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3D modelling trough planar slides, from digital to physical. Experiments on Palazzo Mazzonis' atrium in Turin

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***Abstract* – In recent decades, 3D acquisition has become one of the standard methods of documenting Cultural Heritage. At the same time digital fabrication has seen a recent massive diffusion for several applications, not least the field of Cultural Heritage, being used for study, analysis, conservation or access in museum exhibitions. The paper proposes a workflow, that starts from digital survey and modelling, aims to realize a physical model of the atrium Palazzo Mazzonis, an high-representation building, today converted in the Museum of Oriental Art (MAO). The method is grounded on the use of planar sections and of the contours of intersection of planes with the 3D digital model, for creating shape abstractions.**
The ModLab Arch and the ModLab Design of the Department of Architecture and Design at Politecnico di Torino are equipped with laser cut and CNC milling machines that will allow to continue with the experimentations here proposed.

I. INTRODUCTION

The research presented in this paper starts from an international collaboration for the project "Nuevas tecnologías para el análisis y conservación del patrimonio arquitectónico", funded by the Ministry of Science, Innovation and the University of Spain. The research group, coordinated by Roberta Spallone and Marco Vitali at the Politecnico di Torino and with the participation as visiting professor of Concepción López, from Universitat Politecnica de Valencia, has implemented the research work done in recent years, about bricks-made complex vaulted systems in the Baroque buildings of Piedmont with data derived from a metric survey campaign directed by Concepción López and carried out using terrestrial laser scanning (TLS).

The integration between digital survey techniques, two and three-dimensional virtual modelling and prototyping methods leads to a new workflow, that optimize the data and can be used both for architectural scale object and for smaller ones.

In this frame, the role of ModLab Arch and ModLab Design laboratories of the Department of Architecture and Design at Politecnico di Torino, where the author of this paper is research assistant, could be interesting places of experimentation, in particular for the final step consisting in prototyping, thanks to their laser cut and CNC milling machines.

The aim of this paper is to describe the path from surveying to modelling and prototyping, trying to better understand the relationships between survey data, geometric matrices and digital/physical re-construction.

The case study presented here, the entrance hall to Palazzo Mazzonis, is one of the architectural objects recently surveyed and studied by the group and was chosen from a small number of atria that present, as will be described below, characteristics of originality in a panorama of realizations strongly characterized by compliance with well-established compositional schemes.

II. THE ROLE OF 3D SURVEY AND MODELLING IN THE VALORIZATION AND MUSEALIZATION OF THE CULTURAL HERITAGE

Before analyzing the case study it's important to provide a quick overview of the state of the art of methods of preservation and dissemination of cultural and architectural heritage. Among them it's essential to include those based on the recent technologies that have been offered to researchers since a few years. The use of electronic equipment, in fact, makes it possible to carry out some very accurate survey operations which, that do not replace traditional data acquisition procedures, but enrich them allowing the recording of high-level information content. Just think of the use of the 3D scanner which allows to acquire morphologies of great complexity (also related to "free-form" geometries), data on the surface under investigation (smoothness, roughness, etc.) and color information [1].

The "point cloud," obtained by photogrammetry or laser scanning process, can be saved and archived, returning the true state of an object in a given space–time context, avoiding physical contact with it. The so obtained three-

dimensional digital models and replicas, editable and replicable, are then used for purposes of data collection, analysis and expansion of museum offer, through the experience of physical replicas [2].

The phase of geometric acquisition and treatment can be followed by various other operations, which produce a plurality of returns. We can obtain, for example, the clean drawing of plans, elevations, sections, any architectural details, geometric analysis, volumetric studies, chromatic investigations, up to the virtual and real 3d models.

The purpose of digital and physical models is different, as they both are traditionally linked to the concept of usability of an object. They allow the user to view reality in a clear and immediate way, in particular where it is no longer directly accessible.

The most avant-garde museum institutions are beginning to recognize in modern technologies a means to add new “reading” methods to the most traditional visit paths [3,4]. In fact, museums offer more and more multi-layered and multi-sensorial experiences, which go beyond the traditional visit path. Contemporary museums place supports that allow new ways of interaction next to the artworks. Monitors, projections, physical replicas add information, but also they modify the way in which the user approaches the artwork itself. The visitors of a museum can engage personally in the cognitive process, creating knowledge themselves.

