Towards a Computerized Physical Architectural Model

Aldo Rossi and the Theatre of the World

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Introduction

The growing interest on digital technologies let Virtual Reality (VR) and Augmented Reality (AR) become tools widely used for the conservation, representation and dissemination of Cultural Heritage (Bekele and Champion, 2019, p. 1). Over the last years, museums and cultural institutions offers to visitors a combination of historical and artistic heritage material objects and digital/non-physical contents: heritage is made available through the integration of multiple interactive and multimedia experiences in order to stimulate involvement and improve user learning. On the assumption that the architectural model is to be considered a cultural heritage, this contribution intends to examine and explore his expressive and communicative potentials in the light of the aforementioned interactive digital new technologies. The first part of the study presents an overview of the solutions already integrating physical models and digital technologies. The second part describes the conceptual and practical work ongoing on architecture models at the Architecture Models Laboratory (LMA) with the collaboration of the Extended Realities Laboratory (LXR) at the Architecture Department of the University of Florence, taking as an example the model of Teatro del Mondo by Aldo Rossi.

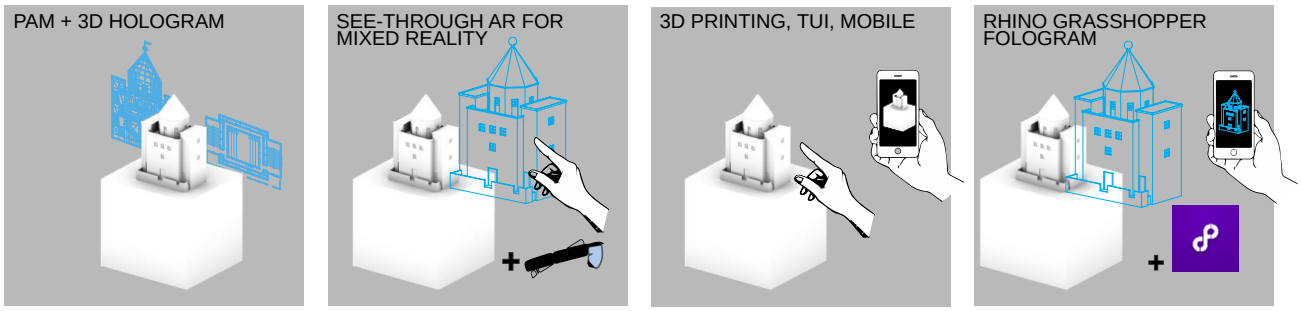

Fig. 1. Graphical summary of possible interactions between PhAM and digital contents

The Material and the Imaginary: on Mixed Reality and Physical Architectural Model

The physical model displays the three spatial dimensions simultaneously: as an abstract and simplified representation, it shows otherwise unintelligible concepts and principles to the eye. In relation to the new dematerialized scenarios offered by digital technologies, in order not to lose the object value of the physical architectural model (PhAM), a question is here proposed: is there an interface that allows integrating the imaginary, the virtual reality of the immersive experience with the physical reality of the material model? What are the experiences carried out until now and which are the possible developments?

To answer these questions, the research was carried out by examining scientific publications and articles in specialized online journals and consider the exhibition methods of some museums or architecture events. The possibility to integrate physical model with digital contents is not a new topic. Contributions to this purpose come from different fields of studies and have been applied with more or less success to the architectural model since the end of the Nineties (Milanovic et al., 2017).

Thanks to this overview, different modes and levels of interaction can be identified: from technologies which only allow remote observation or others requiring the use of a personal device and a simple application, to systems providing the ability to interact with the physical object (usually replicas) through touch. Interactions and augmented experiences with PhAM can occur even through a system application specially designed for that object (Fig. 1, Table 1).

