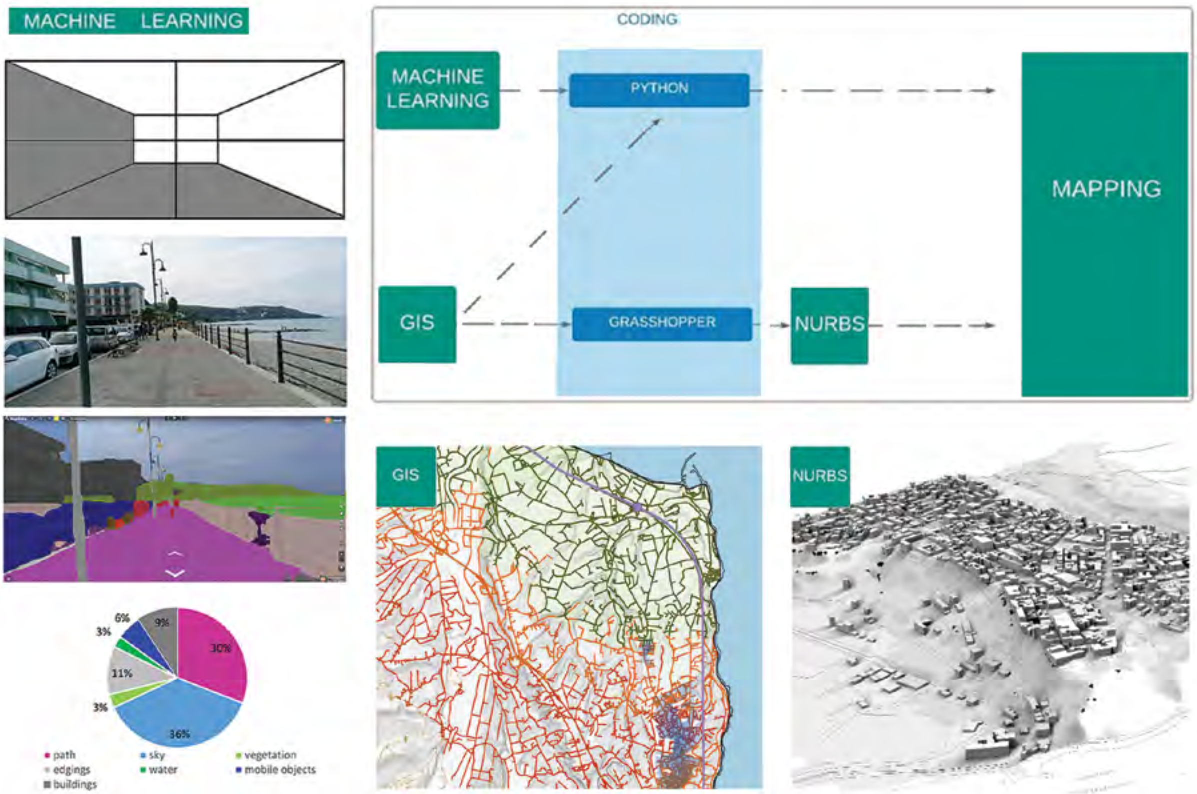

Fig. 2 - Methods of analysis evaluation

This ecosystem of digital tools makes it possible to import the shapefiles and process them to automatically generate a precise three-dimensional representation of a territory from the DTM. The use of Grasshopper as an actual programming language has also made it possible to manipulate
data in the most valuable ways to analyze and improve networks of connections. The combination of all the tools experimented so far has been the realization of a georeferenced road network altimetrically located on the territory from which a selection of roads can be extracted whose slope is known and lower than a given value, in this case, 10%. It is helpful to specify that all the procedures detailed above result from an ad hoc parametric processing, which means programming a visual language to obtain the input territorial data, the 3d model, and the three-dimensional network of roads with the relative slope. This type of approach's parametric nature guarantees the possibility (with the same algorithm) of obtaining a different result with different inputs, as the parameter varies. It is possible to obtain a 3D model starting from any DTM of any level of precision; applying to this model a slope algorithm, and it is possible to obtain the analysis of the network slope, displaying in real-time which roads satisfy the given condition. By its very nature as a visual programming language, Grasshopper is subject to limitations, i.e., it is possible to combine icons (commands) in an infinite number of ways to construct the algorithm, but it is impossible to use iconic commands that are not already preconfigured unless the commands themselves are programmed individually. However, a second problem associated with this programming language is the limitation of hardware resources. Grasshopper uses single-thread technology instead of the more powerful multi-thread technology standard on all processors. The complexity of the (Andrea Rolando, Domenico D'Uva, 2021) calculations involved, especially on large portions of land with many roads, would significantly benefit this type of improvement.

The Machine Learning method

The third methodology is based on landscape assessment, and it originates within the research ecosystem of the E-scape observatory, Politecnico di Milano, where the developed analysis system based on two primary levels has been developed(Bianchi et al., 2020). The first level analyses the landscape from a zenithal point of view through GIS techniques that provide an assessment by recognizing the elements present extrapolated from Open GIS databases of that area. The second level analyses the landscape from the point of view of the user of the route. This type of analysis is carried out with a methodology that requires very advanced knowledge of computer tools. It is based on recognizing elements from images captured at the human eye level processed with artificial intelligence technology. The system returns a mapping of the image by inserting a photographic image, separating the individual elements that compose it. This latter measures the amount of space occupied in the image by the individual element and how many times the object appears. A classification of the elements helpful in assessing the path's quality and relative weight was also developed using a formula for the actual calculation. The verification of the effectiveness of this methodology was done by analyzing different territories, including the "Costa dei Trabocchi" near San Vito Chietino, the area of Termoli, and the "Cammino dei Monaci" in the south-east quadrant of Milan. In all the verifications made, the assessment was consistent with the quality of the route. Python's use was the key to efficiently managing spatial data, applying Machine Learning (ML) systems intending to define a reliable system to assess the quality of slow mobility routes. ML system is a large family of digital tools, which has several different aims. The common element among all these aims is the possibility of these systems to learn new information and behaviors from the progressive input of new data. The specific use of the ML system in this research is the extraction of elements from a photographic survey. These elements belong to a library (training model) of previously recognized elements. The tested ML engines are Rekognition from Amazon, Imagga, and Google. Based on data from Google Street View, the latter formed an initial basis for work carried out in an almost entirely manual manner. Based on the experiments taken, the latest tool in terms of time was Mapillary, which, like Google Street View, allows access to street-level photos and makes it possible to upload new images and easily share with other users. The current methodology begins with a route imagery survey, which requires the GPS track to be recorded, and photographs are taken every 10 meters, orthogonal to the route direction, using the web application Mapillary. It is a web platform that collects street-level imagery taken by users with a regular smartphone to

