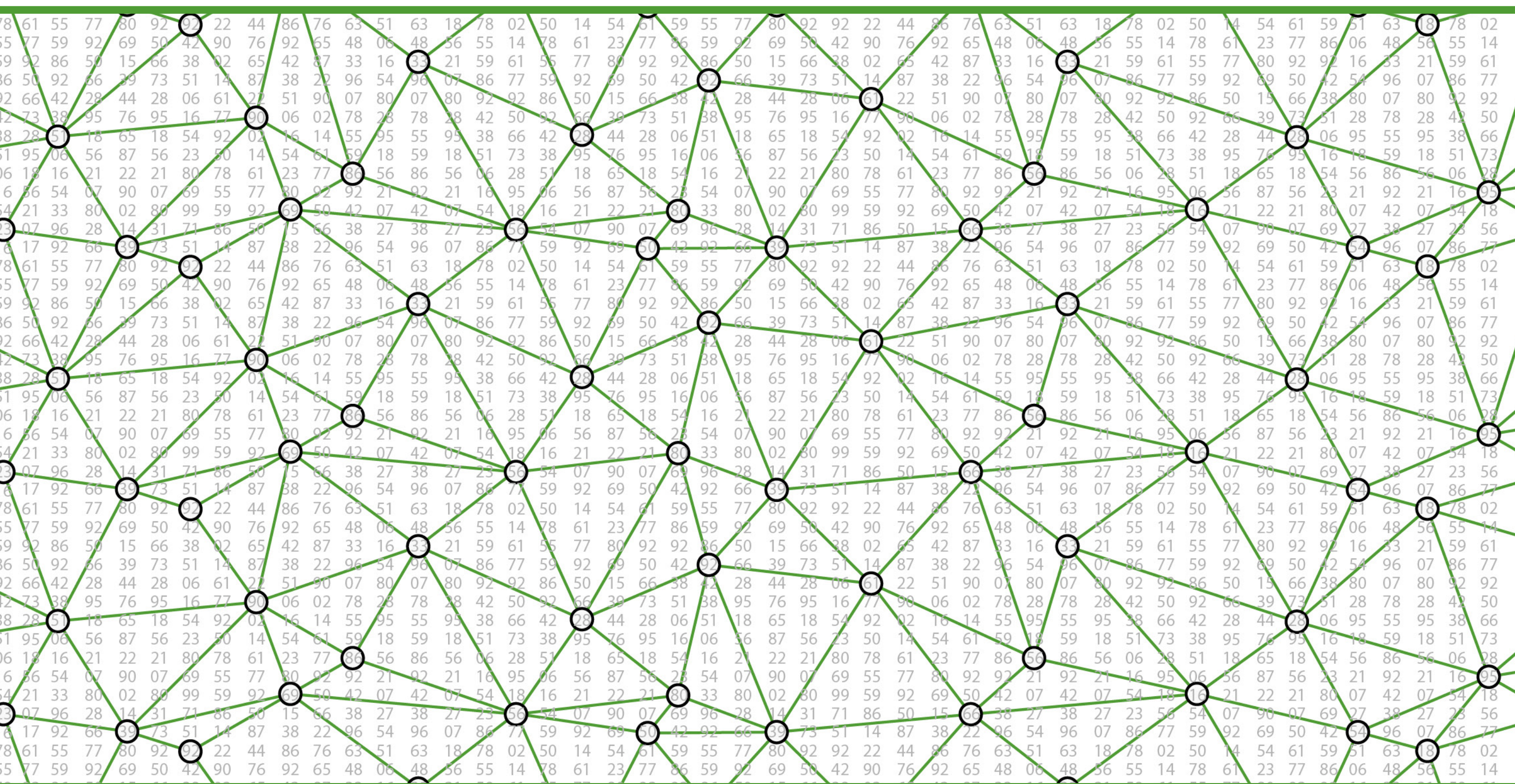
Architectural Maquette. From Digital Fabrication to AR Experiences

