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FROM POINT CLOUD TO VIDEO PROJECTION MAPPING: KNOWING MODERN ARCHITECTURE BY USING LIGHT PROJECTION

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Abstract. The ClusterLab HeModern of the Università Iuav di Venezia has been working in recent years on the study, knowledge and conservation of 20th century architecture. This interdisciplinary research group (History of Architecture, Geomatics, Building Technology, Restoration Project) intends to investigate how to analyse and evaluate the state of conservation of the materials of which the modern architectural cultural heritage is composed by identifying specific application protocols for intervention, preservation and valorisation.
In 2018, the collaboration between the above-mentioned ClusterLab, the LéaV of the Ecole nationale supérieure d'architecture in Versailles and the Archivio del Moderno of the Accademia di architettura in Mendrisio - Università della Svizzera italiana, culminated in the identification of the works and career of André Bloc as a case study. In the context of this study, the Tour, the Engineer's posthumous work, was selected to serve as a sample for research on the methods of communication of the contents of the architecture, the survey procedures used and the elaborations obtained. So, after the survey campaign, which took place via topographic, laser scanning and photogrammetric methods, two different levels of restitution were conceived: the first, made according to the canonical graphic paper methods, represents the procedural and surveying information, the material characterisation and the state of decay; the second elevates the same contents by applying them to physical reality. In this phase, the research focused on the possibility of making the different projects collaborate through the technique of rapid prototyping and video projection mapping. This particular form of augmented reality was used to enrich, through the mediation of light projections, the sensory perception of the observers by adding more information and emphasising those of greatest interest, proposing an alternative way of storytelling. In fact, unlike other forms of augmented reality, in the case of video projection mapping, the observer has the possibility to interact continuously with the physical reality, whose character is static, while the transmission of data is dynamic and can range in heterogeneity.
The elaborations produced were presented in form of a museum exhibit at the international conference “Arti e architettura. Il contributo di André Bloc 1950-1970”, which took place in the exhibition rooms of the Università Iuav di Venezia.

1. Introduction

Throughout the years, the discipline of architectural surveying has contributed through its tools and practitioners to the valorisation and documentation of cultural heritage. However, the knowledge of the formal and compositional characteristics of a work using images, descriptions and annotations is not always sufficient to deeply understand all aspects, especially those linked to the emotional sphere, which can only be grasped by physically contact it. Rapid prototyping is one of the tools best suited to this type of problem: the application of 3D printing technologies in the field of cultural heritage has expanded exponentially, guaranteeing remarkable levels of accuracy and becoming a fundamental tool for the transmission of information [1]. This has happened through the research and dissemination of new forms of musealisation, where physical replicas have become an indispensable tool for the fruition of cultural heritage: in fact, in the area of museums, the possibility of faithfully reproducing three-dimensional objects makes it possible to enhance exhibitions and collections, while access to information becomes 'customisable' depending on the user, content and complexity [2].

The object of the survey and analysis, the Tour (or Sculpture-Habitacle III), is located on Bloc's original property in Meudon. It is 23 metres high and was erected in 1966. It is formally configured as a vertical labyrinth consisting of an enclosed central nucleus, from which external ascending paths lead to the top: a belvedere opening onto the panorama of Paris.

Because of these peculiarities, the object lends itself to different studies. This led to the development of a project whose objective was to explore the communicative possibilities of architecture and its contents, basing the elaborations on the concept on which the ClusterLAB HeModern of the Università Iuav di Venezia works: the need for interdisciplinarity intended as the interaction of skills and disciplines.

The work has therefore been divided into two phases: one is analytical by nature, from which it is possible to obtain geometric, formal and material information; the other is experimental, and relies on the techniques of 3D printing and video projection mapping within a specific exhibition. Although they are distinct, they are planned to merge into the same museal exhibit.

The entire research is based on the fundamental procedures of architectural surveying.

Figure 1. The Tour.

Figure 2. The maquette.

2. The survey of the Tower

The information acquired during the instrumental survey, characterised by local reference systems and different instruments, suitably integrated, allows the documentation of the geometric and physical characteristics of an artefact, making it possible to define its material and degradation consistency and monitoring changes over time [3].

2.1. Topographic survey

The workflow was conducted in the traditional way, starting with the design of the topographical network. The area, characterised by considerable changes in height and unevenness of the terrain caused by the explosion of military bombs, led us to build an open polygonal, also considering the presence of heavy vegetation, which was partly adjacent to the tower. The network was materialized as an isostatic triangle and an open polygonal.

