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SfM and Digital Modelling for Enhancing Architectural Archives Heritage

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***Abstract* – 20th century architectural archives of the pre-digital era are today at the center of the interest of scholars involved in historical studies as well as in conservation, valorization, and communication disciplines. The enhancement of wide archival heritages could take advantage of methodologies, techniques, and tools offered by digital revolution. This is the case of the work shown in the present proposal. It develops an experience of SfM applied to a physical scale model that represents the Turin Horse-Racing designed by Carlo Mollino. This practice fuels considerations and new interrelations of knowledge, where the archive could take the role of a place of convergence between real and virtual.**

I. DIGITAL TOOLS FOR ENHANCING ARCHITECTURAL ARCHIVES HERITAGE (RS)

The issue of conservation, valorization, and enhancement of Cultural Heritage today involves 20th century architectural archives that come to us with their often considerable amount of materials, where the predominance of design drawings arises. Interpretation, fruition and sharing of archival materials aimed to deepening the knowledge of contemporary masters and architectural movements address the works of many international scholars.

In particular, using the continuous innovations of digital modelling tools, a field of this research is developing reconstruction and new interpretations of masters' unbuilt projects or disappeared buildings. Focusing on 20th C. archives of the pre-digital era, they contain different materials: not only drawings – that, as said, are at the center of the projectual activities -, but also technical reports, correspondence, pictures, photomontages, scale models, audio and video recordings. The value of these archives is justified by the real meaning they take: being a proof of a phase in the design process that ended with the construction or remained on paper.

This is the case of Carlo Mollino's Archive, since 1973 kept in the Archivi della Biblioteca Centrale di Architettura "Roberto Gabetti", Politecnico di Torino, Fondo Carlo Mollino. Only about twenty, among more than 130 architectural designs collected in the Archive completed the cycle that goes from conception to realization; even fewer are those built according to design drawings and those today existing, because of thoughtless demolitions [1].

Several designs by Mollino were in the last years digitally reconstructed in the ambit of Master Theses worked out in the School of Architecture at the Politecnico di Torino, and supervised by Roberta Spallone and Sergio Pace. A more recent development of the research work aimed to group together in a unique collection the digital models of the most interesting and documented works, applying the latest low-cost technologies for users' interaction and the potentialities of interoperability between 3D modeling application, publishing, and online sharing systems. The prototyped platform, named "Digital Interactive MOllino" (DIMO), is experimental and replicable [2].

Frequently, Mollino flanked his designs with physical scale models, documented by photographs and photo-montages, but not preserved. They allowed him to imagine the building in its physical appearance and inserted in the environmental context.

Although the original models were destroyed, among

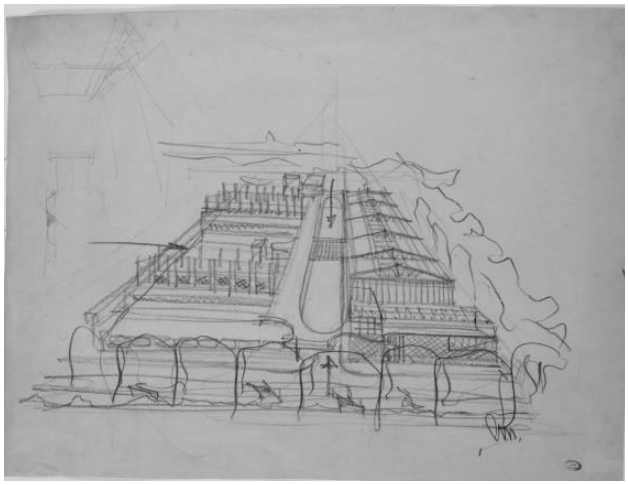

Fig. 1 Mollino, sketch of Turin Horse Racing. (Archivi della Biblioteca Centrale di Architettura "Roberto Gabetti", in the following BCA, Politecnico di Torino. Fondo Carlo Mollino)

Mollino's designs, there is the Turin Horse-Racing, built from 1937 and demolished in 1960, that was represented by a wood scale model (figg. 1, 2). It was presumably realized in the Seventies or Eighties and is preserved in the Biblioteca Centrale di Architettura.

Fig. 2 Wooden model of Turin Horse Racing. (Archivi BCA, Politecnico di Torino. Fondo Carlo Mollino) .