The more complex and articulated interactions are possible thanks to Mixed Reality systems; the use of devices such as AR reading glasses, makes the surrounding reality added with digital and sometimes dynamic objects, also reactive to certain gestures. This interaction mode was tested by Greg Lynn (2016) during the Venice Biennale, enabling him to propose to visitors a way of acting on the PM by recalling information through gestures and viewing them through the device provided, i.e. Trimble Connect with Hololens. The Arctron 3D Company (2020) offers combined solutions of VR and AR experience and also of the use of hologram display systems combined with historical models or miniatures of artworks. As part of the teaching about urban and architectural design, the interaction between digital and physical has given rise to a prototype that allows the manipulation of physical objects printed with conductive materials and the consequent visualization on tablets or smartphones of the volumes modified by acting on objects (Narazani et al., 2019). Compliant with the use of Rhinoceros and Grasshopper, Fologram (2020) is an AR software to be used with Hololens or directly via tablets and smartphones. It generates contents from superimposing physical reality through AR. In his interesting work and experimentations, Nofal (2019) examined how tangible interaction can be used on physical models, to enable the communication of qualitative information about a built heritage. In Table n.1 these systems are summarized and briefly described.

Table 1. General overview on systems which combines PhAM and digital contents.

System	Short Description
PhAM + Hologram	The historical PhAM stands inside a glass box, contents are displayed aside the model and only remote observation is allowed.
PhAM + Qr code	Insertion of a Qr code in the PhAM, referring to multimedia contents regarding the original project and the model itself.
Image recognition App	Image recognition APP of the model by scanning and obtaining information found on the internet.

Rhino + Fologram (AR)	Through Fologram, an Augmented Reality APP, holdin a smartphone or a tablet, 3D models created with Rhinoceros CAD can be superimposed in the space surrounding the model and the user.
See through AR	Wearing an HMD the user can see the real world with computer-generated information superimposed on top and interact with gestures.
3d printing TUI	Combining a mobile, an app and 3d printed tangible objects (made with conductive materials or other techniques) it is possible to create a virtual model involving the visitor in a personal interaction with the model.
Phygital Heritage	In his PhD thesis, Nofal (2019) presents the original approach of *"Phygital Heritage*", intending to disclose heritage information via simultaneous and integrated physical and digital means. The four studies conducted are examples of the interaction technologies systems to connect physical and digital experience: a tangible interactive museum prototype, an augmented reality experience, an in-situ interactive projection mapping, a tangible gamification installation.
Projection Augmented Model	A physical three-dimensional model, touchable, onto which a computer image is projected to create a realistic looking object or to visualize other information

Aldo Rossi and the Theatre of the World: Model Making

The physical architectural model, as a synthetic representation, has been used for centuries to facilitate the understanding of objects that are complex or dimensionally too large to be understood in their entirety. Unlike the digital 3D model, the PM is capable of establishing a lasting and stable cognitive relationship with the one who looks at it. But is this very materiality of the PM that makes it impossible to obtain a series of information. In the PM, matter, context, construction often remain in a state of generic analogical simulation. If, thanks to the immateriality of digital elaborations, the shape of the space acquires further possibilities, its description must be subject to the rules of construction: first of all, the reproduction scale dictates the conscious omission of a series of information in favour of a better overall readability of the project. Attempts to overcome this limit have generated historical examples, first among which are the sixteenth gargantuan models for St. Peter's Basilica in Rome. The AR lays the foundations for a possible overcoming of this limit, giving the possibility of integrating information relating to the material to the construction systems in a small size model, to insert it into the context without the need to create large models such as that of the 'basilica that is not there' of San Gallo (Zander, 2018, p. 4). The proposed example, Aldo Rossi's Theatre of the World, was selected because, similarly to the Sangallo cathedral, it 'does not exist'. Designed and built by Aldo Rossi for the 1980 Venice Biennale, it was dismantled the year following its inauguration, at the end of his legendary journey across the Adriatic. The small architecture was then rebuilt in 2004 in Genoa, only to be dismantled again. Its physical figuration through the material model was conceived precisely for this ephemeral characteristic, for its absence: it almost expresses the need for a simulacrum, capable of recalling the photographic images of his first appearance, which proposed him as a specular abstraction of the customs point to which it was anchored.

The realization of the PM of this little architecture imposes particular difficulties: if externally the metaphysical volumes of which it is composed are easily achievable with multiple technologies (from 3D printing to the more traditional woodworking), the internal construction system consists of an intricate mesh of thin tubular, whose scale representation would undergo such a resizing as to invalidate a correct description of the work (see Fig. 5).