Using the Leica TCR 1103 Total Station, 37 points of detail, identifiable in the targets applied on the external surface of the Tour and arranged to cover it homogeneously, were surveyed from the station points; moreover, measurements were taken on some surrounding architectural points to increase redundancy.

The observations were then processed by least-squares calculation using MicroSurvey StarNet software, in order to obtain the compensated coordinates of the surveyed points and the standard deviation of each of them (maximum SQM obtained ±2mm).

2.2. *Laser scanning survey*
Laser scanning survey was performed using two FARO FOCUS 3D CAM2 S120 phase difference terrestrial laser scanners.

The complex articulation of the building led us to divide this phase into two different projects, one for the exterior and one for the interior.

For the external area, 10 scans were made with an angular step of 0.035°, to guarantee the acquisition of a point every 6mm at a distance of 10m, an appropriate density for a restitution at a scale of 1:50. The georeferencing of the point clouds in the local reference system took place in the FARO Scene software with the automatic identification of the targets.

The acquisition of the internal part of the Tour took place in a different way, because the building is built in height with a central closed staircase and a labyrinthic external path. This particular conformation made it impossible to materialise topographic points by using targets inside the staircase of the structure. Realising that the alignment of the scans would therefore be based on the identification of homologous architectural points, it was decided to take scans very close to each other. For all these reasons it was decided to set an angular step of 0.070° in order to acquire a point every 12mm at a distance of 10m so as to obtain, during the overlapping and merging phase, a density of points in any case adequate for 1:50 scale representations. For the interior, a total of 55 scans were taken, which when combined with the 10 exterior scans through the recognition of some exterior targets and architectural points, produced a model consisting of 1112808012 points.

2.3. *Photogrammetric survey*
The photogrammetric acquisition phase did not take place according to the canonical schemes and methods due to the physical impediments mentioned above.

It was therefore decided to use two digital SLR cameras for the exteriors, the Nikon D3200 and the Nikon D610, while for the interior surfaces and the upper part the Sony RX100 compact camera was used with the aid of an extendable bar so that even the spires could be fully surveyed; it was also decided to use the GoPro Hero4 fish-eye camera and the Nikon KeyMission360 spherical camera in test form, mostly following the ascending route inside the Tour.

All photogrammetric blocks were processed in the Agisoft Photoscan software; for each camera was created a chunk, so data could be compared and merged in order to obtain suitable data for the 3D printing phase.

Table 1. Specifics obtained from each elaboration.

	Frames	Point Cloud	Dense Cloud	Mesh	GCPs, Rsme
NikonD3200	218	126797	8220409	1644081	23, ±0.0065m
Nikon D610	50	30849	2884877	57757	18, ±0.0067m
Sony RX100	114	52850	4055535	272858	7, ±0.0068m
GoPro Hero4	808	201204	15752869	3150572	24, ±0.0064m
Nikon KM360	275	-	-	-	-

Concerning the Nikon KeyMission360 spherical camera block, a valid model was not obtained. This is probably due to the fact that for this type of architecture, which is characterised by complex geometries and a repetitive pattern, the image matching algorithm for image orientation did not work properly and a higher number of control points should have been used.

3. The survey of the maquette

In addition to the Tour survey, the maquette survey was also carried out. This one, built on a scale of 1:5, with a total height of 4.5m, is conserved under a roof located close to the Tour.

After marking the surrounding space with 16 targets, the photogrammetric survey was carried out using the Sony RX100 camera, which captured 242 frames. The photos, once processed in Agisoft Photoscan, produced the following results:

- point Cloud: 98709 points;
- dense Cloud: 4617422 points;
- mesh: 106036 polygons.

Six laser scans were then taken. Georeferencing was performed in the FARO Scene software using the first scan as the reference for the others, then the coordinates of the targets and some architectural points were identified. These coordinates permitted the orientation of the photogrammetric model, whose Rsme is ±0.005575m.

4. Representation

Once the orientation of the Tour's photogrammetric models had been completed, we moved to the restitution phase, which took place in two distinct ways: the first through orthophotos, vector representations such as plans, elevations, sections, metrical, materic and degradation analyses on a 1:50 scale; the second through the use of 3D printing and the video projection mapping technique as an alternative form of communication of the contents listed above.