The availability of ontologically different representations of this project could became an interesting field for testing new developments of DiMO prototype. Indeed, in this particular case it is possible to create a circular process of knowledge between physical archival heritage and digital interpretation. The SfM applied to the wooden model is the base for the creation of a 3D digital model that could be compared with the one resulting from the re-construction realized starting from the original drawings. Moreover, the physical model could be the basis for marker-less experiences of Augmented Reality that link other archival materials, point clouds and interpretative digital models, as well it could be done using as a basis the archival drawings. The archive could become a place of exchange of knowledge experiences, At the same time the website could contain links to a selection of archival documents and to interactive repositories, such as Sketchfab® or 3DHOP®, enhancing the fruition of the archive and encouraging the visit and the consultation. The present phase of the work is focused on the issues of SfM applied to the physical model and the creation of 3D digital model of the Horse-Racing.

II. DIGITALIZATION OF PHISICAL MODELS AIMED TO INTERPRET AND SHARE ARCHITECTURAL HERITAGE (GB, FR)

The digitalization of physical models assumes even more importance when applied on entities that are about to be built or that do not exist anymore, as the proposed case.
A lot of models' surveying practices use photogrammetry and laser scanning techniques combined as for producing an integrated and accurate 3D representation. Both techniques are particularly useful while talking about Cultural Heritages, because they don't imply the direct contact with the object.

With the transition from analogical to digital culture, the approach and the transmission of data has radically changed in the principles and in the ways, guiding, consequently, criteria of acquisition and analysis in a different way [3].
The possibility to digitize a wooden model, to put it in the real context and to compare it with historical sources are new digital tools which allow a new approach in the history of architecture but also in the process of improvement of Cultural Heritage.
This is the case of Masieri Memoria building developed in 2011 [4], where both methods are used to obtain models as precise as possible, that were compared nearly overlapping.
The digitalizing techniques were used also to show how it could appear having the building realized.
A city model has been realized using municipal cartography (plans) and some scans acquired by the laserscanner (heights). Using the camera-match of 3D Max Studio®, was applied a procedure which is similar to a backward resection using the city model of the context.
Another interesting case of different techniques combination is the one of the surveying of Antonio da San Gallo maquette of the Basilica di San Pietro carried out in 2007 [5].
The survey was made with the laser scanner technique focusing on both the inner and the external views. The model in this case becomes a mean to evaluate the project, its spatiality, its geometry (through control cross-sections to define main generatrix and directrix) and its lighting characteristics. Thanks to the great accuracy of the model it has been possible to analyse single elements of it and to compare them with the main classical treatises.
The maquette was also used to realize a virtual model through a process of reverse modelling. Starting from it, a video at an human point of view was realized to highlight the spatial characteristics of the building and brings out some limits of Sangallo's project, confirming some doubts about lighting by Michelangelo.
This use of both virtual and reconstructed models introduces some interesting reflections about these different representing tools. The possibility of reconstructing a physical model (in some cases easier to construct and manipulate than a virtual model) in order to develop a digital model (more suitable for controlling dimensions and making drawings) therefore represents a particularly interesting track for the definition of new work approaches. This type of practice can benefit from numerous interactions between the analogue and digital model [6].
Another possible work on the digital acquired model is the implementation with BIM technologies, or Collection Information Modelling (CIM), so called in the work (2019) on the collection of Museo Egizio di Torino [7] aimed to realize a 3D database of mobile heritage. Even if the objects of this work are often smaller than a maquette,

it's interesting to analyse how museums can utilise achieved digital models for different purposes: to monitor their collections and offer the users (visitors) the possibility of exploring objects, even those ones that cannot be put on display due to a lack of space.
The analytic and interpretative approach to the model presented with these case studies could be applied to the Turin Horse-Racing maquette, giving it a scientific relevance and significance richness.

III. STRUCTURE FROM MOTION APPLIED TO PHISICAL MODELS (FR)

Today digital and numeric models are gradually substituting maquettes, in particular the handmade wooden ones. Through modern 3D representations and surveying technologies (digital photogrammetry in this case) we can insert in the current context projects, as Turin Horse-Racing one, not visible anymore, survived in the shape of wooden model. Through translating processes of the realization of maquettes and their digitalization is possible to re-create reality, in a specific context, engaging in dialogue with a specific public.
The automated photogrammetry gives the possibility to transform maquettes into digital models. The digitization of a wooden model is not yet common: normally the applications concern a whole building or small objects, and not medium-sized things. Different sizes and different accuracy bring to utilize different instruments and methods.