REPRESENTATION CHALLENGES
New Frontiers of AR and AI Research for Cultural Heritage and Innovative Design

edited by

Andrea Giordano
Michele Russo
Roberta Spallone



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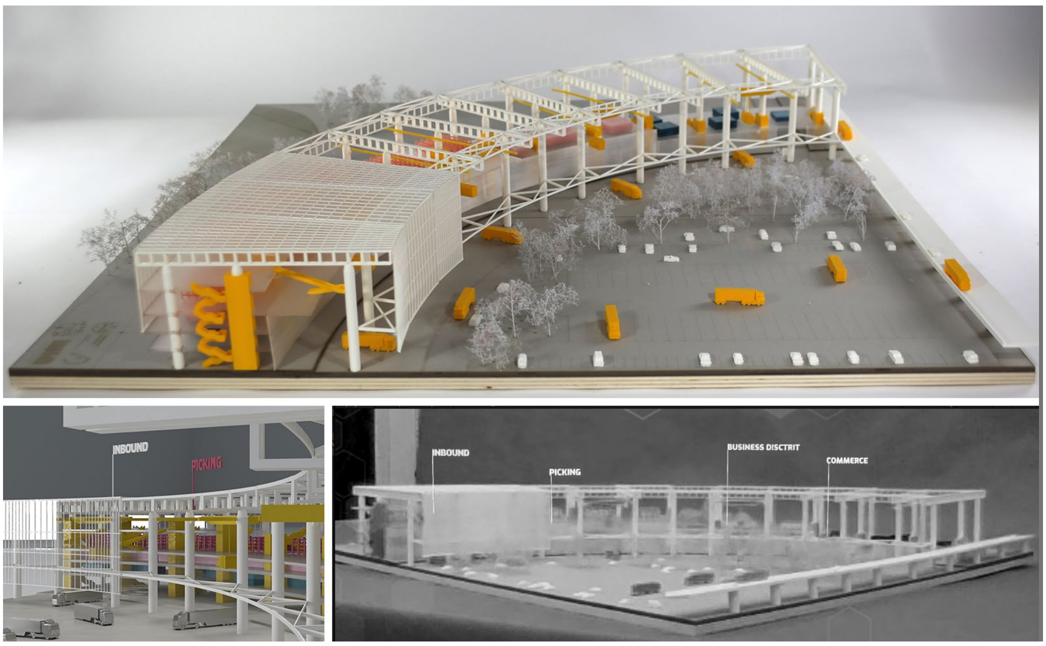
Architectural Maquette. From Digital Fabrication to AR Experiences

Giulia Bertola
Alessandro Capalbo
Edoardo Bruno
Michele Bonino

Abstract

With this paper, the authors want to reflect on how, in the age of the immaterial, a plastic model is a tool still current in the representation and able to connect with the new digital tools of augmented reality (AR). In this context, we would like to present a practical case concerning the realization of two static scale models, realized through Digital Fabrication technologies, aiming to increase the accessibility to knowledge about the architectural project in an exhibition context.
The final goal of this work is to develop a methodology that allows the user to obtain information about the architectural project not only through the real model but also through static and dynamic virtual models overlaid using the current AR technologies. In particular, the following tools were used for tracking: Unity®, a multiplatform graphics engine, and Vuforia®, an augmented reality software development kit.

Keywords
3D modelling, maquette, augmented reality, digital fabrication, multimedia.



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AR Technology for the Enhancement of Architectural Maquettes