Several Italian scholars of Representation discipline have carried out very interesting and multidisciplinary research projects about 3d survey and modeling for museum exhibition purpose.

Among them it’s very inspiring the work carried out by Paolo Clini and its multidisciplinary research group in the Museo Archeologico Nazionale delle Marche in 2017. [5]

They have developed a project based on the fruition paradigm of "learning by interacting", which makes it possible to go beyond the traditional ways of presentation/observation of the heritage through display cases, stimulating the visitor to become an active viewer.

The visit has thus been enriched with a visual and multisensory experience, whose most innovative element is the installation that integrates the haptic device for tangible interaction with virtual models of some artifact.

At the same time, the three-dimensional visual investigation is supported by the Digital Library, that collects high-resolution images of some selected work.

In its totality, the project allows the direct connection between traditional information and digital "copy" of the artifact. The three-dimensional digital model allows to recall images, texts and videos and navigate between them, thus improving the learning of the contents and the cognitive experience.

Another Italian reference in this field, is the research conducted by Alberto Sdegno, at the Department of Engineering and Architecture of the University of Trieste, on some significant artworks, using most sophisticated declinations of investigation tools: from advanced modeling, to three-dimensional scanning, form 3D printing, to the interaction experiences offered by Augmented Reality technologies. [6]

These examples represent a point of reference for this research, they offer didactically 'interactive' paths, through the integration of different representation tools, giving space to tactile explorative moments.

III. PALAZZO MAZZONIS: ORIGINS AND TRANSFORMATIONS

Palazzo Mazzonis (originally named Solaro della Chiusa) has been from the beginning a representation building for residential use, privately owned. It is the result of a transformation of a pre-existing building (1639) and of subsequent works, wanted by Francesco Amedeo Ludovico Solaro della Chiusa and completed in 1735. This intervention has been traditionally attributed to Benedetto Alfieri, as written by Luigi Cibrario [7], even if archive documents never explicitly mention him.

During the 18th century, after various interventions, the building assumed the current shape. It is constituted by a central part, along via San Domenico, and other two parts embracing the central inner courtyard, linked to the road by a great colonnaded atrium.

Augusto Cavallari Murat, in *Forma urbana e architettura barocca* [7] underlined the consistency of the structure of the palace with the model of the majority of Turin noble palaces of 17h and 18th century. They were set following axial schemes that gave importance to the inner courtyard, visible in perspective through the atrium.

The only decorated element of the building is its façade, characterized by a portal [8].

The great atrium, adorned by an elegant stone colonnade, is connected by a sumptuous two flights staircase with stone balustrade to the hall of honor at the first floor. The central part of the building at the first floor has maintained the original architectural character, the rooms at the upper floors and in the lateral wings have undergone heavy modifications.

Over the centuries the palace passed into the hands of several owners, as can be seen in the decorative apparatus.

In 1830, it passed to Earl Clemente Solaro della Margherita, who commissioned, in 1845 (fig.3), the survey of the building (now preserved in the Historical Archive of the City), from which emerges a layout very similar to the one previous to the restoration works of 1982.

In 1870 the building was sold to a textile industrialist, Paolo Mazzonis and the ground floor was converted into the offices of the Manifattura Mazzonis S.n.c.

In 1910 was recognized the historical value of the building. In 1968 the company stopped its activity and the - building remained unused.

In 1980 the ownership of the building passed to the City of Turin and in 1982 underwent restoration works designed

by architect Andrea Bruno and subsequently used as the headquarter of the judicial offices until their transfer to the new Palace of Justice in 2001.

From 2004 it has been transformed into the Museum of Oriental Art (MAO), the interiors preserve only partially the original decoration [9].

The final project for the construction, constitution and exhibition of the Museum was developed by the Cultural Buildings Sector with the direction of the architect Andrea Bruno [8,9].