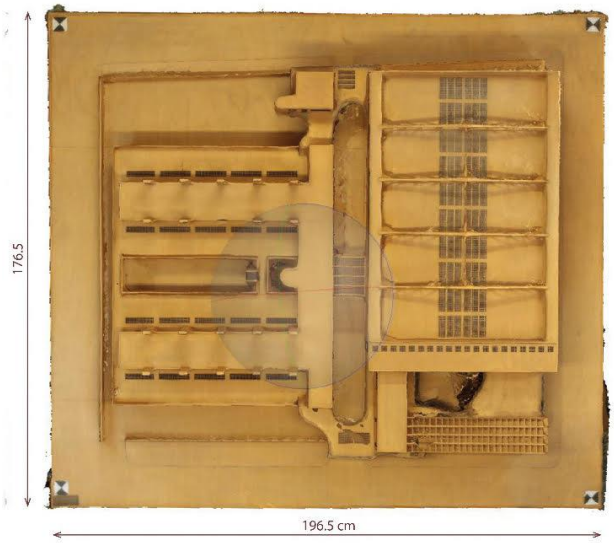

Fig. 3 Orthographic image of the 3d model using automated SfM photogrammetry.

The wooden model of Turin Horse-Racing (fig. 3), in scale 1:50, has a size of 176,5 (length) x 196,5 (width) x 20 cm (height), so it can be considered neither big nor small, therefore, using exclusively the method of photogrammetry was important doing a great amount of photos from different points of view and having good conditions of illumination, in order to obtain a model as precise as possible.
It was easy to survey the artefacts on site. The maquette was in fact totally accessible from all sides and quite accessible from the top, positioning the camera at a sufficient hight to take the entire maquette, except from a zenithal point of view.
The followed scheme is that of converging shoots taken all around the model at three different heights, changing the inclination of the camera. The pictures were acquired in order to avoid deep shadows, which could generate difficulties in collimation, orientation and design phases. As can be seen from the graph (Fig. 4), the most critical issues are marked by the signs in red.
They correspond to the internal courtyards, that are difficult to reach with the camera, and to metal trusses of the roof and to the fences, characterized by extremely minute details.

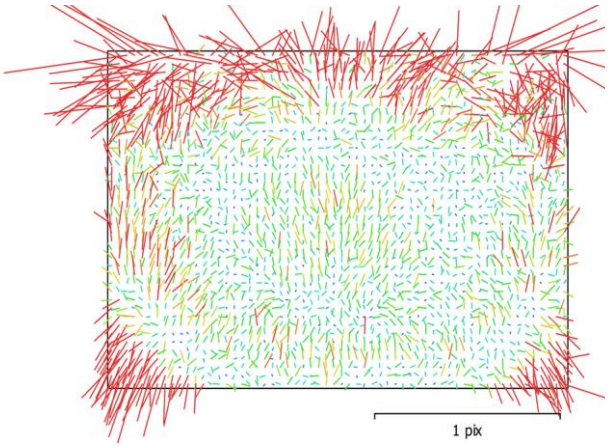

Fig. 4. Image residuals for Canon EOS 1300D (18mm)

We used four adjustable tripods with four lights 4000K, two of them paired with reflecting umbrellas and the other two located in soft-boxes to spread and uniform the light. The model has also been equipped with markers positioned near the perimeter (to make easier the phases of orientation and positioning of the picture).
During the survey some measurements were taken to scale the wooden model and using other measurements we made a validation of the scale-transformation.
The photos were shot from three different heights, so we obtain three values of GSD and a medium value of them (Table 1).
Although the acquisition protocols envisage the use of any kind of digital camera, obviously image resolution affects the quality of the final restitution. We chose to use a Canon 1300D, with a 18-55 lens and an 18 mp, 5184X3456 pixel APS-C (1.6x) sensor. We manually took 390 JPG format shots using always the same focal of 18mm.
After our work in field, that lasted just few hours, we processed the data using Metashape® environment, we moved on to the analysis of the sharpness and focus quality of the images (Estimate Image Quality), before proceeding

with the alignment phase of the frames (Align Photos).

Set of photos	Number of aligned photos	Photos' shoot distance [m]	GSD [mm/pixel]
Set1	208	1,61	0,4
Set 2	92	1,25	0,3
Set 3	90	1,15	0,3
Medium value			0,33

Table 1. Calculation of GSD factor

IV. FROM PHISICAL TO DIGITAL MODELS (GB)

A good combination of multiple scan positions (fig. 5) allows to create a complete and realistic point cloud of the detected object. Once the photos are uploaded to the program, Metashape® generates a sparse cloud (fig. 6).

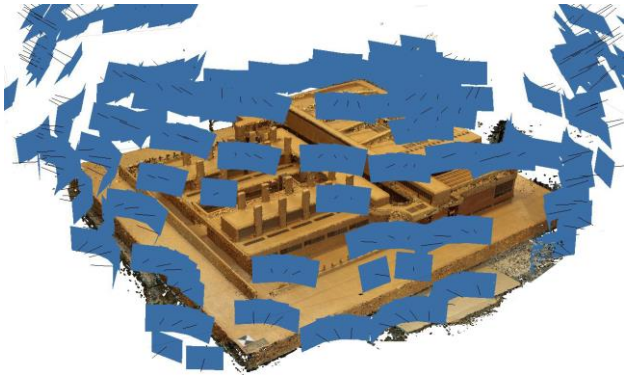

Fig. 5. Images captured.