This paper reflects on how the narrative of architectural design today requires an increasingly interdisciplinary approach supported using of virtual tools for the simulation of architectural and urban space and by digital fabrication technologies for the construction of physical models. Architectural model is a tool that is still current in the field of representation [Sardo 2004, p. 195] and can be integrated with the new digital tools of AR (Augmented Reality) and AI (Artificial Intelligence).
In particular, the link between maquette, AR and AI is currently articulated along two main lines of research. The first is based on the construction of real information models, the second on 'human-material' interaction through the practices of 'augmented craftsmanship' and 'design by making' [Vitali 2021, p. 62].
The maquette can be considered as a narrative artifact to anchor information and create different levels of interactivity and immersion. The authors propose an approach between amusement and edutainment that aims to convey and understand contemporary architectural design [Meschini 2016, p. 4].
The authors intend to present a practical case focused on the construction of multimedia content and its visualization using AR technologies by anchoring it directly to the maquette. The reference project is a circular logistics center characterized by vertical operation, developed after Politecnico di Torino won the third prize in the international urban design competition "Future *Shanshui* City Dwellings in *Lishui* Mountains" in October 2020. Following the competition, the ModLabArch laboratory, where one of the authors is a research fellow, proposed to create a 1:200 scale model to be exhibited in the *Lishui* Exhibition Centre.
The aim of the research is to reflect on how the new scenarios of craft 2.0 extend and intertwine with the more established universes of design and architecture, and how the practices, processes and methods of project communication are currently changing [Micelli 2016, p. 5]. This process is also happening thanks to the continuing trend of placing new digital technologies alongside more traditional techniques. [Pone 2017, p. 9]
In this case, the maquette is a narrating artefact on which information can be anchored, thus generating different levels of interactivity and immersiveness and proposing an approach between amusement and edutaimnent aimed at communicating and understanding the contemporary architectural project. [Meschini 2016, p. 4]
In the following paragraphs, a methodology will be exposed that allows the user to learn information regarding the architectural project not only through the real model but also through static and dynamic virtual models superimposed on it through current AR technologies.

AR and Architectural and Urban Maquette: the State of the Art

The features and benefits of using physical models in architecture are numerous and well known, while the potential of augmented reality applied to real models is still being explored and developed. Although AR can no longer be considered a novelty, its applications in architecture and the possibilities it opens for representing the architectural and urban environment need to be further explored.
The fusion of physical and digital models creates a powerful tool that can represent the static built environment in a physical, tactile, and three-dimensional way, while allowing the visualisation of dynamic elements such as shadow projections, people and objects in motion, text objects, etc. [Piga 2017, p. 104].
When talking about the interaction between real model and digital model, TUIs – Tangible User Interfaces – are often referred to. A first example is the Luminous Table of the Fausto Curti Urban Simulation Laboratory (LabSimUrb) of the Department of Architecture and Urbanism of the Politecnico di Milano made in 2010. It allows simulating dynamic environmental conditions based on a physical model [LabSimUrb 2010]. Altri esempi sono the In-Form and CityScope projects, each one interactive simulation tools for urban planning aimed at increasing public involvement [Follmer 2013].

In terms of augmented reality applications, reference can be made to the plastic model at Apple Park in Cupertino, in the heart of Silicon Valley (2017), where visitors to the center can see a virtual version of the campus overlaid on the metal model in front of them by using an IPad. They can change the time of day to see how the massive glass structures look when hit by the morning sun. They can also tap on any building to get a small view of the interiors and see how solar energy is collected by cells on the roofs of the buildings and how air moves through the buildings [Cupertino ApplePark 2017].
In the Italian context, we can refer to the monographic exhibition Tex Willer and the project AR, developed by Josef Grunig. A project in which the tracking of the physical model is done through an image and with Apple's ARKit technology, requiring an initial scanning with an iPad, keeping the lighting conditions at the exhibition site constant and not changing during the exhibition day [Tex-70 Years of a Myth 2018] (Fig. 1).

The Case Study: the Logistic Hub of Lishui

The activity presented here started after Politecnico di Torino was awarded the third prize of the "Future *Shanshui* City Dwellings in *Lishui* Mountains International Urban Design Competition" in October 2020.
It is a project developed by 44 teachers, researchers, Ph.D. students, and undergraduates belonging to the research groups of the China Room (DAD and DIST) and the Institute of Mountain Architecture of DAD.