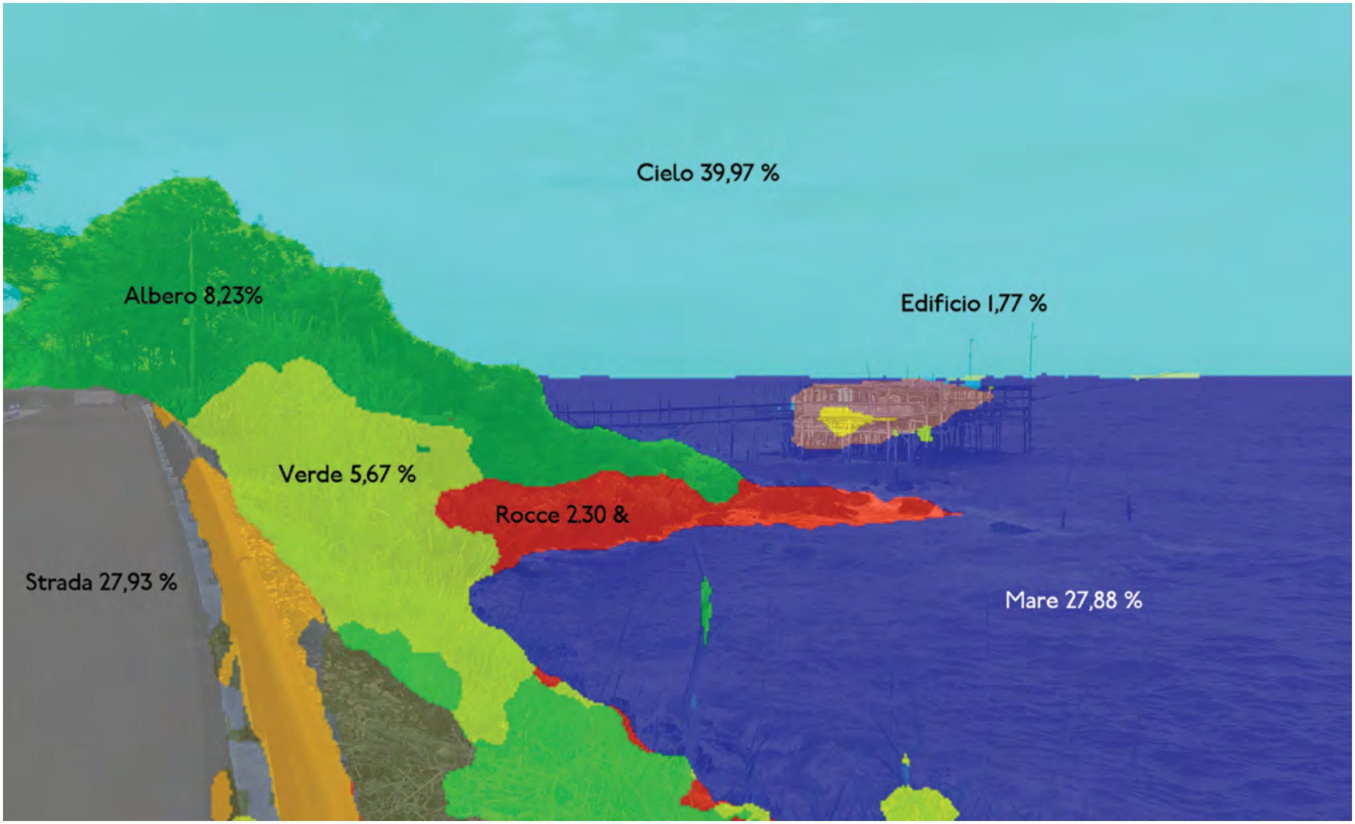

Fig. 3 - Machine Learning method output

automate mapping operations. Mapillary uses computer vision software to recognize each element in the images and their segmentation(Song Yuheng, 1985) to quantify their occurrence. The approach is focused on the identification of objects in images using Image Segmentation technology. This technology is part of the ML digital ecosystem, which allows identifying object perimeters and measurements across the entire image. The artifacts, assimilated to the elements in a training model already present in the ML engine, and a percentage of the framed field of view occupation is given. In Python, an ad hoc algorithm was written to extract these quantitative data from each image. This algorithm allows the ML's heavy computational burden to be shifted from local machines to remote cloud systems, which more efficiently perform recognition. This feature has allowed quantitative measurement of the elements present within the images to group together and understand which features are common to the different sections of the selected routes.

Conclusions

The research aims at defining a set of tools that support the process of analysis and mapping of a fragile territory, where the complexity of the landscape and the scarcity of information require non- conventional procedures based on the integration of heterogeneous sources. The case study is a prototype to test the effectiveness of the various tools, and the research is proceeding to refine the methodological framework. At the current stage, the results seem to be promising. Firstly, to define a digital terrain model that can be adapted in a parametric way to more refined analysis, also resulting in site-specific features. Secondly, to support the analysis of slow mobility paths with a more accurate interpretation of landscape visual characters.

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COMPUTATIONAL DESIGN IN THE STUDY OF FORMS OF NATURE

Abstract

The increased level of computer literacy that has characterized the last few decades has led designers to investigate processes that underlie the used daily Computer. This interest has promoted a new type of modelling focused on the formulation of algorithms, systematic procedures based on a uniquely interpretable succession of instructions, which explain how to achieve a goal. Used in the drawing discipline, the computational process opens to a new research direction based on code concept: if a problem resolution can be described by a finite number of steps, in the same way the shape's identity is a consequence of the set of discrete rules that define it. In synergy with the digitization of production processes capable of constructing complex morphologies starting from the numerical model, algorithmic modelling has allowed the morphological freedom that distinguishes recent design or architecture productions. This paper investigates the reciprocal link between computational modelling and digital fabrication in studying morphologies typical of the natural world, searching for a new formal language based on efficiency and functionality.

L'accresciuto livello di alfabetizzazione informatica che ha contraddistinto gli ultimi decenni ha portato i progettisti ad indagare i processi che sottendono il funzionamento dell'elaboratore quotidianamente utilizzato. L'interesse ha promosso un nuovo tipo di modellazione incentrata sulla formulazione di algoritmi, procedimenti sistematici basati su una successione di istruzioni univocamente interpretabili, che spiegano come raggiungere un determinato obbiettivo. Utilizzato nella disciplina del disegno, il processo computazionale apre ad un nuovo indirizzo di ricerca basato sul concetto di codice-procedura: se la risoluzione di un problema può essere descritta da un numero finito di passi, allo stesso modo l'identità di una forma è conseguenza dell'insieme di regole discrete che la definiscono. In sinergia con la digitalizzazione di processi produttivi capaci di costruire morfologie complesse a partire dal modello numerico, la modellazione algoritmica ha permesso la libertà morfologica che contraddistingue le recenti produzioni nel mondo del design o dell'architettura. Questo scritto indaga il legame di reciprocità tra modellazione computazionale e fabbricazione digitale nello studio di morfologie proprie del mondo naturale, alla ricerca di un nuovo linguaggio formale basato sull'efficienza e sulla funzionalità.

Introduction

The complex morphologies today realized in the design or architecture sector are possible thanks to the intended use of the digital medium, no longer bound by assisted design software. The study of computer processes that underlie the form generation has equipped the designers with an alternative approach capable of developing ad hoc tools used in unique design and research experiences. The process is based on the possibility of controlling the geometry by studying algorithms, logical procedures based on a succession of uniquely interpretable instructions that explain to the computer how to achieve a specific goal. Any problem solved in these terms is said to be computed. Used in the drawing, it promotes a research direction based on the centrality of the concept of code- procedure: if the resolution of a question can be described by a finite number of steps, in the same way, the identity of a shape is a consequence of the set of rules discrete that define it. For the design disciplines, the study, comparison and reasoning of the morphological properties are fundamental for the effectiveness and efficiency of what is conceived. The result of any project depends, in fact, on the ability to respond to project requirements related to the timing and resources necessary to achieve a goal. This leads to a formal simplification, which adapts to the tools and manufacturing processes since for design purposes the possibility of designing articulated geometries would be useless without the opportunity of a realization. Technological evolution has today expanded production capacities thanks to construction processes, summarized by Digital Fabrication definition, able to interpret the digital model and translate it into different levels including the exact modelling of the parts, assembly and construction, defined both in the components and systems, whether in the process leading to production or construction. For the first time in the project's history, the information necessary for the design and production of artefacts is summarised by a single representation, in a paradigm that allows the creation of hitherto advanced morphologies.
Some of these have long been known as they can be found in biological systems. The natural world was, in fact, the first model of design inspiration since man began to represent natural organisms and phenomena within caves to understand their principles. Although the functional efficiency observed in nature has constantly stimulated equally effective solutions in the world of artefacts, abstracting and transforming natural principles into technology is a discontinuous process linked to the theoretical tools and technologies available. The modern world of design is thus adapting scientific culture trend that abandons the deterministic vision of reality to embrace a model more consistent with the real world, admitting that all phenomena, even if to different degrees, are characterised by nonlinear processes. Below are examples of how this approach reveals its potential in studying and formalising morphologies typical of the natural world that open to a new language and to innovative solutions.

Triply Periodic Minimal Surface

A minimal surface is a surface whose mean curvature is always zero. This definition answers to Plateau problem: if a closed polygon plane or oblique is assigned, then there is always a system of surfaces, including all possible surfaces that touch the frame, which can minimise the area.[1]
The most interesting geometric shapes for the research are the Triply Periodic Minimal Surfaces (TPMS), three-dimensional symmetry surfaces, invariants for translation in Cartesian space. This property allows periodic replication of the single surface in space to form a new modular structure, seamlessly and without intersections, in which the physical iteration between the modules (a polyhedron called Fundamental

Cell) causes a compensatory effect that significantly increases their structural efficiency while maintaining minimal use of material[2]. These characteristics are known because triple symmetry minimal surfaces are widespread in nature and are studied by different disciplines in numerous systems. The objectives of those researches[3], and this study too, lie in understanding the principles on which the remarkable properties depend and then transfer them to technological applications. The solution proposed concerns the safety of construction workers. The investigation showed how many bricklayers did not wear helmets due to weight and amount of heat, especially in the summer period[4]. The TPMS's characteristics to create stable morphologies are therefore functional to realise a resilient but lightweight, protective helmet with a breathable structure capable of solving the user problems detected.