4.1. Graphic representation

The starting point for this type of representation is the laser point cloud. In Pointools Edit Pro software, it was cleaned of all superfluous points or points not belonging to the surface of the construction and then integrated with the photogrammetric models. From this operation it was possible to obtain a complete discrete model from which the orthophotos of the elevations, vertical sections and horizontal sections were exported for analysis and redrawing at a scale of 1:50, i. e., for sampling theory, with a pixel size of 0.004m.

The following documents were produced:

- 4 sheets for the North, West, South and East facades, containing the orthophotos obtained from the photogrammetric survey, the laser scanning survey and the integration of the two. On the latter, the quoted vectorial drawing was made;
- a sheet containing 5 horizontal sections and the top view in raster and vector format, respectively quoted;
- 2 sheets containing 4 vertical sections in raster and vector format, respectively quoted;
- a sheet concerning the structural, materic and degradation analysis with the identification of the elements, of the structures and of the different degradation phenomena on the façades and on the horizontal sections.

4.2. 3D modelling and representation

In recent years, the development of 3D technologies applied in the field of Cultural Heritage has led to results of great impact both from the point of view of conservation, as well as enhancement, communication and fruition of our heritage [4].

One of the objectives of this research was to create solid models suitable for 3D printing of both the maquette and the Tour, so the models obtained from the survey were processed within the Geomagic Studio rapid prototyping software.

The polygonal model of the Tour was created through a careful process of point cloud cleaning followed by manual reconstruction of the parts characterised by gaps. Because of the large amount of data, it was decided to divide the work into parts after a few tests. The internal scans oriented in the local reference system were imported, processed and transformed into meshes individually in the same software. A forced alignment was executed using the ICP algorithm and only then the continuous models were merged. For the exterior, we used the photogrammetric meshes, which were combined after a precise phase of cleaning and removal of the double surfaces. The last step was the integration of the two parts into one project and, as explained above, the reconstruction of the gaps.

The digital model was then optimised for the next printing process by decimating the number of polygons describing the surface, from a model of 29717618 triangles to one of 5570160.

Similarly, the maquette was modelled by integrating the laser scanning model with the photogrammetric model.

The models obtained were inserted into 'CraftWare' slicing software in order to transform them and make them interpretable for 3D printing, which took place at various scales using the Craftbot Plus and Delta WASP 2040 PRO FFF (Fused Filament Fabrication) printers.

For the production of the larger copy, on a scale of 1:20 with a total height of 1.15m, the Wasp company was directly commissioned. This representation took place in two versions, one in its entirety, which was subsequently plastered, and one divided into six parts to reproduce the horizontal sections described in the previous phase of graphic restitution.

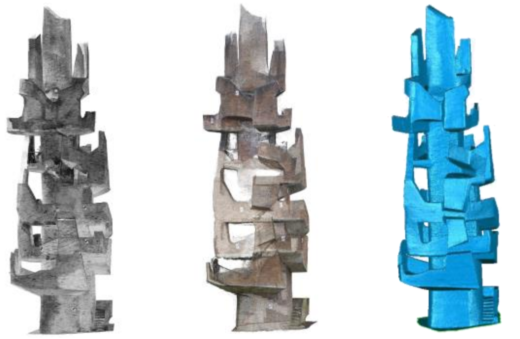

Figure 3. Tour models.

Figure 4. 3D printed models in 1:20 scale.

4.3. Video projection mapping

As mentioned above, one of the investigations of this research concerned the communication of content through the technique of video projection mapping.

This particular form of augmented reality appeared to be the most efficient in transmitting heterogeneous information to the audience in an immediate way, allowing at the same time a continuous interaction with the physical reality, which is represented by the printed model [5].