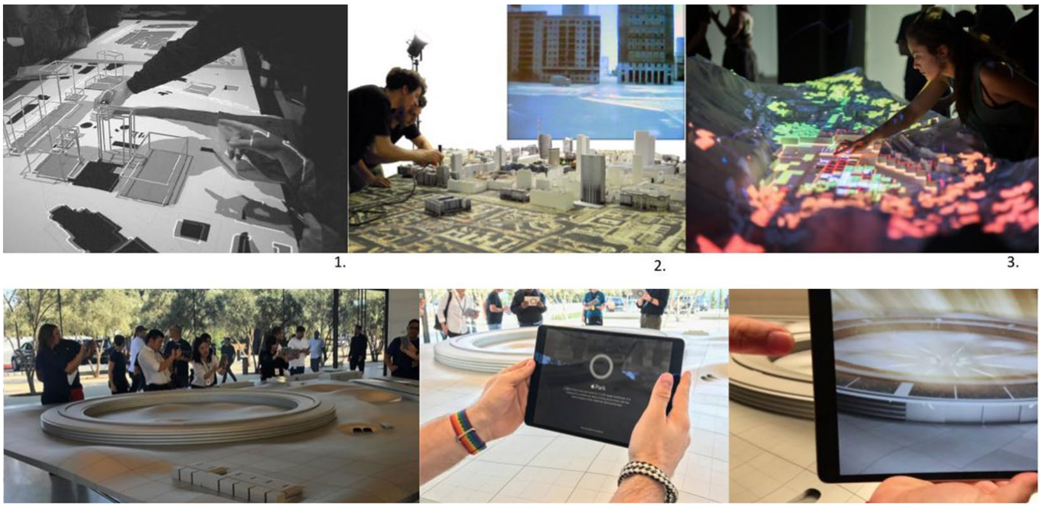

Fig. 1. Luminous Planning Table (LPT), Massachusetts Institute of Technology (MIT), 2000; Luminous Table, Laboratorio di Simulazione Urbana Fausto Curti, Politecnico di Milano, 2010 CityScope, City Science Group del Media Laboratory – Massachusetts Institute of Technology (MIT), 2015; Apple Park, Cupertino, California, 2017.

The work focuses on the *Lishui* Plain, the only plain in southern *Zhejiang*. This area is an important resource for both ecology and agricultural production.
The goal of the master plan was to protect this area and its production by focusing on three project areas: the valley, the housing developments, and the ecological system. Areas that must adapt to the existing city and its main mobility infrastructure without compromising the ecological integrity of the mountains.
The result is a new urban area that shifts its core from the old city to a large central agricultural park designed as a highly specialized and technological platform for production, research, and leisure.
Following the competition, the ModLabArch laboratory proposed to make two 1:200 scale models of two buildings representative of the project to be exhibited in the *Lishui* Exhibition Centre.
The building that is the subject of this case study is a circular logistics center with an area of 192,000 sq.m., located at the crossroads between the air freight system and the road transport system that crosses the valley.

The shape and height of the building are modeled on an air freight system: plants are delivered via cable cars on the upper floor and gradually descend to the lower floors during the various stages of processing until they arrive at the first floor, where they are loaded onto trucks and shipped.
The building has four floors above ground and is organized vertically: the goods coming from the cable cars are deposited in the entrance area, a space dedicated to receiving the goods, unpacking them, and placing them on the conveyors for access to the lower floor; the picking area, where the sorting, storage, and loading of the goods onto containers takes place with the help of overhead cranes; the business district; the commercial area and the public spaces that connect the building with the surrounding villages (Fig. 2).

Methodology Development: from Digital Modelling to Digital Fabrication

For the present work, a workflow has been applied that foresees the coexistence and overlapping of different representation methods, both traditional (drawings and physical models) and modern (3D modelling, integrated CAD /CAM systems, tracking and AR systems). They are all useful for the different communication phases of architectural and urban design (Fig. 3). These different imaging techniques and the relationships that develop between them are becoming increasingly important in defining the new frontiers of architectural practice [Mitchell et al. 1995]. In particular, the work focused on: the three-dimensional digital modeling of the building, the identification of Digital Fabrication techniques (3D printing and laser cut), the executive design of the individual parts, the printing and cutting of all the elements, the assembly and photo-shooting, the design of the AR experience through the identification of specific types of content.
After defining the aesthetic and scale characteristics of the real model, it was decided to use a scale of 1:200 to represent only a quarter of the building, given its large dimensions. The