IV. THE ATRIUM: FROM SURVEY TO GEOMETRICAL ANALYSIS THROUGH MAIN SECTIONS

The atrium is characterized by two main areas, divided by architraved pillars, associated with columns. The part near the entrance from the street is covered by rectangular base sailing vault intersected with a barrel vault, set on the transverse axis and corner sailing vaults (fig. 1). The space facing the courtyard has three aisles covered by a central sail vault and two lateral groin vaults (fig.2) [10].

Fig. 1. Palazzo Mazzonis: vaulted system of the atrium near the entrance. Photo by F. Ronco.

Fig. 2. Palazzo Mazzonis: vaulted system of the atrium near the courtyard. Photo by F. Ronco.

If we consider the descriptive geometry as Migliari states [11], as "the gymnasium of the space conception", or "science that combines the abstract thinking with the synthetic verification of the intuitions elaborated by thought, carried out through the image", we can also ideally approach the act of "representing" with the action of "building" forms in space regardless of the instrument used.

The architectural "construction" and the geometric "re-construction" is the interpretative key used in the work.

The analysis and interpretation of the intrados surfaces of the vaults studied starts from this explicit geometric approach that aims to reconstruct the spatial patterns at the basis of the design thinking, the decorative apparatus and any constructive imperfections are excluded from this analysis.

The geometric interpretation method has been suggested by Palazzo Mazzonis archive drawings and supported by on site eidotypes and the digital reconstruction built on laser scan 3D point cloud.

The work methodology used in Palazzo Mazzonis has been based on obtaining graphic representations using terrestrial laser scanner Focus 130 x 3D model of the Faro. The registration of point clouds has been carried out with the Lighthouse Scene 19 program.

The point cloud has been imported in AutoCAD®. Here the process of interpretation starts: the quasi-continuity of the detected data is discretized into a series of lines, proceeding to a rigorous two-dimensional graphic representation of the real state of the vaults in a first step and in a second step to its geometric ideal drawing.

The plan and sections are drawn tracing horizontal and vertical intersections between the point cloud and cutting plans (fig.3).

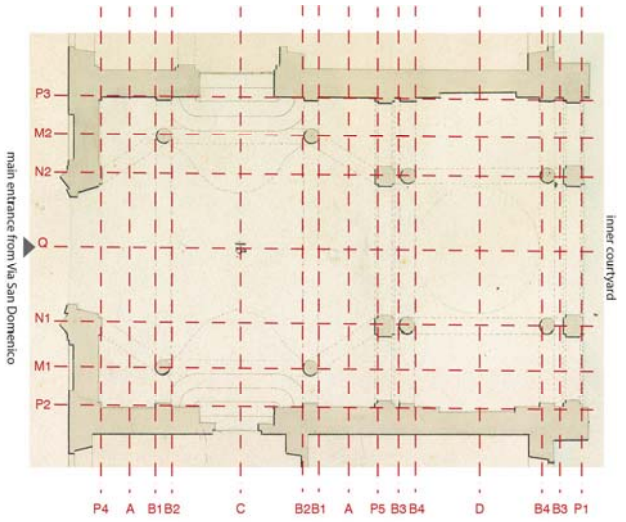

Fig. 3. Palazzo Mazzonis: Excerpt of the survey drawing of Palazzo Mazzonis, 1st July 1845. Source: Archivio Storico del Comune di Torino, Tipi e dis., cart. 63, fasc. 9, dis. 1, tav III. Graphic processing by F. Ronco.

Their position was decided thinking about their relevance to describe, in a simplified way, the intrados surfaces. Sections along main longitudinal and transversal axis were carried out, together with sections in correspondence of the supports and along perimeter walls.

V. FROM GEOMETRICAL ANALYSIS TO 3D PHYSICAL MODELLING

Once all the distinctive sections of each surface have been defined (fig.4), an interpretative model has been created using the Rhinoceros® software using classic three-dimensional modeling tools. The following steps have been the creation of section planes and the consequent contours of intersection of planes with the 3D digital model (fig.5).

The final aim of the proposed case study is to create a physical model morphologically similar to the object acquired, transforming the above mentioned sections in real tangible slices of a conceptual model that capture the overall structure of the atrium shape. Sections are therefore the key instrument both for virtual and physical modelling, discretizing the intrados surface of the vaulted system through its main curves.