It was decided, for the purpose of presenting the work in the form of an exhibition, to plan a phisical installation: considering the dimensions of the 1:20 scale models, the space necessary for the reproduction of an illustrative video and the available supports, it was established to work on a vertical surface of 3 x 1.8m divided into three panels. The sectioned solid prints were attached to them, while the entire model was placed on the flat. After that, preliminary projection tests were conducted and the position of the projector was determined to ensure that the surface was properly illuminated. From the same position, we took a frame of the set-up with the Nikon D610 camera with a 20mm fixed focal length lens; this frame, appropriately scaled and corrected by perspective projection, once projected matched the panels and solid models. This allowed this image to be used as the basis for all the various elaborations of the video mapping. The preparation of the contents to be mapped began: the different phases of the survey and all the data obtained were initially recreated in video format; the orthophotos of the north façade (the one directed towards the public), previously inserted into the sheets, were cropped and mapped to ensure that there was a precise correspondence with the illuminated surfaces; the vector drawings were animated and aligned with the models, as well as the section lines; similarly, the metric, materic and surface degradation data were projected. This part was particularly interesting because it was supported by an illustrative video showing portions of the masonry on a scale of 1:2 with descriptions and notes on the type of apparatus, the dimensions of the individual elements, the causes of specific types of deterioration and possible restoration techniques.

Once mounted, the animations and videos were imported into the MadMapper mapping software, where local adjustments were made through the warping phase to match the images exactly to the physical surfaces.

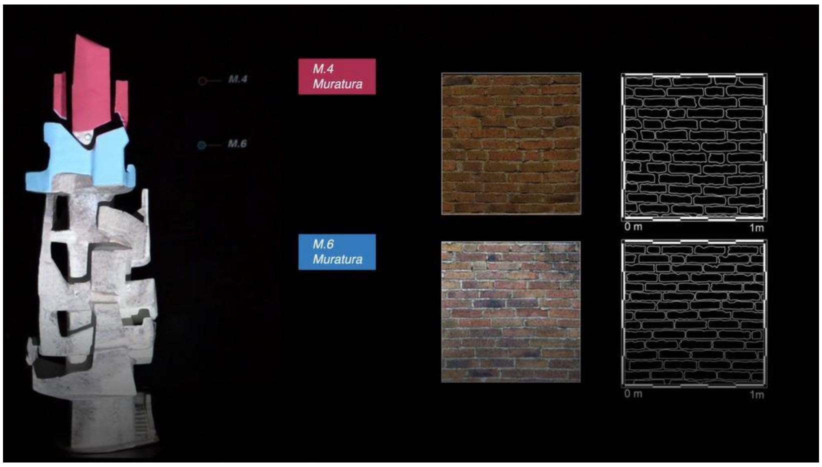

Figure 5. Video mapped model including informations about the wall equipment.

5. Conclusions

The Tour is an architecture that exceeds the standard in terms of use and form and represents an important moment in the modern movement. Thanks to survey activities, the necessary documents for investigation and study were produced for the first time, also in view of a restoration project. In fact, the building had never been surveyed before, and therefore no plans, elevations and sections or dimensioned drawings had ever been produced to allow scientific knowledge of its geometry and dimensions. This prompted us to process redundant data and reflect on the possibility of communicating them more efficiently than through traditional paper format. So, using current digital technologies, it was decided to create an installation containing a form of autonomous information transmission. This took place through solid printing and video projection mapping, techniques that were valid in the pursuit of our objective because they allow us to have physical contact with the object, even if it is scaled, and to change its appearance according to the type of information to transmit. This latter factor was particularly appreciated by those who were able to have a look at the exhibition because it allows the different fields and disciplines to coexist and collaborate when projected onto the same threedimensional print.

References

[1] Balletti C, Ballarin M and Guerra F, 2017. 3D printing: State of the art and future perspectives. *Journal of Cultural Heritage* **26** (2017) 172–182

[2] Ballarin M, Balletti C and Vernier P, 2018. Replicas in cultural heritage: 3D printing and the museum experience. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, **Volume XLII-2**, 2018. ISPRS TC II Mid-term Symposium "Towards Photogrammetry 2020", 4–7 June 2018, Riva del Garda, Italy

[3] Balletti C and Guerra F, 2015. The survey of cultural heritage: a long story. *Rendiconti Lincei*, **Vol. 26**, pp. 115-125. doi:10.1007/s12210-015-0411-8

[4] Balletti C, D'Agnano F, Guerra F and Vernier P, 2016. From point cloud to digital fabrication: a tangible reconstruction of Ca' Venier dei Leoni, the Guggenheim Museum in Venice. *ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci*. **III5**, pp. 43-49, doi:10.5194/isprs-annals-III-5-43-2016

[5] Petrucci E and Vannicola A, 2017. Incompleta Reficere: The Incomplete Façade of the Church of San Lorenzo in Montedinove and Its Virtual Image. *Proceedings* 2017, 1, 881 doi:10.3390/proceedings1090881.