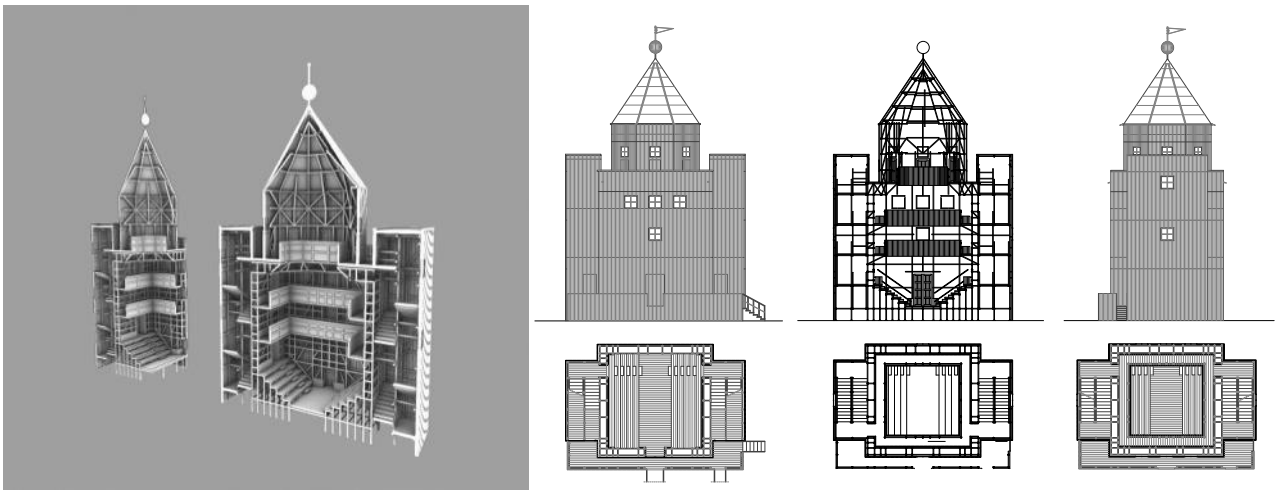

Fig. 2. 2D drawing and 3D modelling in Rhino by Enrico Pupi.

Reconstructed on the drawings published by Francesco Fera (2009, pp. 128–137), the original 2D drawings were reproduced and subsequently 3D modelling was carried out through the use of McNeel Rhinoceros and Grasshopper (see Fig. 2). In this popular plugin based on a visual programming language and environment, a specific script capable of controlling the size of the tubular section of the internal structure has been created, in order to adapt them to the 3D printing types and to the various scales of representation. It has been noted, however, that even using techniques such as laser sintering, capable of a high level of detail, it is not possible to achieve a perceptually correct conjugation between the section of the structure and the size of the architecture that contains it (Fig. 3).

In order to represent the structure, it was decided to start an evaluation on the possible interactions with the AR, to verify if and how the conjugation between the two technologies may fill this gap. The system chosen for the initial experimentation was QR code insertion on the PM of Teatro del Mondo.

By framing the code, it is possible to gain access to a public Drive folder containing information about the project and the model, also coming from the studies conducted by Enrico Pupi during his internship at the Architectural Models Lab: 2D drawings, 3D models for 3D printings, references, more graphic information, a specific bibliography etc.

a *b* *c*

Fig. 3. 3D print of Teatro del Mondo, material: white PLA, printer: Raise

The purpose to distribute the results of the many internship courses carried out within the DidaLabs Laboratory System is thus made possible thanks to the current digital resources, accessible from

the major online platforms, disposing a link with specific resources and reachable by everyone in an easy manner.

The 3D CAD material obtained from the internship was necessarily reworked thanks to Ylenia Ricci from the Extended Reality Lab (LXR) for the production of virtual contents via Cinema 4D and Unreal (Verdiani et al., 2020, see Fig. 4–6). This virtual content has been added to the public Drive folder and can also be experienced with immersive Head Mounted devices.