A few years ago, radically new steps for shape fabrication were done in this direction. The main idea was to drastically simplify the overall prototyping procedure by fabricating a plausible representation of the digital model, instead of its exact copy. This class of methods, called “illustratives”, are based on a simple concept: approximating an object does not necessarily lead to a visual or comprehension deficit.

The idea is to use mesh joinery approach [9] to fabricate illustrative shape approximations made up of several interlocked planar pieces.

Such slices have been fabricated at a scale of 1:50, using the 2D cutting device of ModLab Arch Laboratory (Totrec Speedy 400®) of Politecnico di Torino, employing relatively inexpensive material (such as cardboard) and then assembled through a sequence of manual operations.

The digital fabrication process has involved the realization of the base, that corresponds at the impost plane, where a series of pockets are realized to fix the longitudinal and transversal sections, giving them more solidity (fig. 6,8,9,10).

The base and sections have been realized respectively with 4 mm and 2 mm natural cardboard, the whole process has lasted 7 min.

The observing of the laser cut processing discarded parts (fig. 7) brings also to an interesting consideration. Another schematic model could be realized changing the solids and voids, allowing the user to experience directly from above the intrados section line.

This work is a first experimental step in the direction of a more complex work related to the doctoral thesis of the author (Arquitectura, Edificación, Urbanística y Paisaje program of Universidad Politècnica de València) that aims to rise the accessibility of the MAO, through building a multisensory expositive path. This path could include tactile models of architectural spaces and part of the museum collection and informative panels to support them.

The making process has been currently focused on the vaulted system, the next step could be the realization of the whole space, including the underlying colonnade space. The nature of this space suggests the use of mixed fabrication techniques. In particular, the columns could be realized by 3d printing process, added to the rest of 3d cut model.

This work, despite its simplicity and experimental nature, could be useful to bring the user closer to architecture, making him/her understand its geometrical matrices and generative process. For a more permanent use, obviously, it will be necessary to realize the model with more strong and lasting material, like plexiglass.

This tactile experience could be particularly useful for didactic purposes focused on vaulted systems. However, the manual mounting, can become part of the experience and entertainment for the final purchaser of the prototype.

Fig. 4. Palazzo Mazzonis Atrium: Orthophoto of the longitudinal section. Scanning by C. López, processing by F. Natta

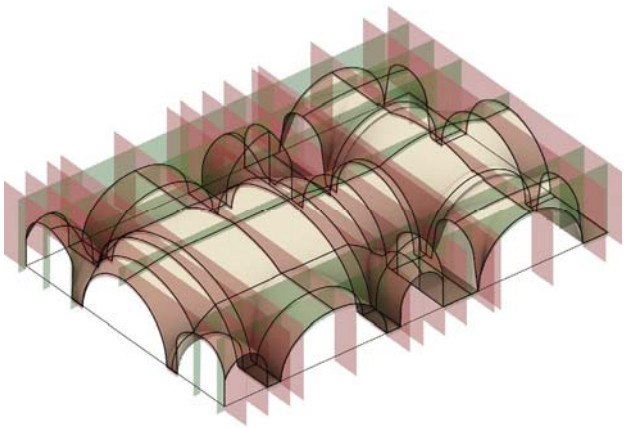

Fig. 5. Palazzo Mazzonis Atrium: axonometry of virtual model elaborated starting from the point cloud, section plans and intersection lines. 3d modelling and graphic processing by F.Ronco

VI. CONCLUSIONS

Fabrication of digital objects has found a considerable interest by researchers in computer graphics and geometry processing. This field shows an interesting potential for the specific needs of CH applications.

Touch and manipulation of objects, physical or virtual, offers the advantages of creating a stronger connection than mere sight, between the individual and the object.
In the wake of these theories, museums are devoting particular attention to "touch." Because it presents risks to their preservation, touching the objects in museums has typically not been allowed [13].

Particular attention has been given to haptic senses, through the creation of touchable exhibition, and handling sessions that enable the user to personally interact with the object they are looking at.