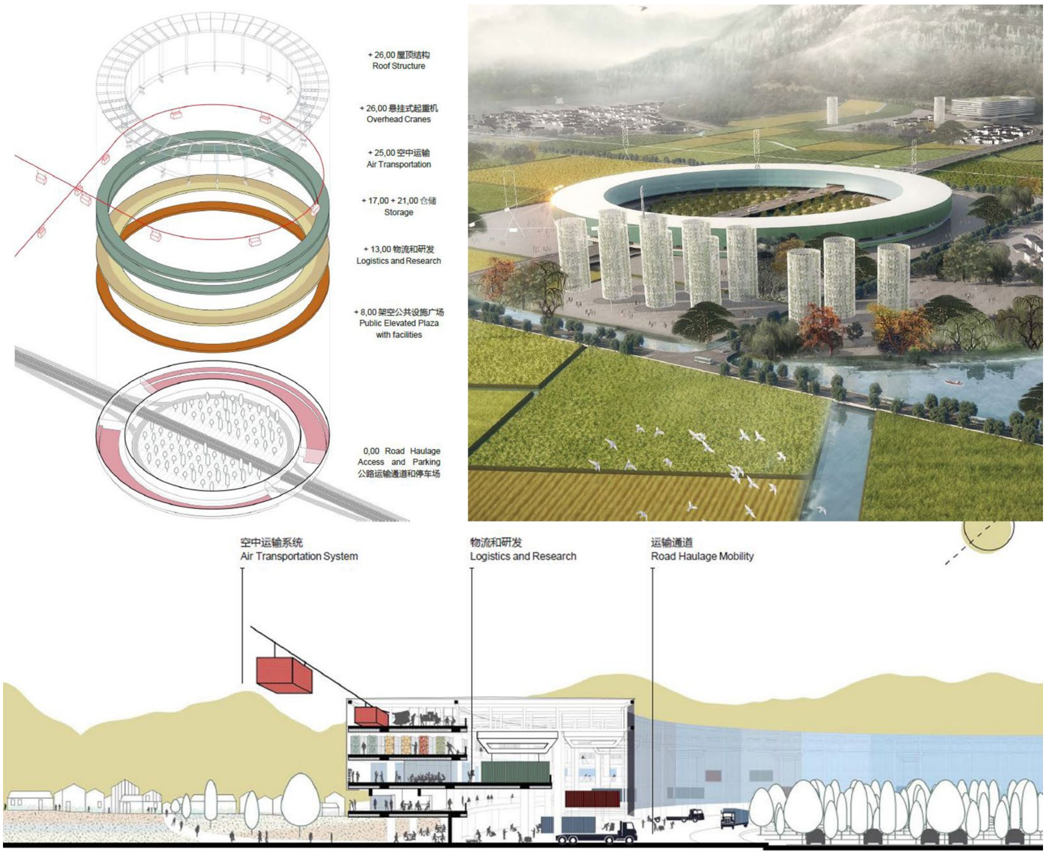

Fig. 2. Prosperous Lishui. South China University of Technology: School of Architecture and Politecnico di Torino, China Room and Institute of Mountain Architecture, Future Shanshui City – Dwelling in Lishui Mountains International Urban Design Competition, 2021.

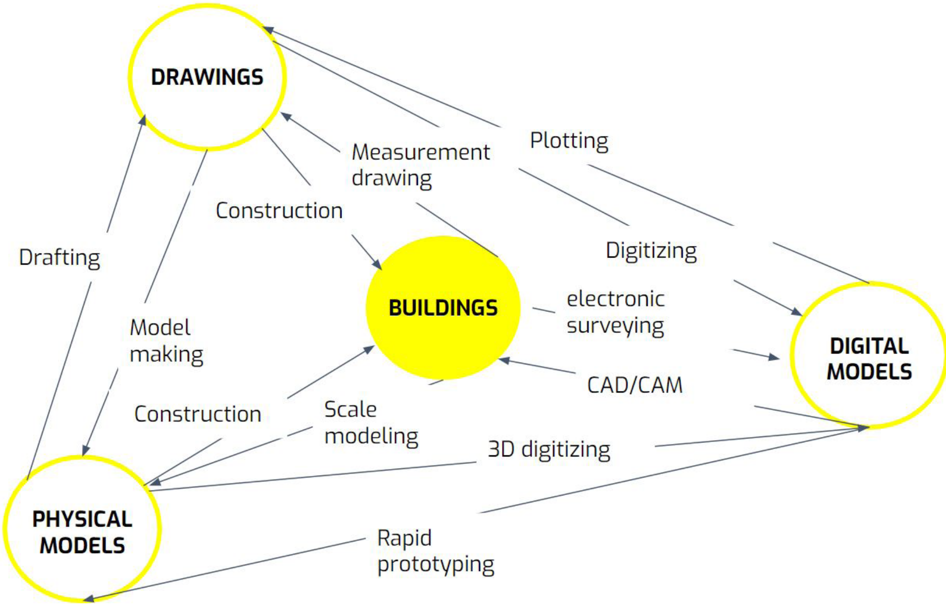

Fig. 3. Mitchell and McCullough, diagram showing the translation paths between physical drawings, digital models, physical models, and the building itself.