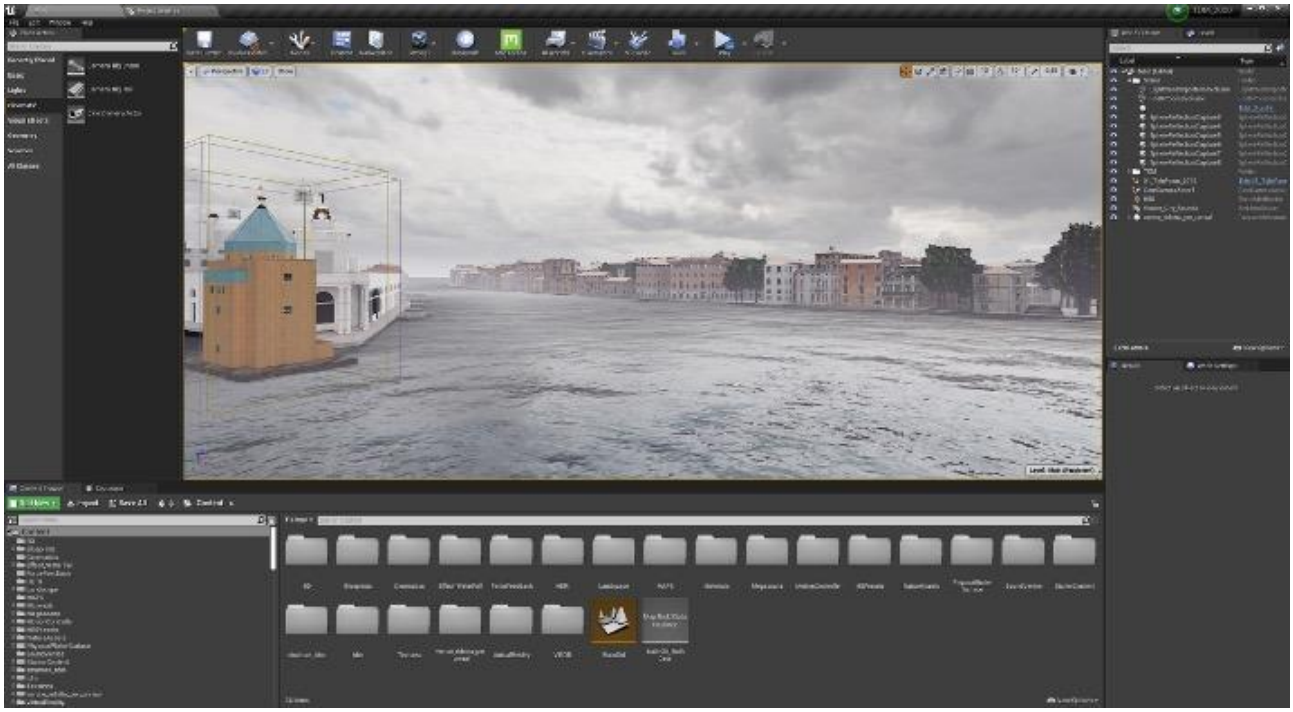

Fig. 4. A screenshot from the working configuration in Unreal Engine, Image by Ylenia Ricci (LXR Dildalabs).

Conclusions and perspectives

Thinking about some practical uses of the above-mentioned systems in model making techniques, it can be hypothesized to use AR systems such Fologram with Hololens as an aid in visualizing the PM before its construction, and as a guide to its construction. In the exhibition context, it could be used to understand the construction of the model but also to give information on the project.

The Smithsonian Institution Digitization Program Office focuses on developing solutions to further the Smithsonian's mission of "the Increase and diffusion of knowledge" through the use of three-dimensional capture technology, analysis tools, and distribution platform. Thanks to this program through the online museum platform, various digital 3D models are made available free of charge in various formats, for viewing only or even for printing. Taking as an example the experience of the Smithsonian, we could hypothesize to apply this process to architecture. To facilitate and spread the physical and tangible experience with the architectural model, it can be suggested to set an online platform where offer free access to 3D architectural models, printable by schools or for personal use, to physically interact with: the possibility of fixing a personalized point of view on the scaled object is what makes the PhAM unique and indispensable. In addition, having a material object could act as a bridge between a visit to the museum and an online digital experience, which could be applied also to PM, not only to cultural heritage objects as replicas (Petrelli et al., 2017).