The first problem to solve is the digital control of TPMS. It has already been written that minimal surfaces are characterised by zero mean curvature. The peculiar property of these loci is, however, not easily usable in their digital generation.
A method is based on Karl Weierstrass's[5] parametric equation, which expresses every minimal surface as holomorphic functions. This equation, however, is characterized by a complex formulation that makes the computation process complicated. The most effective process is the implicit formulation that describes a surface through a linear function of three variables, f (x, y, z) = 0. The trigonometric form is appropriate to the digital description because it allows the large number of elements that characterize TPMS without overloading the calculation process and does not allow self-intersections. Using Grasshopper, a visual programming language that works in Rhino 3d (CAD) environment, it

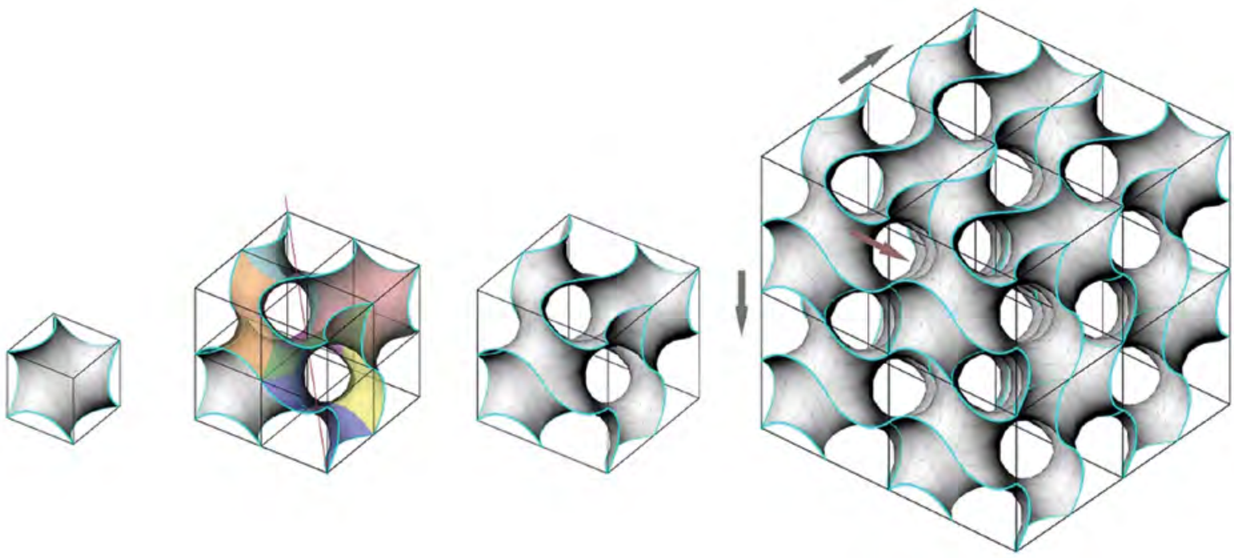

Fig. 1 - TPMS based on Gyroid principles of construction

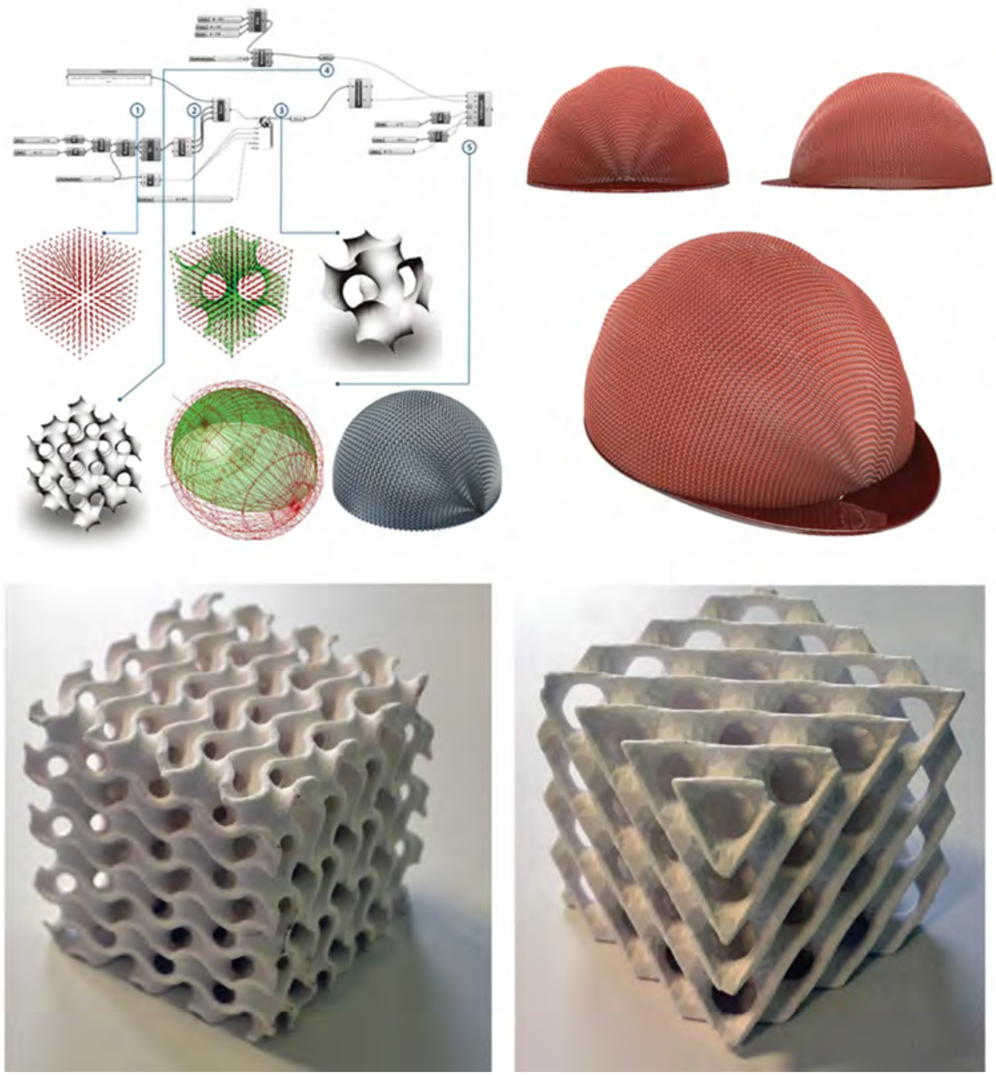

Fig. 2 - Step of the algorithm: 1) Definition of points in the fundamental cell; 2) Triangulation creates the surface; 3) Gyroid surface; 4) Invariant translation to create a TPMS based on Gyroid; 5) Discretization of the Hemispherical dome to obtain a safety helmet composed by Gyroid. Below TPMS based on Gyroid and Diamond Surface manufactured by 3d printing process.

is possible to define algorithms that describe the minimal surfaces expressed in the implicit formulation with good approximation. We can observe the construction example of a TPMS derived from Gyroid. This surface is generated exclusively by curves and distinguished by the absence of reflection symmetry between the eight fundamental units. It does have C3 axes of symmetry (along one diagonal of the unit cell) and 4-fold rotoinversion axes. In other words, the fundamental units are placed at 120° intervals along a diagonal, while the rotoinversion operation rotates them by 90° and performs the inversion through the centre of cube. This creates a morphology that separates the space into two enantiomorphic regions, which are specularly symmetrical and overlapping with a plane outside them, but not by rotation (Fig.1).
In nature, these structures are present where one needs strength and lightness, such as in the sea urchin exoskeleton or butterfly wings. In addition, the morphogenesis processes take place for stratification, similarly to what happens in manufacturing through 3D printers. These features make Gyroid particularly interesting for the design purposes proposed.
The algorithm translates the algebraic equation into a finished form that can be studied, manipulated and replicated. The process can be conceptually simplified, imagining that the equation “selects”, in the domain of Cartesian space points, those belonging to the surface to represent. The following algorithm’s instruction connects by triangulation the points creating the surface. It is now possible to exploit the symmetry characteristics of the single unit by replicating it and studying adaptation processes to the considered morphology. The example in figure 2 shows how, via computational modelling, it is possible to integrate the properties of the minimal surfaces into a protective artefact. The digital helmet model was solved with a NURBS surface, discretized in parallelograms coinciding with the lower base of the pyramid trunk in which every single Gyroid will be recalculated.