model was designed to reveal both the internal and external organization of the distribution, as well as the most representative architectural and structural elements (Fig. 4).
The selection of the dimensions of the different elements was based on the Digital Fabrication techniques available in the ModLabArch laboratory: the Ultimaker S5® 3D printer and the Trotec Speedy 400® laser cutter. Consequently, we proceeded with the choice of materials: colored PLA (polylactic acid) for the structural and distribution components and for the transportation means, grey vegetable cardboard, and opaque and transparent plexiglas for the base and floors. Although for AR experiments it is better to have a solid color and opaque materials, in this case, given the need to have a model that can be understood without digital devices, it was decided to use color anyway (Fig. 5).

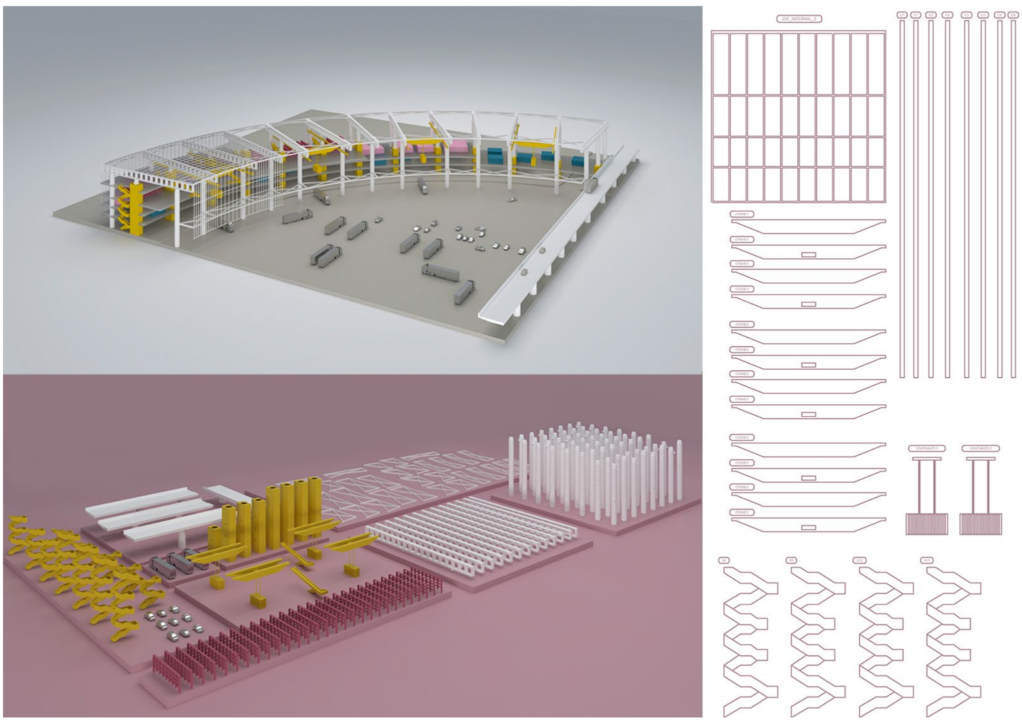

Fig. 4. The 3D model: example of organisation and numbering of some pieces of the model and rendering images. (Project of the Logistic Hub developed by Giulia Bertola, Edoardo Bruno, Alessandro Capalbo, Camilla Farina. 3D model and executive design by Giulia Bertola, Alessandro Capalbo, Enrico Pupi. Rendering and graphics by Giulia Bertola).

Augmented Reality Project

Augmented reality (AR) in the field of architecture and urban planning can be very effective when used to anticipate design projects and their impacts, and to support informed dialogue among the various stakeholders involved in the processes of architectural and urban transformation. This can be done on-site, by acting directly on the area being transformed, or off-site, by using physical scale models [Piga 2017, p. 106].