Before generating the dense cloud, to optimize processing times, it is necessary to clean up the sparse cloud from the points defined as "disturbing", and choose Depth Filtering values, with medium quality and mild depth filtering parameters.

Depth Filtering mode allows to work on outliers caused by noise and blurred images. Point groups are filtered and eliminated so that they no longer appear on the final model. The Mild algorithm is particularly suitable if in the model there are small details, as in our case, important to recognize during the reconstruction phases of the scene. An object can be described in a more or less detailed manner based on the distance between the points used to describe it. The more dense a cloud is, the more it is able to represent the shape of the object, the surface or the space detected in a way that is faithful to reality. Once generated and cleaned out of scattered cloud, Metashape® generates the dense cloud. Metashape® allows to generate and display a model with a dense point cloud. The quality of the parameters was set to specify the detail and geometric accuracy resulting from the reconstruction. The work was performed in Medium quality.

Fig. 6. The sparse cloud model

Although the images were not used with the original resolution, the result was satisfactory, considering reasonable processing times and the easily manageable .ply file obtained.

Once created the dense point cloud, is possible to create the mesh (fig. 7), or rather the process of connecting the points in the cloud in triangles to create as surfaces.

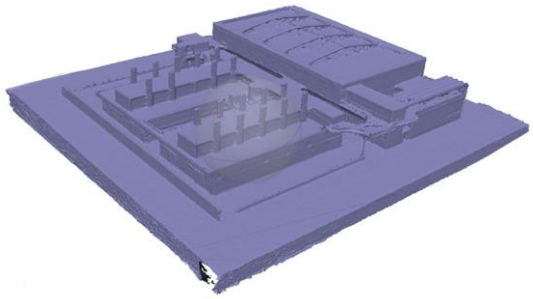

Fig. 7. The mesh model

Subsequently textures, obtained from the acquired images, are applied to the meshes, generating the texturized model (fig. 8). The extraction is based on the construction of region by region correspondences, according to the subdivision of the geometry.

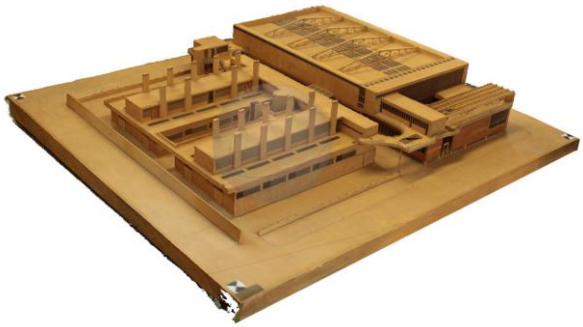

Fig. 8. The texturized model

The Generic setting for the mapping mode parameter allows to create a uniform texture.

The Mosaic setting for the blending mode parameter attempts to pick the sharpest photos to give the most accurate result. While acknowledging the potential of the work and the opportunities that derive from it, it is nevertheless necessary to highlight and take into consideration its limits: the automatic construction of the

mesh model, in fact, does not include the interpretation of the geometries of the architecture and discretizes its shape through an interpolated surface. All the operations oriented to the extraction of characteristic sections and to the model will therefore be further investigated, without counting the limits deriving from the approach, which inevitably relies and returns only the external surface of the analyzed object.

SPARSE CLOUD		
Points	257,976	
Alignment parameters	Accuracy	High
Reconstruction parameters	Quality	Medium
	Depth filtering	Mild
DENSE CLOUD		
Points	9,485,212	
Reconstruction parameters	Quality	Medium
	Depth filtering	Mild
MESH		
Faces	1,216,208	
Reconstruction parameters	Quality	Medium
	Depth filtering	Mild
GENERAL		
Mapping mode	Generic	
Blending mode	Mosaic	
Texture size	4,096 x 4,096	

Table 2. Processing Parameters

V. FROM POINT CLOUDS TO INTERPRETATIVE DIGITAL MODELS AND AR EXPERIENCES (RS)

In the present case study, the plastic model is one of the first, if not the first, interpretative representation of the Turin Horse Racing.

As far as we learned from the heirs of the company that built the plastic model Falco&Boulanger s.a.s. (Moro Esculapio), it should have been made between the 70s and 80s, i.e., after the demolition of the building. We can therefore imagine that the model was constructed from the same iconographic material that guided the reconstruction using a digital three-dimensional model.