Depending on the final aim of the model a different level of accuracy is required. A variety of technologies allows to create physical reproductions of 3D digital models with a great precision at low costs. 3D printers and subtractive techniques, performed with CNC milling machines, are the most commonly used machines to produce accurate physical objects. Although current digital fabrication technologies still have limitations, the accuracy of the reproduction has reached an excellent level of quality [14].

Beyond accuracy, other issues still need to be addressed as standardisation and the definition of guidelines to decide which technology and which material best suit a specific application and to help users preparing the digital 3D model before fabrication [15].

The proposed approach provides limited but low-cost solutions due to the simple cutting technologies employed and the relatively inexpensive material used. Although the proposed slices structure approximates, to some extent, the original geometry, it cannot be considered as a "physical copy". Nevertheless, this can be more attractive in specific markets, such as in artistic, illustrative contexts or didactic field where assembly is a key part of user experience, even in museum context.

The use of mixed representation techniques and technologies, as shown in the 2nd paragraph, could be the evolution of this work. Some applications could be simple images overlapping between real and virtual model or more advanced augmented reality experiences that link, for example, a real exploration of the maquette with the virtual point cloud model.

Recent studies, indeed, have demonstrated that this approach represents an easier way for people to learn and experience reality [16], becoming practically compulsory when objects are used for didactic purposes, in addition, tactile models allow access to blind and partially sighted people. Laser scanning and rapid prototyping offer great opportunities to bring back tactile experiences in our cultural heritage, extending accessibility in a "Design for All" perspective, a context where all people benefit from these improvements.

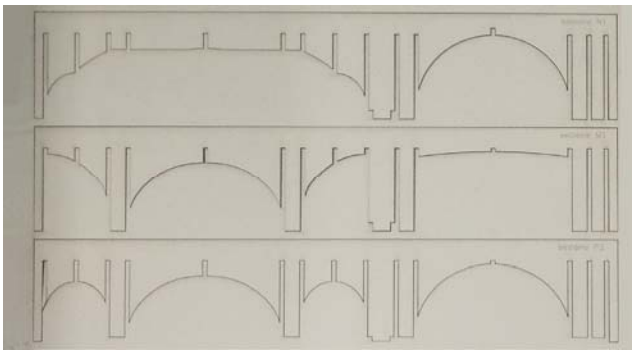

Fig. 6. Palazzo Mazzonis Atrium: example of sections realized with laser cut printer on natural cardboard. Modelling and processing by F.Ronco

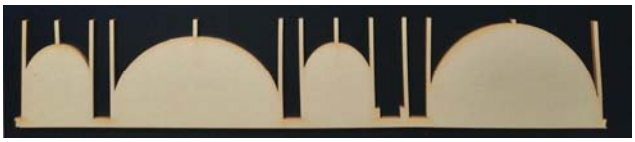

Fig. 7. Palazzo Mazzonis Atrium: example of waste of a cut section

Fig. 8. Palazzo Mazzonis Atrium: maquette mounting process, joint between transversal sections and the plan

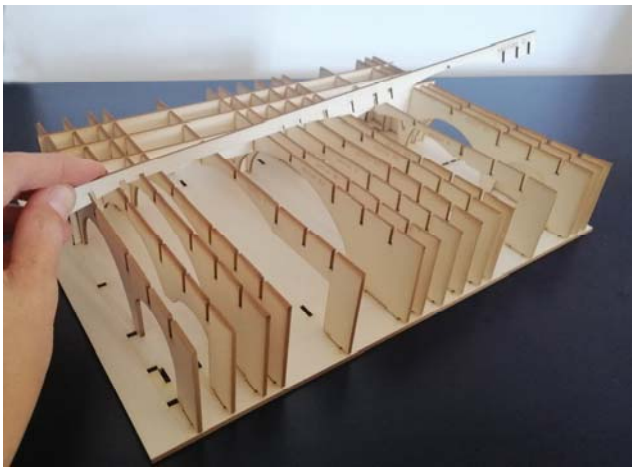

Fig. 9. Palazzo Mazzonis Atrium: maquette mounting process, joint between transversal and longitudinal sections

Fig. 10. Palazzo Mazzonis Atrium: mounted maquette, inner views

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