The only technology available today for the creation of such a digital model is 3D printing. After assessing the cost-benefit ratio and research intentions, the first experiments were conducted with the Zcorp Spectrum Z510 plaster-based 3D Printing. Regardless of the software that generates the format needed for 3d printing (stereolithography) is. STL, which describes the model through a triangular mesh. If in a digital domain a surface is an ideal geometric object without thickness, its translation into the physical world requires specifications:

1 Correct topological relationship among the mesh triangles, which must not have discontinuities or overlays.
2 Clarify the perpendicular to the triangles to allow the machine to recognize the interior and exterior of the artefacts.
3 Optimizing printing speed concerning material and geometry.
4 Considering that printers deposit layered material, moving vertically, it is necessary to provide the correct arrangement to support the protruding parts to prevent the structure from collapsing during printing.

Broccoli, lungs and geometry

The following examples investigate how a conscious use of computational processes in design can describe and control the complexity factors of the biological reference model. The first example concerns a vegetable that has always fascinated scholars of different disciplines for its morphological characteristics: Roman broccoli[6].The reputation is probably due to the broccoli’s “rosette” (the small cone) fractal arrangement, which reproduces the same geometry on different scales following the rules of internal homothety. In other words, each broccoli’s cone generates a succession of other cones on its lateral surface in a continuous sequence. Another interesting aspect is that this sequence can be expressed as a quotient of the Fibonacci sequence, or rather, as the ratio between this sequence's numbers in which each quantity is the sum of the previous two. The algorithm first describes a logarithmic spiral belonging to the XY plane. This spiral is defined algebraically so that the vector radius r is a continuous and monotone function of an angle q, describable in the Cartesian plane by polar coordinates such that x = r cos q and y = r sin q, where r is the distance of a generic point P from the origin of axes (considered as the spiral pole). The angle q indicates the inclination of OP with respect to the polar axis. The curve projection on the cone lateral surface allows obtaining a three-dimensional logarithmic spiral in which the polar axis OZ coincides with the cone height.

The next step divides the curve according to the Fibonacci sequence, obtaining proportional segments. The extremes will correspond to the base centres of cones that will constitute the new peaks. The algorithm constrains the cones height to the radius and the radius to Fibonacci sequence so that, depending on the point of generation, it respects the tangency condition with the bases of the adjacent cones that lie on the same curve. Like this, the size of the "rosette" decreases proportionally as the spiral approaches the cone apex. It is sufficient to repeat the process n times to obtain a geometry that approximates the existing vegetable precisely (Fig.3).

The geometric study also reveals the phyllotaxis reasons: the angle of 137.5° that accurately distances the cones base

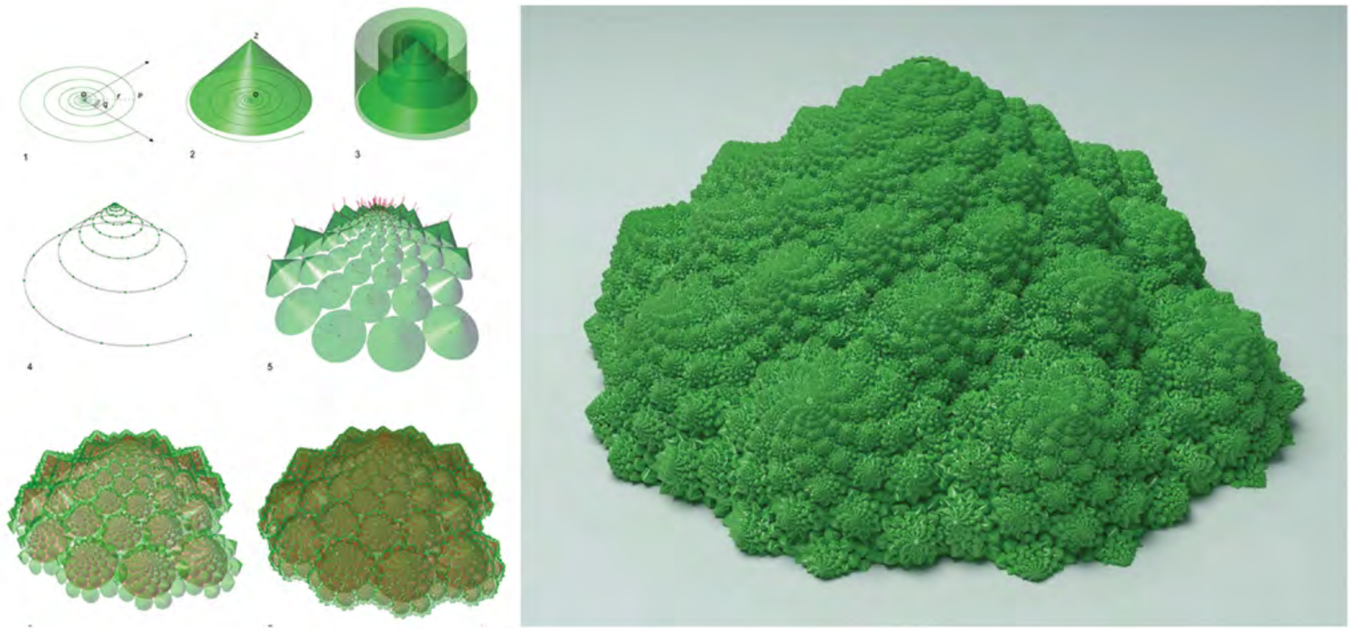

Fig. 3 - Algorithmic development of a Roman broccoli

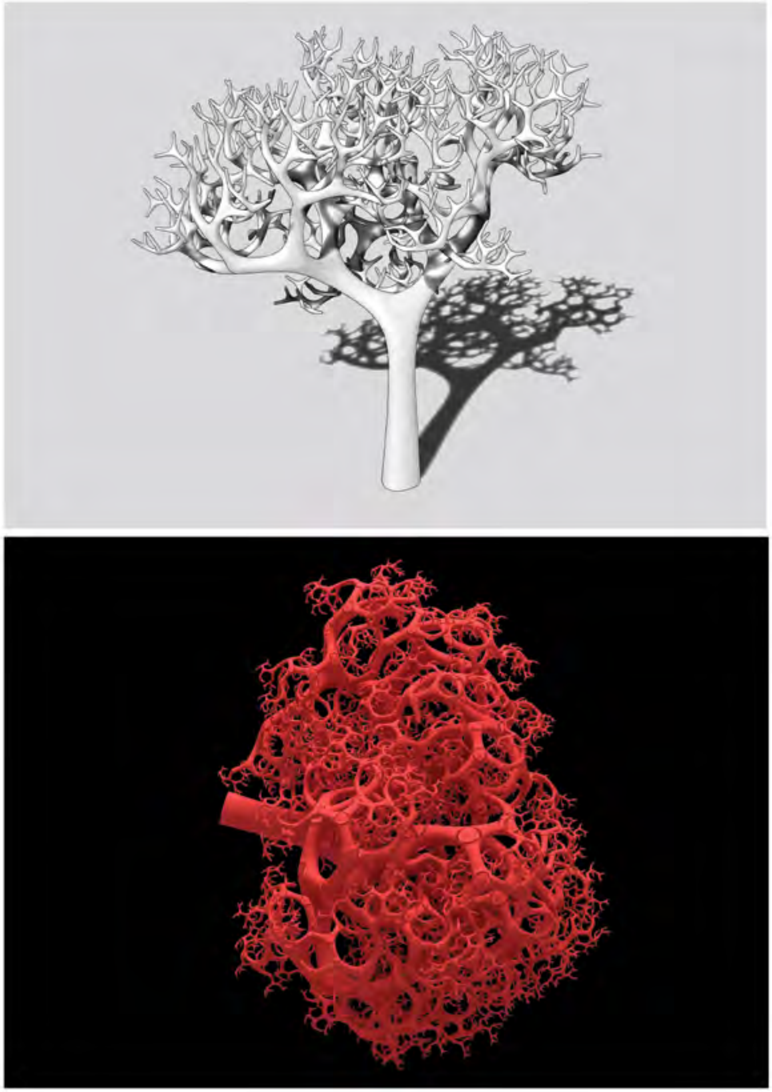

Fig. 4 - The same algorithmic description, by parameters variation, can generate a tree morphology or the articulated distribution of the pulmonary circulatory system.

centres, corresponding to the peaks, allows the space to be exploited with excellent efficiency. If the divergence angle had, for example, an amplitude of 120°, or any other rational product of 360°, the cones would align radially, leaving a large amount of unused area among them. At this point, one may wonder why Roman broccoli develops cones starting from a circular base rather than using another polygon capable of seamlessly tessellating the surface, such as a square or a triangle. The finished model analysis seems to provide some explanation: it will be noticed how the self-similar principle orients the cones in every space direction. The continuous cone curvature allows for maximum exposure to light rays regardless of incidence[7].