Mollino's Turin Horse Racing was immediately recognized as a masterpiece by contemporary critics: in the early 40s Giuseppe Pagano, Armando Melis, and Gio Ponti showed the building on the most famous journals of the time [8], [9], [10].

Therefore, the documentary iconographic materials range from the original sketches, diagrams, technical drawings, and perspective views to the drawings prepared by Mollino for publishing, to the photographs and photo-montage, taken after construction and worked out by the same architect and Riccardo Moncalvo (figg. 9, 10, 11). The idea to collect a selection of them together with the journals' articles, and the texturized model obtained through SfM survey could find the most effective repository in a BIM

Fig. 9. Reconstructive digital model of Turin Horse Racing, in the urban context of the time (Modelling: Florida Canaj).

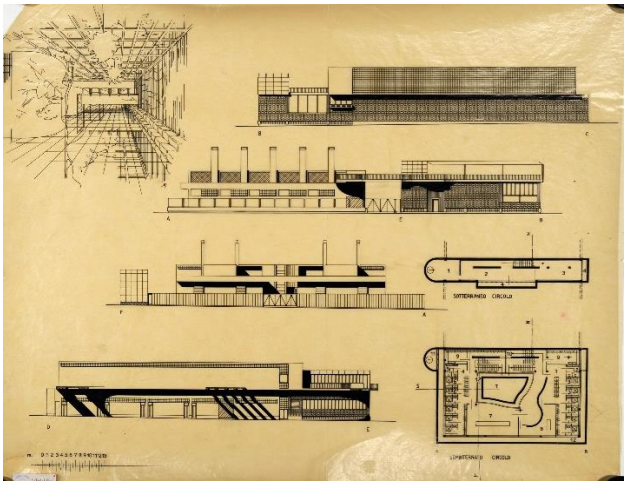

Fig. 10. Mollino, technical ink drawings of Turin Horse Racing. (Archivi BCA, Politecnico di Torino. Fondo Carlo Mollino).

Fig. 11. Mollino and Moncalvo, photo-montage of Turin Horse Racing. (Archivi BCA, Politecnico di Torino. Fondo Carlo Mollino).

model. Moreover, this BIM model, created starting from the most reliable and consistent original drawings, document a design phase that could be interesting compare with the mesh model obtained by photo-modelling. Another possible application could be a process of reverse engineering from the point cloud acquisition of the plastic

model to BIM modelling, aimed to recognize the design phase the wooden model refers and to compare with the digital model realized from design drawings.
The final step of this experience broaden the scope of applicability of Augmented Reality from the archival design drawings to the wooden maquette.
This process applies the results of previous experiences [11], [12], involving the recognition and tracking of two and three-dimensional objects in AR applications connected to the collected data. Recent developments in this field relate to the technology available on widespread mobile devices (e.g. tablets and smartphones), allowing for real-time 3D scanning. Software development kits (SDK) like Vuforia, Wikitude and ARKit feature real-time 3D object recognition and marker-less tracking. Furthermore, they are supported by many environments for app programming, including Unity, which is one of the most advanced and widespread cross-platform game engines.

VI. CONCLUSIONS (RS, GB, FR)

The possibility to digitize a wooden model, to put it in the real context and to compare with other designs are new digital tools which allow a new approach in the history of architecture but also in the process of improvement of Cultural Heritage. We can assign an important and objective-metric role to wooden model as a part of the design process.
With the use of digital technologies applied to Cultural Heritage, we obtain digital copies of wooden models which can be published in virtual museum but also can be used by scholars to have a free access to an object which is difficult to handle and to move.
The use of different representation techniques, the overlapping of different documents (historical photos, photos of the maquette and original drawings) could be very interesting (fig. 12).
This "mixed technique" envisages a relationship between the virtual reality of the model reconstruction and the physical reality of the material of the studied object. These interconnections between different realities brings to a better knowledge and to a more precise analysis.
Finally, this experience could pre-figurate new virtuous links between archival materials and digital interpretations, where the archive could take the role of a place of convergence between real and virtual.

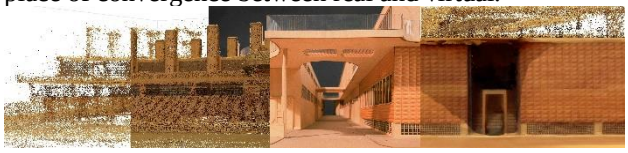

Fig. 12. Images collage: sparse cloud, dense cloud, texturized mesh, photo of the original model.

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