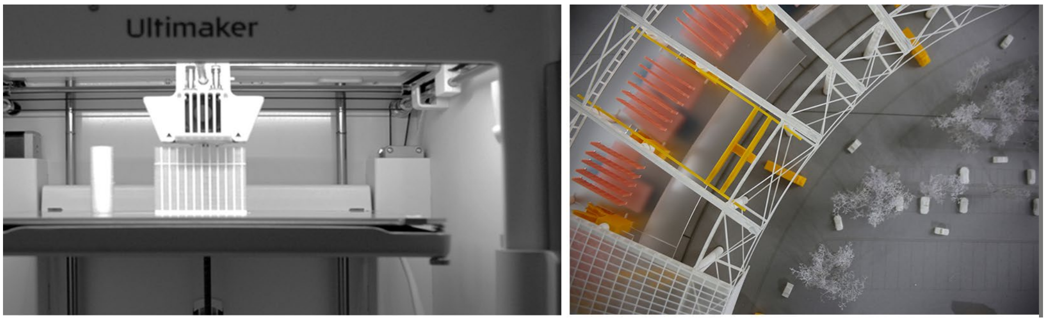

Fig. 5. The final Hub maquette (3D Printing by Giulia Bertola, Enrico Pupi, assembly operation and photoshooting by Giulia Bertola, Enrico Pupi, Areej Awada).

As for the former, static view content can be created where text documents, meaningful images, videos, project drawings, and conceptual schematics can be linked to the maquette through a system based on the recognition of target images placed directly on the model. Users can access the content through downloadable applications or connect directly to a dedicated website for the project, accessible through devices such as phones or tablets. For this project, however, it was decided to focus on the construction of static three-dimensional content that is dynamically displayed directly on the real model. Starting from the 3D model and using special rendering tools, it is possible to create three-dimensional objects that can provide additional information on structure, distribution, energy, and environmental aspects. When the user frames the model through a device, objects appear on the screen that complement the real model (texts or additional architectural and structural elements that are not present in the plastic model). This process was also made possible by the fact that the real model and the multimedia content are derived from the same virtual model.
Finally, it is possible to make the same content dynamic by simply animating the three-dimensional objects.
As for the choice of tracking tools, the following applications were used: Unity®, a multiplatform graphics engine and Vuforia Engine®, an augmented reality software development kit.
Before we could proceed with creating the augmented reality experience on Unity®, we needed to be clear about which model recognition method we wanted to use. One of the best and most popular SDKs (software development kits) for augmented reality is VuforiaTM®, a tool that works very well with Unity® and allows tracking of layers and 3D objects in real-time. A target is a predefined object that the VuforiaTM® engine recognizes in the real scene and tracks in space. The two most common types of targets are the single image and the 3D object.
In this case, since the object to be tracked is directly the hub model, a 3D object target was created. Using the Model Target Generator (MTG), a software from VuforiaTM®, it was possible to upload the digital model exported directly from Rhinoceros® in .fbx format. In general, for the creation of the Model Target, it is necessary that in the transitions between Rhinoceros®, VuforiaTM®, and Unity® there is: a match of the coordinate system, the scale of the object is set 1:1 and there is a general reduction of the complexity of the model. These checks can be performed directly in the Model Target Generator. In the MTG you will then get the auxiliary view, an image file that stylizes the image of the 3D model, in the same position in which it should be framed now of use. Given the complexity of the Hub model, when creating the Model Target, it was necessary to eliminate some components to avoid detection of invisible parts or non-existent features. In the Model Target Generator (MTG),

random colors can also be applied to parts of the 3D model to improve tracking performance. At this stage, colors and textures do not have to be true to reality. On the contrary, the use of photorealistic textures or materials that try to emulate certain physical effects can lead to the opposite effect.
Once the procedure is complete, the Advanced View is created and the Model Target is exported to a .unitypackage file, ready to be imported into the project on Unity®. The first step is to set the device on which the experience will be tested. When you open the Build Setting window, you will find several settings, including the ability to switch between different operating systems.
A preliminary operation to be performed is the setting of the device on which the experience is tested.
Being a preliminary study phase and having a stationary object during the AR experience, it was decided to use the camera of a laptop placed directly in front of the model.
Usually, the use of static movement significantly improves the quality of tracking.
After adding the VuforiaTM package to the project, we proceed with the insertion of the AR Camera, the new Unity® basic camera, the Model Target, and the Child object to be displayed during the AR experience.
The experience takes place when the Game View is activated; in this phase, it is possible to visualize the Guide view (the Model Target), superimpose it on the model, and automatically visualize the Child object (Fig. 6).