The second algorithm computes a particular type of branched structure typical of some tree families and found in many living beings' respiratory vascular systems. The study is a three-dimensional development of a fractal known as the Pythagorean tree. It is based on a binary iterative procedure structured on the well-known relationship between square and triangle a2 = b2 + c2. Each square has one side in common with a triangle, which in turn has the other two sides in common with two other squares and so on, in a succession of rotations and homotheties which, despite their simplicity, generate branched structures of great complexity. The three-dimensional construction follows the same rule but requires replacing the cube or parallelepiped with a triangular-based prism.

Three-dimensional triangle equivalent is, in fact, the tetrahedron, which, having triangular faces, does not allow the construction of polyhedrons characterized by four faces. Solids characterized by square and triangular faces, such as the square-based pyramid or the cuboctahedron, could be used, but the binary relationship that distinguishes the morphology growth would be lost.

Each branch is divided into two parts that follow the face perpendicular, halving in section, in a repeated process that allows adequate coverage of the space without interference among one branch and the other. The algorithm then transforms the polyhedron into cylinders to better simulate the studied natural shapes. In this case, it is also possible to experiment with different parametric variations, realizing why the dichotomous subdivision of the trachea into bronchi and the bronchi into bronchioles, similar to the branching of many plants, is the simplest way to occupy a volume (Fig.4). While breathing, the lungs inhale oxygen (O2) and exhale carbon dioxide (CO2), while chlorophyll photosynthesis reverses this process. In both cases, the exchange efficiency improves as the surface increases, so that the continuous branching of the structure in constant proportions allows to have in a relatively small volume such as that of the lungs variable surface between 50 and 100 m2, equivalent to a tennis court. The specific relationship between the bifurcation angles then guarantees the maximum space coverage avoiding the branches overlapping.

Conclusion

This paper illustrates how computational modelling allows the representation of complex natural morphologies and sufficiently precise control to make them available for production purposes. The synergy with new machine tools is a decisive factor. However, technology does not guarantee the development of a coherent project because the form is not only a result of software or production technology. The main characteristic of the new approach is that conceiving a form algorithm forces one to systematize the design. The critical issue is not the knowledge of the programming language: a computational process can be separated from the computer, but a forma mentis capable of decomposing and analysing the steps that lead one to the outcome. Although able to manage and optimize thousands of data related to a problem, the computer cannot determine the generation rules that the designer must formulate. To prepare the form for computation, it is necessary to know the geometry. In a process where the digital model directly informs the machinery capable of producing it, the role of the design is not only a descriptive and planning tool but, today more than ever, to shape the material.

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Notes

[1] See Buratti G., 2013, pag. 133.
[2] See Emmer M., 2009.
[3] See Bar-Cohen Y., 2011.
[4] See Buratti G, Santini M., Dellera L., Mosconi G., 2010.
[5] Karl Theodor Wilhelm Weierstrass (1815 –1897) German mathematician, also known as the father of modern analysis.
[6] Brassica oleracea italica.
[7] In fact, Roman broccoli is a cauliflower variety with a medium autumn-winter cycle.

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Mirco Cannella Architect, PhD, is Researcher in Representation of Architecture in the Scientific Sector ICAR/17 at the Department of Architecture of the University of Palermo. He was research fellow from 2013 to 2016 in the ERC Cosmed project at the Department of Architecture of Palermo and, from 2016 to 2018, at the Department of Culture of the Project of the IUAV University of Venice, where he designs and develops applications of augmented reality for the *Cité de la Architecture at du Patrimoine* in Paris and for the Archaeological Park of Selinunte. His research activity is focused on the study, documentation, geometric analysis, and representation of the architecture using the most advanced 3D digital survey and representation technologies. He is the author of numerous articles and papers in journals, contributions in volumes and conference documents.

TECHNIQUES AND PROCEDURES FOR THE DEFINITION OF AR

APPLICATIONS IN ARCHITECTURAL AND ARCHAEOLOGICAL CONTEXTS

Abstract

The growth and development of Augmented reality applications and their use in different contexts has been recently fostered by two factors: i) the hardware and computing power of mobile devices has been radically improved; ii) Apple and Google have released two development platforms for AR applications.

AR has been a major topic in research on cultural heritage fruition for many years, but the latest developments are really promising, and they seem capable of overcoming the difficulties that have delayed the diffusion of this technology. The paper focuses the potential and criticalities of augmented reality systems used for fruition purposes in architectural and archaeological contexts. The description of the research experience starts with the strategies adopted for the construction of the models, which have been developed using laser scanning and photogrammetric surveys as references; the following discussion will be dedicated to the solutions adopted to overcome the most critical features in AR applications, e.g. georeferencing.

Negli ultimi anni si è assistito a un esponenziale incremento di applicazioni di realtà aumentata destinate ai contesti più diversi. Questa condizione è stata favorita principalmente da due fattori: la dotazione hardware e potenza di calcolo raggiunta dai dispositivi mobili e lo sviluppo da parte di Apple di e Google delle due principali piattaforme di sviluppo per applicazioni AR.

Alla luce di questa rivoluzione, che dopo diversi anni di ricerche rende finalmente concreta l’adozione di tale tecnologia, il presente contributo analizza le potenzialità e le criticità dei sistemi di realtà aumentata adottati in contesti architettonici e archeologici. Attraverso la disamina di alcuni casi studio saranno illustrate le procedure e le strategie adottate per la costruzione dei modelli, realizzati a partire da rilievi laser scanning e fotogrammetrici, e le soluzioni adottate per superare gli aspetti più critici come quelli legati alla loro georeferenziazione.

Evolution of augmented reality

More and more museums and archaeological parks offer to visitors digital applications capable of enriching their experience of visit with virtual reality systems - successfully used for a decade - and with augmented reality solutions which, in recent years, have been applied to the fruition of cultural heritage. The first AR researches date back to the second half of the 1960s, when I. Sutherland, a teacher of the Harvard University, developed the prototype of a head-mounted display; in 1992 T. Caudell and D. Mizell produced the first effective AR application, intended for Boeing aerospace technicians engaged in aircraft wiring operations. The computational limits and the size of the hardware needed for such applications at that time, prevented their widespread adoption of AR. Augmented reality reaches the public in 1999, thanks to with the open-source project ARToolKit developed by H. Kato and M. Billinghurst of the University of Washington; ARToolKit allowed the development and