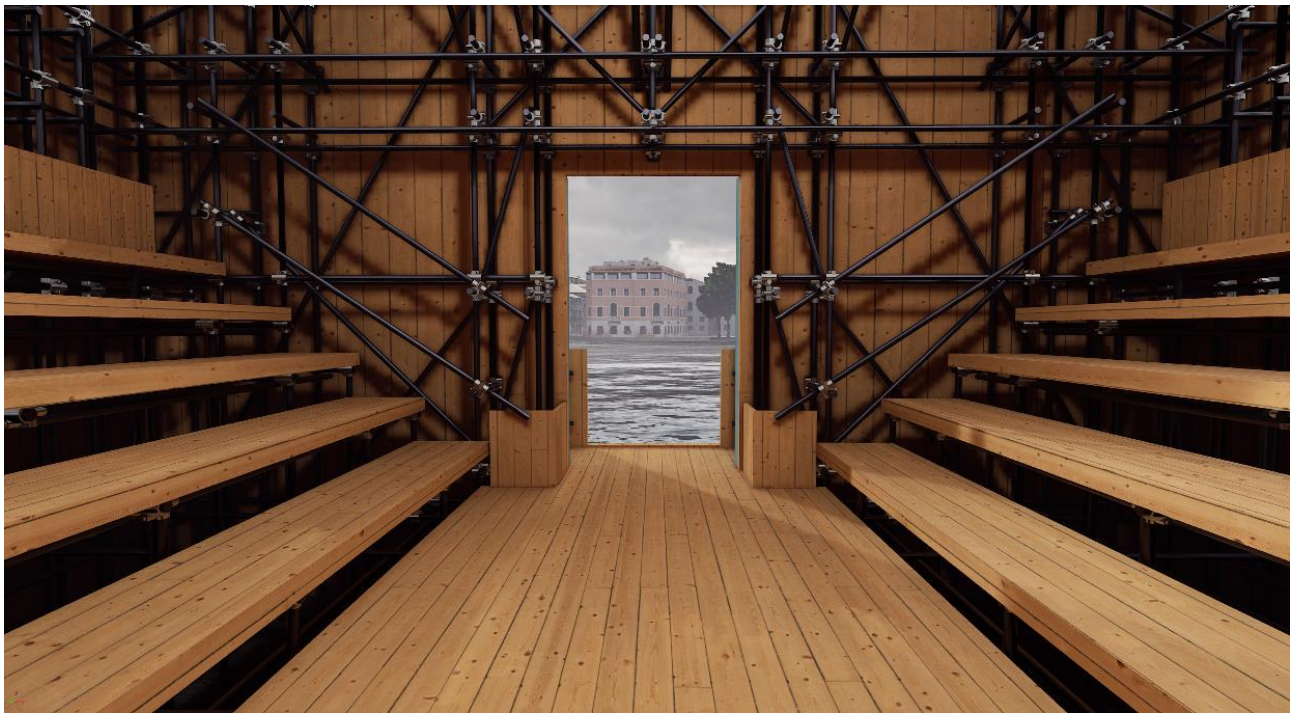

Fig. 5. Possible contents: a view of the interior structure of the Theatre, Image by Ylenia Ricci (LXR Dildalabs).

The latest development of this ongoing research led to testing the model itself as a marker: the physical model printed in 3D FDM was scanned and subsequently processed on Arkit for iOs and XCode, version Reality Composer. The use of AI for image recognition and the integration of search systems within the major platforms allows the use of the physical model as a link. Not only through the insertion of specific QR codes but also through its clear aesthetic identification. In this way, through the physical model, an interaction is activated that allows the user both to manipulate the digital version of the model and to reach detailed contents on the project.

The current high availability of online applications, devices and platforms for sharing digital 3D models, combined with the increasing deployment of rapid prototyping technologies, could be a further boost to the development of new augmented architectural models and new interaction modes.

Fig. 6. Possible contents: The Theatre and the Venice Lagoon, by Ylenia Ricci (LXR Dildalabs).

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