DIGITAL MODELLING FOR ARCHITECTURAL RECONSTRUCTION. THE CASE STUDY OF THE CHIESA CONFRATERNITA DELLA MISERICORDIA IN TURIN

M. Lo Turco [a, *], M. Sanna [a].

[a] Politecnico di Torino, Italy, I Faculty of Engineering, Department of Building Engineering and Territorial Systems, (massimiliano.loturco, marco.sanna)@polito.it

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ABSTRACT:

The subject of this paper concerns the modelling phase of the digital reconstruction of the Chiesa Confraternita della Misericordia in Turin. The first stage was constituted by survey operations in order to acquire data for the next production of 2D digital drawings (plans and sections); these documents were the basis for reporting most of remarkable degradations such as efflorescence, infiltration, dampness and cracks. This work was done in collaboration between DITAG (Department of Land, Environment and Geo-Engineering) and DISET (Department of Building Engineering and Territorial Systems) of the Politecnico di Torino. This phase has involved a systematic use of different techniques, including: total station, 3D orthophotos, laser Scanner 3D, solid images.

In particular, the laser scanner data acquisition, integrated with digital images referenced to the points cloud, constituted an excellent database for the construction of 3D model, especially in some areas where the 2D drawings were not sufficient for an easy and precise geometry reconstruction.

The software mostly used for 3D reconstruction is 3DS Max 2009, because of the excellent management capabilities of polimesh, essential to get photorealistic mapping of the digital model. Some parts of advanced modelling difficulty level, such as statues and decorative baroque system were created using other software (Poser, Zbrush) that are useful for optimizing many geometric modifications at a subobject level.

In order to proceed to the vaults modelling, some sections were extracted by the points cloud and imported into 3DS Max. The mapping phase was carried out with the technique of UVW mapping: this procedure requires a close dialogue between the modelling setting and photo-editing software.

The applications of this work concern the possibility to evaluate different hypothesis related to some possible actions to restore the shape of the ancient church, which over the centuries has been undergone many interventions: in particular the possible reopening of some walled up windows in the central dome and currently buffered, it would significantly change the amount of natural light entering from the window surfaces. The three-dimensional model allows to set a physically correct lighting, in addition to constitute a database used by different workers: conservators, architects, building physics experts.

Another application includes the possibility to create different kinds of animations or navigable virtual models, even using stereoscopic vision, in order to raise awareness of the beauty of the building, in order to collect the necessary funds for completing the restoration of the religious complex. These animations are also informative purposes even for common people who can explore the church through online virtual explorations.

1. INTRODUCTION

The technological improvements in the field of architectural survey and three-dimensional modelling caused a rapidly evolving technique of acquisition and data processing.

Nowadays we have a wide choice of instruments and procedures, some of them in the trial phase, which need to be integrated with each other, some others are characterized by with a certain part of empiricism.

In this article we present a significant case study represented by the three-dimensional modelling subsequent to 2D drawings in a 1:50 scale of the interior part of the Chiesa Confraternita della Misericordia, carried out in 2008 by a group of the Politecnico di Torino's researchers.

The research group of Politecnico di Torino was constituted by two different departments: DISET (Building Engineering and Territorial Systems Department) and DITAG (Department of Land, Environment and Geo-Engineering Department).

The three-dimensional modelling phase, below described in detail began after the collaboration between the Politecnico and Arciconfraternita and it was carried out by the authors of this article as a pure scientific advanced search experience in order to understand how to successfully use data derived from the laser scanner survey and 2D drawings in order to optimize the modelling and mapping procedures of digital model. So, this essay describes the case study underlining the following topics:
- the application of advanced procedures for optimizing the time of 3D modelling phase;
- the application and testing of innovative techniques to optimize mesh modelling and mapping;
- the completeness of case study, starting from the surveying up to dynamic representation, and its complexity, given by non-simple geometries modelling;

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* Corresponding author.

- the manipulation of the model, in order to make it navigable.

1.1 Description of the case study

We will briefly describe the main features of the building before proceeding to describe how we modelled the interior of the church and the details.

The survey concerns the interior of the Church of the Baroque period (sixteenth century) that has a single nave of about 36 meters of length and it measures between 10 and 15 meters of width. The room is filled by a succession of three principal brickwork vaults – a ribbed vault over the faithful, a banded vault over the altar and a simple dome with lunette over the apse- connected together by barrel vaults with lunettes. The height of the ridge of the three main vaults are respectively 16.5, 23 and 14 meters.

The decorative baroque part is obviously very rich, characterized by embossed stucco decorations and trompe d'oeil paintings.

1.2 Summary of data and survey's products

The survey project had to take into consideration the constraints and performance requirements to the work - such as the level of graphical detail and metric precision consistent with the content of a 1:50 scale - but also the timeline by optimizing the use of equipment and human resources. The work became in this way characterized by a systematic use of remote sensing techniques:
- Total Station;
- 3D Laser Scanner;
- 3D Orthophotos;
- Solid Image;
- Construction of the database of 3D data issued from 4 laser scans, after filtering and geo-scanning together, using the experimenting software Sirio (beta version) developed by S.I.R., Spin Off of the Politecnico di Torino, achieved by the DITAG researchers.