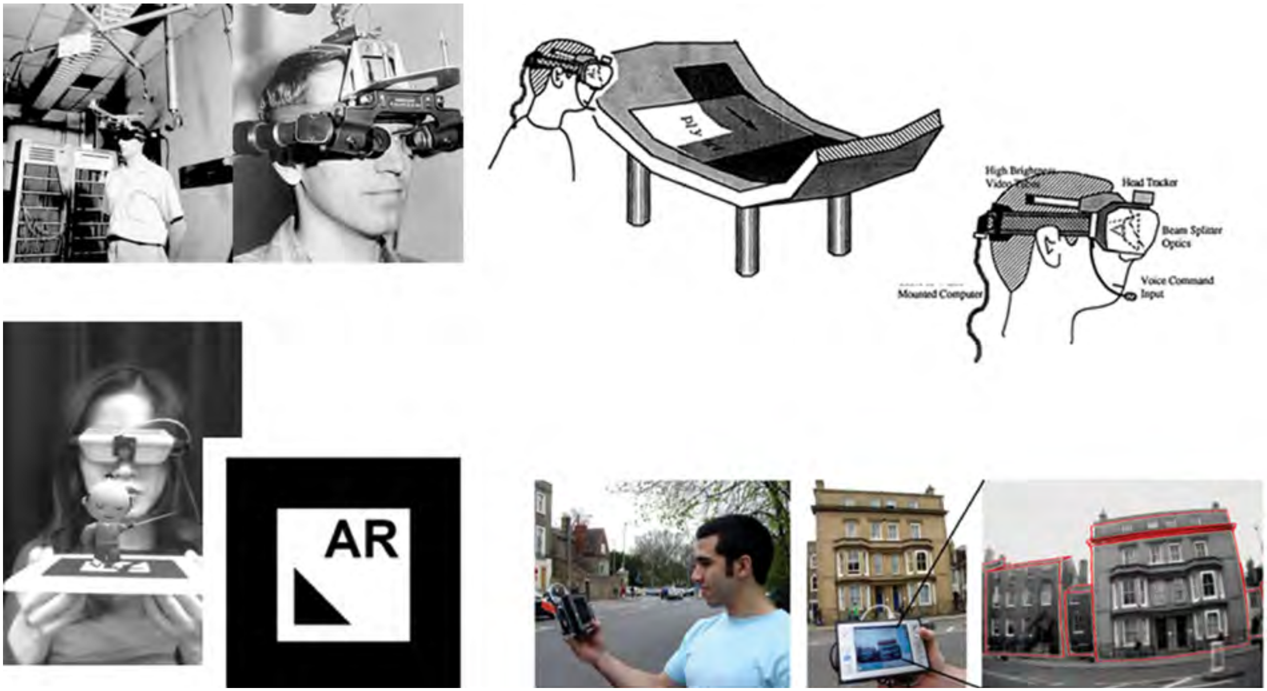

Fig. 1 - Top right: first HDM prototype developed by I. Sullivan of the Harvard University (1968). Top left: Concept of a head mounted AR system by T. Caudell and D. Mizell (1992). Lower left: the open- source computer tracking library ARToolKit, developed by H. Kato and M. Billinghurst of the University of Washington (1999). Lower right: robust Model-based Tracking for Outdoor Augmented Reality, developed by G. Reitmayr and T. Drummond of the University of Cambridge led (2006).

diffusion of numerous AR applications based on the recognition of plane markers; initially the system worked on desktop devices, but, from 2005, it became available on mobile devices.

The research work of G. Reitmayr and T. Drummond of the University of Cambridge led in 2006 to an important contribution for the use of augmented reality in urban spaces, with the development of the first markerless system based on the recognition of environmental features (Fig. 1). From that time on, many research centres have hardly worked for the development and improvement of markerless-based AR; in 2016 the Anglo-Japanese Kudan Computer Vision has developed innovative solutions that use the SLAM (visual simultaneous localization and mapping) technology to track the position of a mobile device inside a specific environment; at the same time Microsoft developed HoloLens, an advanced head-mounted display featuring semi-transparent visors that allow virtual elements to be superimposed to the real environment.

To date, the most widely adopted solutions are based on Google's ARCore technologies, an evolution of the 2016 Tango project, and on Apple's ARKit technology; both platforms allow the development of augmented reality applications compatible with a wide range of mobile devices.

Augmented reality for cultural heritage: case studies and experiments

The first research on augmented reality applied to cultural heritage was developed by the author in 2016, as a part of a research project promoted by the Department of Culture del Progetto of the IUAV University of Venice. The first experiment was developed inside La Cité de L'Architecture et du Patrimoine in Paris, one of the most important museums fully dedicated to architecture and monumental heritage; the exhibition shows some reproductions of French architectural artifacts, ranging from the Middle Ages to present times, through a vast spectrum of media such as moulage, maquettes, drawings, photographs, documentary films and 3D simulations in virtual reality. Due to its museographic, museological and didactic characteristics of a comparative machine, the museum is a perfect case study for the experimentation of augmented reality solutions. This first AR application was dedicated to the moulage room, which hosts full-scale plaster copies of architectural details of civil and religious buildings from the twelfth to the eighteenth century; the proposed application aimed at offering to visitors the visual experience of the virtual recontextualization of the details in the original monument. The application was developed with Tango, an AR platform developed by Google since 2014 and dedicated to the creation of augmented reality experiences on dedicated mobile devices. Actually, Tango could work only on devices equipped with specific sensors, including a fisheye camera, dedicated to the motion tracking system, and an IR projector with RGB-IR camera, for integrated depth sensing. A relevant feature of the Tango system was the ability to store, in the mobile device' memory, the three-dimensional information of a given environment. This feature, called Area Learning, allowed the environment data to be reused and shared with other devices, thus enabling the application to precisely calculate the position of the device inside the scene; Area learning could therefore establish a correct correspondence between virtual objects and the real scene, as expected in the design and development phase of the application (Fig. 2).

In 2017 Tango project was discontinued in favour of ARCore, the new augmented reality platform developed by Google. At the same time Apple developed a similar platform, named ARKit platform, dedicated to the IOS operating system used by its devices. The mission of ARCore and ARKit platforms is the use of augmented reality experiences with ordinary, not dedicated, mobile devices. The discontinuation of dedicated environmental sensors gave a decisive impulse to

the widespread of augmented reality solutions. In fact, from 2018 to today, we have witnessed an exponential increase in augmented reality applications in different contexts such as games, science, education, industry, e-commerce, etc..
ARCore and ARkit platforms are based on three core functionalities: i) motion tracking allows devices to understand their position in the world; ii) Environmental understanding allows detecting the size and position of flat surfaces; iii) Light estimation evaluates the light conditions of an environment and adjusts the lighting of virtual objects in real-time.
The motion tracking technology of both platforms is based on the acquisition of a video stream, taken by the device's camera, on the identification of points of interest, called features, and on the calculation of their position with Structure From Motion techniques. These data, integrated with the values processed by the IMU inertial platform of the device, allow the real-time understanding of the pose of the device. The comprehension of the space and of the position of the device, is refined and adjusted during the use of the App. This feature allows to adjust the reference system in the real scene, thus preventing positioning failures of the virtual objects. To ensure a persistent relationship between the position of virtual objects and the real scene, including an update of the reference system, both ARCore and ARKit allow the use of Anchors. The anchors, associated with the virtual objects inserted in the scene, allow to fix the position and orientation of the objects and make their virtual presence, in the real world, as likely as possible.
A first test on the use of ARCore platform for the development of an AR application for the visualization of cultural heritage was developed in 2018: the application was dedicated to the on-site visualization of the reconstruction model of the housing units in the FF1 residential area of the acropolis of Selinunte. The ARCore platform, not fully refined at the time, did not allow - as it was for the museum in Paris - to record and archive the data of the 3D space; therefore, it was not possible to set up an automatic processes capable of providing persistent AR experiences in time. For this reason, on that occasion, the calculation of the orientation of the device, the pre-requisite to ensure the superimposition of the virtual

Fig. 2 - Cité de la architecture et du patrimoine, Paris. Augmented reality application developed with Google Tango technology.

reconstructive models to the ruins of the archaeological site, demanded a workaround each time the application was used, even if this happened soon after the previous use. For this purpose, a flat surface, characterized by the presence of two circles with a diameter of 10 cm, centred on points having known coordinates, has been prepared. The implementation of the project, actually, demanded the acquisition of a laser scanning survey of the block capable of providing the position of the aforementioned points; the survey data were also used for the construction of a mesh model, capable of documenting the state of the ruins, a fundamental reference for the development of the reconstruction models of the individual housing units. The reconstruction model was referred to the mentioned coupled points: the first one allowed to fix the position of the device, whereas the second allowed the calculation of the orientation. The application, through the process of guided collimation of the two points, made it possible to position and orient the reconstruction model, thus ensuring the visual match with the extant ruins. From that moment on, the user, thanks to motion tracking, could move freely within the residential block and enjoy the visualization of the reconstruction model from any point of view, using the mobile device as a virtual window opened to the past (Fig. 3).

The same technique was used at a later stage for the development of a new application, aiming at testing the efficacy of ARCore in an indoor context as one hall of the "Antonio Salinas" Sicilian Regional Archaeological Museum. The test, developed in the Hall of metopes, aimed at the virtual recontextualization of the metopes from the Temple E

Fig. 3 - Selinunte Archaeological Park. Augmented reality application developed with Google ARCore technology.
Virtual reconstruction of the urban block FF1.

of Selinunte, exhibited on the end wall of the hall. Since the exhibited metopes came from the front of the naos, the 3D model of Temple E is sectioned. The experimentation could therefore test new forms of visualization of 3D models and test occlusion problems as well.
In order to emphasize the greatness of the Temple by comparison with the average size of the hall, the part of the temple virtually included in the museum hall was rendered by opaque surfaces while, the exceeding part was dematerialized to a wireframe representation, obtained by converting the edges of surfaces into solids. (Fig. 4)
At the end of 2020, version 1.20 of Google ARCore introduces an important feature called Persistent Cloud Anchors. This new feature allows anchors to be stored on the cloud, thus allowing the development of augmented reality applications capable of offering persistent experiences over time. The anchors, as mentioned previously, allow fixing the position of virtual objects in the world, regardless the reference system calculated by the service during the learning process.
The possibility of hosting and solving the anchors on the cloud offers the effective possibility of developing augmented reality applications dedicated to the study, documentation, and narration of architectural heritage. In these contexts, it is actually relevant that virtual objects are perfectly related to the built space, to ensure an effective overlap between the virtual world and the real space and make this condition persistent in time.
A first test on the use of ARCore with persistent anchors was developed for the virtual re- contextualization of the statue of giant statue of Zeus, today exhibited in the atrium of the

Fig. 4 - Antonio Salinas Archaeological Museum of Palermo, virtual reconstruction of the Selinunte Temple E. Augmented reality application developed with Google ARCore technology.