Conclusion

This experience intends that the user can acquire additional information about the architectural project. Once the method has been identified, it is planned, in a subsequent phase, to create different types of 3D contents, both static and dynamic, always inserted as Child objects within Unity® and anchored to the Model Target.
The success of modern digital representation technologies is already demonstrated by the rapid spread they are having in various fields of communication. The aim of this study was to show how these applications can have a positive influence on architectural design and the creation of maquettes.

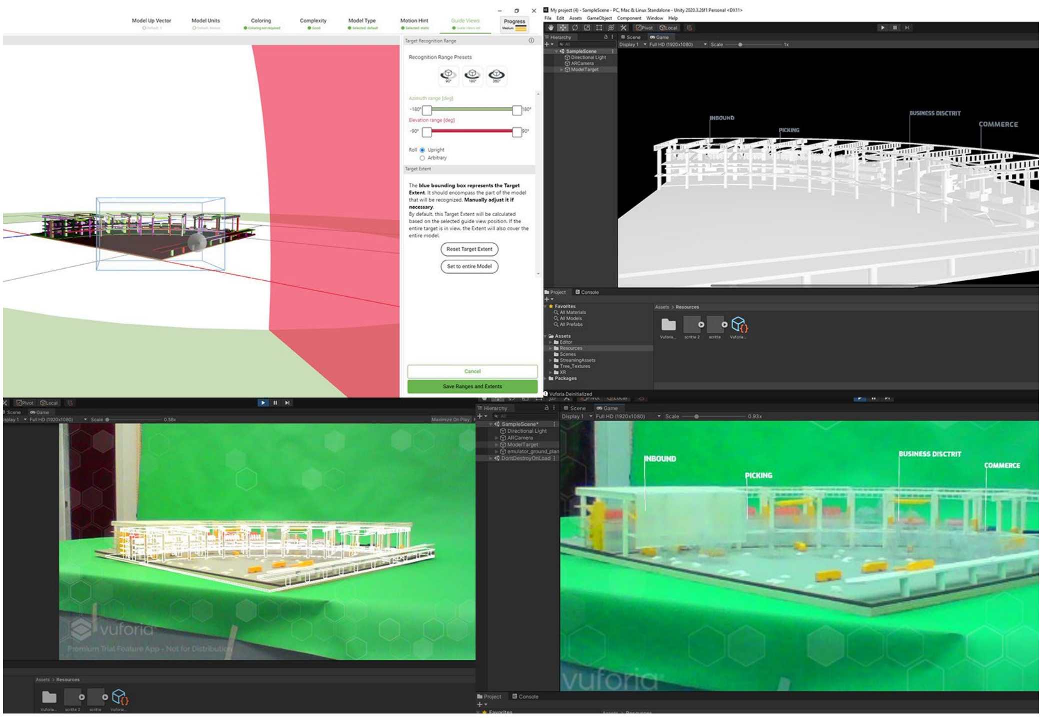

Fig. 6. The Augmented Reality Project. Model Target creations on Vuforia® and the project on the Unity® platform (the recognition of the model target following the overlapping of the real model and the appearance of the Child object in AR). (Design by Giulia Bertola)

Models, even if integrated with such technologies, can still maintain their role as a tangible miniature witness of architectural and urban space and be able to describe the idea of physical space, without simulating its reality but stimulating the critical imagination of the observer [Gulinello 2019, p. 98].
Real models and virtual models can therefore act synergistically even though they come from different approaches: the former maintaining their power to fascinate thanks to the fact that buildings will continue to be designed and built, the latter thanks to their forward-looking approach that helps to achieve other goals such as efficiency in the design process based on the principle of an intelligent process [Schilling 2018, p. 197].

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