Salinas Museum, in its original context, i.e., a sacred area in the archaeological site of Solunto, 15 km east of Palermo. For this purpose, the 3D model of the statue was calculated with SfM photogrammetric techniques.
The experiment led to the development of two different applications: the first one, addressed to developers, aimed at positioning the 3D model of the statue in its original location and creating and at hosting the anchor on the cloud; the second application, addressed to end-users, solves the anchor and displays the statue in AR. The applications have been designed so that the information panel placed near the sacred area can be used as a support where the virtual anchor, associated with the model of the statue of Zeus, is placed (Fig. 5).
To this purpose, laser scans of the sacred area provided the necessary data to calculate the size of the information panel and refer its position to the ruins of the sacred building. The digital model of the statue has been arranged so that its origin point matches the centre of the rectangular area of the panel. This condition allows to use the dedicated application to accurately calculate the position of the virtual model; the positioning process can be described as follows: i) the information panel is captured with the smartphone camera from different points of view; ii) the application recognizes the information panel as a flat surface; iii) the anchor associated with the model of the statue is placed on the barycentre point of the flat surface. At a later stage, a guided workflow helps the operator to take the information needed for the creation of the anchor. The operator must make movements around the central point of the anchor, following a circular path, while keeping the camera of the device constantly oriented to the anchor. This procedure allows the application to reconstruct the position in space of visible features, while a graphic indicator shows the quality of the acquired data in real-time. Once an adequate quality has been reached, the anchor can be hosted on the Cloud and named with a specific identification code.
The identification code will be used by the AR App to allow

Fig. 5 - Solunto Archaeological Park, re-contextualization of the Zeus statue. Augmented reality application developed with Google ARCore platform and the Persistent Cloud Anchors feature.

further users to start the recognizing process and the anchor's resolution; the user will be simply requested to frame, with the device's camera, the information panel located near the sacred building. At this stage, an almost automatic and real-time process will solve the anchor and will place the virtual statue in the proper location; the user can now move freely around the site and visualize the virtual statue from any point of view at any distance.

The same technology was tested for the AR visualization of the virtual reconstruction of Porta Nord, a relevant part of the defensive system of the acropolis of the greek town of Selinunte. The reconstruction of the original layout of this fortification was carried out after the "restorations" proposed in the first half of the XX century by the French architect Jean Hulot (Paris 1871 -1959). Hulot's reconstruction drawings were a part of the research work that he carried out thanks to the scholarship grant dedicated to the winners of the Grand Prix de Rome and the following research period at the French Academy in Rome. The test conducted in this area aimed at testing the reliability of the workflow tested in Solunto in a wider and more complex context. The morphology of Porta Nord is actually very articulated, since the defensive walls extend over an area characterized by variable altitudes. The building is characterized by the presence of several volumes consisting of rectangular and semi-circular towers, interconnected by long galleries and mighty defensive walls. The ruins of Porta Nord are clearly visible today on site, and therefore it is a mandatory that the AR visualization of the virtual model perfectly matches the existing ruins. The reconstruction model was therefore referred to a mesh model of the ruins, generated by laser scanning and photogrammetric data. The mesh model also allowed to calculate the position and orientation of the model with respect to an information panel placed on site, a solution that echoes the test developed in Solunto.

The mesh model of the site was used for the management of the visualization hierarchy of real and virtual elements as well. Usually, in fact, the visualization of virtual objects is superimposed to the video stream taken by the device's camera.

When some elements of the real scene occlude some parts of the reconstruction model, trees in the case of Porta Nord,

Fig. 6 - Selinunte Archaeological Park, virtual reconstruction of the Porta Nord. Augmented reality application developed with Google ARCore platform and the Persistent Cloud Anchors feature.

they must stand in front of the virtual model. This is why the mesh model of the real scene, optimized to limit the number of triangles as much as possible, has been assigned a specific shader capable of occluding the objects behind it. This experimentation verified the tested workflow, with an optimal overlap between the virtual model and the real world, and a robust motion tracking of the device, able to restitute the correct perspective of the model from any point of view within an action range of about 10 meters from the origin point on the information panel (Fig. 6).

Conclusion

The evolution of software and hardware today allows today an effective use of augmented reality solutions in various application areas. In the field of cultural, architectural, and monumental heritage, the adoption of augmented reality solutions opens new research paths, addressed at the study and development of new methods of representation and visualization, and at the same time provides a powerful tool capable of a high communicative power, useful for the dissemination of architectural heritage to the wide range of visitors.

The Augmented reality solutions tested in this research work offer a powerful support in museums and archaeological sites, but its use can be extended, for example, to architectural design. This possibility can give a new and effective tool for the participatory approach to design and offers to stakeholders the possibility to view and evaluate in situ different design proposals before their actual realization.

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Round table

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Ph.D, Fabrizio Agnello was Born in Palermo in 1965 and Doctor in Architecture in 1992. PhD in Architecture Survey and Representation (IX cycle) at the University of Palermo in 1996; researcher in Drawing in 2000 and Associate professor in 2015.

Teacher of Descriptive geometry and Digital survey and representation at the Department of Architecture in the University of Palermo, his research interests are focused on the use of digital surveying and representation techniques for the geometric analysis and the virtual reconstruction of historic and ancient buildings. In the last decade he has developed several researches on the use of perspective restitution form photos for the virtual reconstruction of gone buildings and urban sites.

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PhD, Francesco Maggio was born in Palermo in 1963 where he graduated in 1987. He is full professor of Representation at the University of Palermo where he teaches “Laboratorio di disegno e rilievo”. His research interests concern the representation of architectural design understood as an investigation of the expression of an idea that is in any case verifiable. He is the author of monographs and essays on his research topics. He has been teaching and researching at the Department of Architecture of the University of Palermo since 2002. He is an elected member of the scientific society UID (Unione Italiana Disegno) recognised by ANVUR. Editor of the journal Diségno, he is on the Scientific Committee of several scientific journals for which he is also a reviewer. He was a visiting professor at the School of Architecture of the University of Miami. He founded the national seminars ‘Idee per la rappresentazione’.

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WILL DRAWING BE USED TO STUDY AND TEACH ARCHITECTURE IN THE NEXT CENTURY?

Drawing is the language of the architect. Drawing has been the language of the architect since the very beginning of architecture. Drawing and architecture have probably been born at the same time.
In this millennium, the use of digital tools for representation (and survey, but the subject will not be discussed here) has rapidly and deeply modified the study and the design of architecture. The rapid evolution of this mutation prompts the following question: will drawing be the language of the architect in the next century?
The relation between drawing and architecture dates back at least at 2400 years ago; safe some traces found on Egyptian monuments, the eldest drawings of architecture (as far as the author knows) have been found in 1980 by the German archaeologist Lothar Haselberger on the walls of the hypethral naos of the Temple dedicated to Apollo in Didyma (ionic coast of Turkey), whose construction started in the 4th century BC. The drawings, that covered an area of approximately 200 sqm, served as a guide for craftsmen to sculpt the blocks and bases of the columns of the peristyle. Lines and circles are engraved on the stone blocks of the walls of the naos;. The construction of the Temple was dismissed in the 2nd century AD, when the Temple was not finished; this is why the walls of the naos were not levigated and the drawings were not erased. The practice of carving drawings on stones is witnessed up to the Middle Age, but drawings were made on papyrus or parchment as well.
In the 13th century Villard the Honnecourt drew on paper his notes on architecture; Villard's drawings are evidence the use of drawing as a tool to study and teach architecture. Drawings on paper, and the start of printing in the second half of the 15th century, definitively lead to the distinction between the caput magister (the director of construction) and the architect, that was not forced to live aside the yard, and could move or stay in his studio, leaving his drawings as a guide for craftsmen.
In the following seven centuries the evolution of the theory of representation (Desargues, Monge, Poncelet) and the refinement of drawing instruments did not modify the connection between drawing and architecture; drawing continued to be the unique and irreplaceable tool to study, teach, and design architecture.
Villard de Honnecourt had proved that the drawings of extant buildings allowed the study of the rules of architectural design, proportions, geometrical patterns, and the like. Three centuries later, Michelangelo and Palladio visited and drew the Roman remains; the aim of their drawings was not the mere description, but the shaping of their idea of architecture, through the decoding of the architectural design of ancient monuments.

In the 18th century the birth of archeology after the discoveries of Pompei and Ercolano, along with the first travels to Greece, opened a season of studies of architecture that were based on 'tours' aiming at the discovery of the architecture of the past and at the reconstruction of the greatness of ancient sites and buildings.

The last echo of the 'Grand Tour' travels can be found in the 20th century travel carnets of Asplund, Le Corbusier, and Aalto.

The use of the camera obscura in the 18th century and the creation of photography from the second half of the 19th century did not weaken the role of drawing as the only language of architecture.

When, at the end of the past millennium, personal computers and digital representation tools became available to most architects, it seemed that the new tools would not corrupt the link between drawing and architecture: digital representation tools were mainly used to draw plans, sections and fronts, printed by plotters. In these years of transition, perspective and axonometric drawings suffered a progressive dismission: it was clear that these drawings would be substituted, in a bunch of years, by views of 3D models, but 3D modelling was still a hard task and was not so effective for the communication of a design concept, even for those architects who had learned to draw with a Personal Computer.

The years have passed and today 3D modelling has become the language of architecture; the simulation of light and materials is today commonly used to depict an architectural concept.

But the hidden structure, the 'scheme' of architectural design has almost preserved the features that recall the tradition of this discipline; many designs produced with digital representation and modeling tools can be studied and understood with drawing tools. These designs are usually developed with the aid of plans, sections and fronts and the 3D model is built for presentation purposes.

Drawing of extant buildings, or re-drawing, is still used for teaching purposes in many schools of architecture; even in those classes where digital representation is taught, students are trained to re-draw or re-model built, or simply designed, buildings. BIM representation tools have empowered the design of the construction process and have linked the shape of a building to its technical or structural components, but still they have not changed the traditional approach to architecture design.

A building designed with BIM tools can be studied with traditional or digital drawing tools.

What suggest the supposition that a time will come when drawing will not be able to support the study of architecture, is the increasing diffusion of AAD representation tools.

The origin of AAD (Algorithmic Aided Design) is usually placed in researches on 'form finding', i.e. the shape resulting as a response to strengths and loads; Gaudì at the end of the 19th century and Saarinen, Nervi, Otto and Musmeci in the second half of the past century, widely experimented this subject. In 1939 the Italian architect Luigi Moretti used, for the first time, the locution 'parametric architecture' to define his researches on shapes resulting from a mathematical calculus; the design for a 'maximum visibility' stadium is often quoted as an anticipation of AAD design.

The idea underlying digital AAD is that a shape can be generated by a sequence of instructions or simulated actions; modeling is executed through the creation of a complex scheme of switches connected by wires.

Re-modeling a shape generated by an AAD representation tool is simply impossible: i) plans, sections and fronts (when available) are of no use, since they do not direct the design process and are simply extracted from the 3D model; ii) any attempt at re-modeling an AAD model could approximate the shape, but will never exactly reproduce the sequence of switches and wires used by the modeler.

This is why AAD models cannot be studied nor exactly copied; even a laser scanning or photogrammetric survey could not lead to the generation of a perfect copy of the scheme that

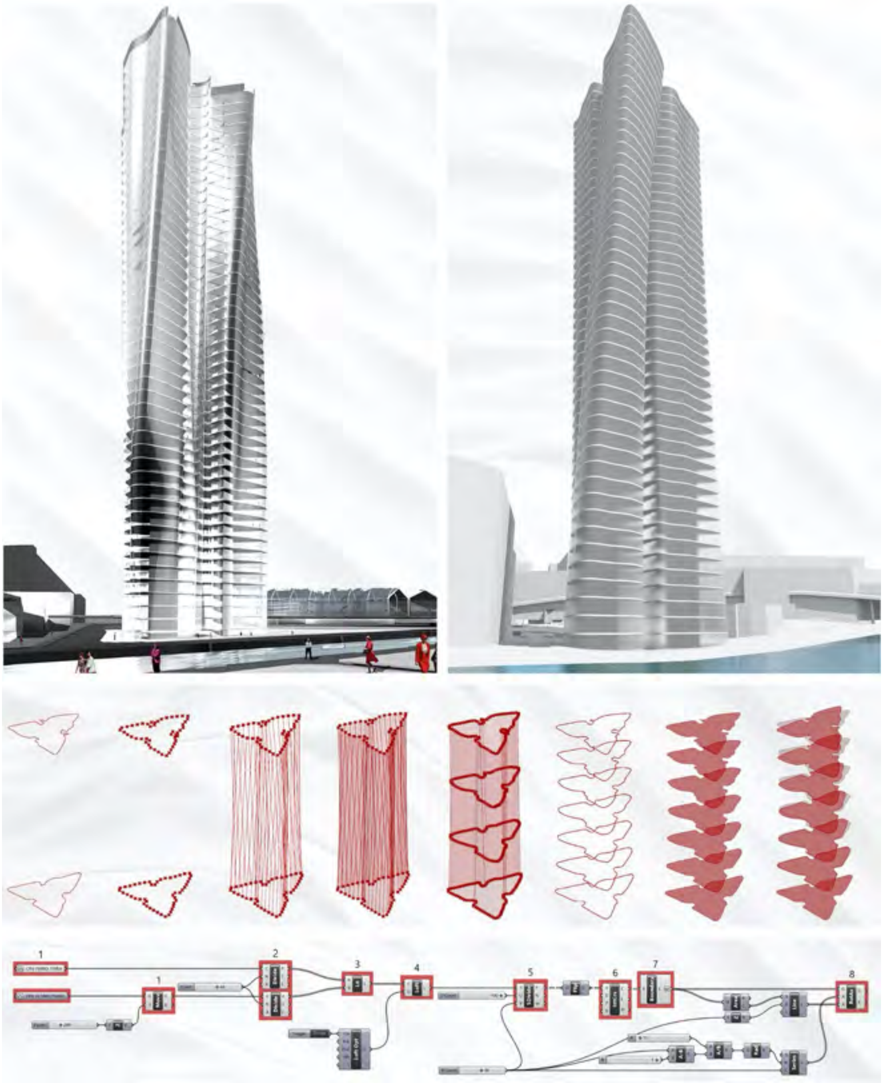

Fig. 1 - Peter Eisenmann, Progetto per la Spree Dreieck Tower a Berlino, 2000. In alto a sinistra: Vista del modello progettato da Eisenmann; in alto a destra: vista del modello ricostruito; in basso sequenza del processo di ricostruzione del modello in Grasshopper. (da Balsano M., 2019).

generated the shape.
Representation (digital representation) will probably be the core of studies in architecture for a long time to come, but which tools will our nephews use to study architecture? Will the destiny of architecture be the design of sculptural shells connected to structural, mechanical, electrical and plumbing components? If so, which future for a millenary discipline that has always been based on the relation with the past and the sites?
The proposed questions are obviously unanswered, but their relevance for the future of architecture cannot be neglected.
In the past three decades the generation of scholars that had been educated with traditional drawing tools, has, not without difficulty, kept the pace of an extremely rapid evolution of the representation tools; in a couple of decades this 'transition' generation will be substituted by digitally born researchers and teachers.Before being passed, the 'transition' generation has a relevant duty: start a long lasting reflection on the future of architecture as a science and a discipline.

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Conclusions

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CONCLUSIONS

A conference day like this is an opportunity for cultural and scientific as well as methodological and analytical exchange and growth.
The variety of topics covered, the insights and the originality of the research themes emerged from each report, exposing methodology, scientificity, innovation and seriousness in research.
The context of the Steri, as a university site, gave the conference day depth and widespread participation within university. The atmosphere of exchange and reciprocity has created the solid foundations for new relationships and new scientific relationships which, without any doubt, will lead to new themes and new horizons....precisely those horizons that research must always overcome and renew without a solution of continuity.
The questions and doubts of the listeners made the day even more interesting and full of new ideas, varied reflections and future resolutions.

The representation as a new language of expression, the representation as a new language of expression, the representation as experimentation with new techniques. Technology at the service of science and not science at the service of technology. Man as thinker and creator at whose service technology is to break down the current limits of research and find new horizons of science.

Thank you all and see you at the next appointment.

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