The points cloud was imported into a vector drawing program and used to identify the decorative parts overhang.
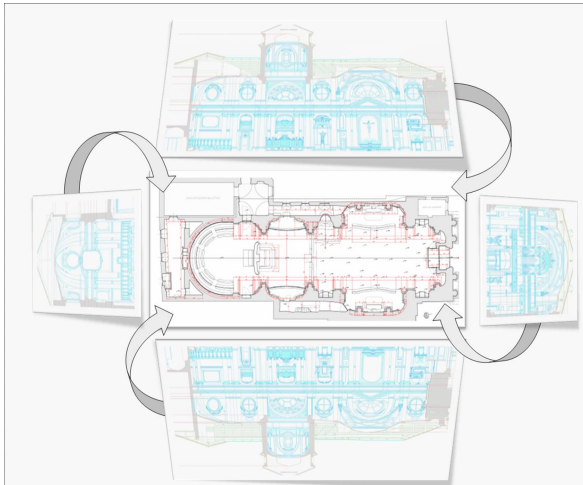

Figure 1. Some survey's products obtained by the first stage of the work

It was tested the use of solid image for the representation of the vaults, using an experimental technique based on the correlation between the Laser Scanner and some digital images taken from a camera assembled with the Laser Scanner.

At the end of the 2D restitution work is possible to state that the only production of two-dimensional graphic drawings does not fully exploit the possibilities of three-dimensional modelling furthered by modern acquisition technologies.

The DISET Department of the Politecnico di Torino in collaboration with the Chiesa Confraternita della Misericordia is planning to develop a research project to investigate the possibilities offered by virtual modelling in order to foreshadow different solutions proposed by the restoration design, with a special look to the lighting system checks and the damaged plasteworks.

2. THE MODELLING PHASE

The three-dimensional modelling process is a step-by-step kind of work. We can identify three main phases:
1) polimesh modelling of surfaces and volumes;
2) mapping for materials appliying;
3) lighting settings: the simulation of the lighting system. We used the technique called "blueprints" for the setting preparation: the two-dimensional drawings - obtained by the architectural survey - were converted in raster format high-definition on rectangular plans suitably located in the work space. This is the way we obtained geometrical data.
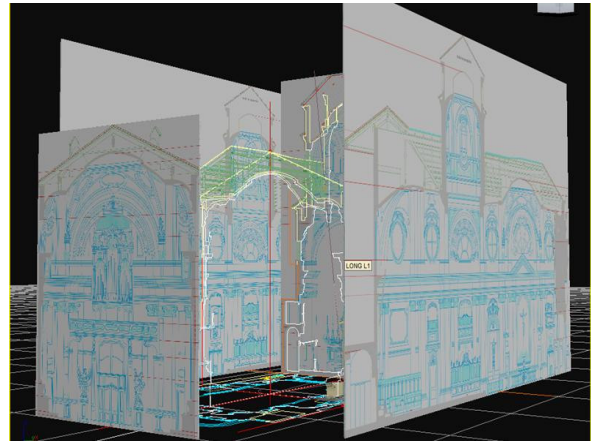

Figure 2. The blueprint technique: 2d drawings and digital images will be assembled together in a 3D environment

We placed sections and plants in the same 3D environment on the vector format resulting from CAD environment in order to obtain the starting geometry for modelling.

The software more used for this kind of work was 3d Studio Max also because some of the three-dimensional modelling application were also used by the authors of the article for some educational contributions for some courses at the I year of Architecture Degree Program at Politecnico di Torino – i.d. "Representation Techniques".

The next step was the polygonal modelling of the structural nave: the pillars, the walls and the vaults. We created the geometry using the technique of modelling polimesh, phasing in details in the subobject way of working, trying to preserve the parametric and reversible features that the software provides until the end of the work.

For the decorations and sculptures modelling we used a software named Zbrush specific for sculpting: it assures a high-level detail definition without increasing the number of vertices of the polygon model. In this regard we created maps of displacement only used for rendering.

Figure 3. The geometrical complexity of the vault system in an exploded perspective

The vaults modelling was conducted extracting solid sections of the cloud of points and then imported into a vectorial modelling software. These sections constitute another three-dimensional reference for a correct draw of the right radius of curvature of convex shapes of cover.

After having completed the 3D model, we carried it to the stage of mapping for a photorealistic materials restitution, giving particular attention to pointing out the state of degradation of some surfaces such as plasterworks and stones. The technique used is called UVW unwrap: the shape of 3D geometries is literally "unrolled" (unwrap) on a two-dimensional work environment; the images resulting from the photographic survey correctly straight were applied over this plane.

3. THE MAPPING PHASE

The mapping materials techniques used were different on the basis of the analyzed element.

We used procedural maps or seamless textures for the covering material of the columns, the balustrades, the altars, the frames and the flooring.
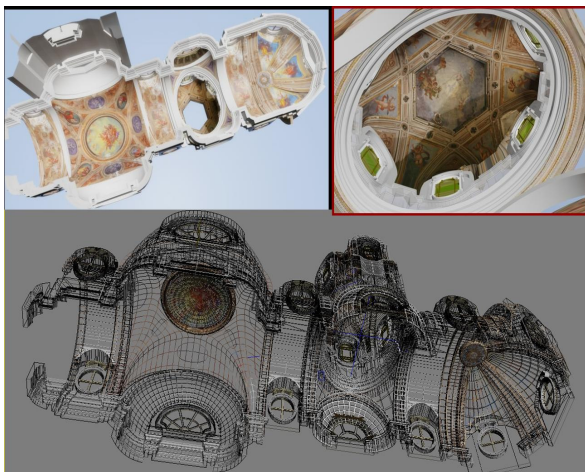

Figure 4. The vaults mapping. On top the final product. Below, the wireframe visualization

The painted walls, the vaults, the statues and the decorations were mapped using the already mentioned UVW unwrap technique, revised in a 2D environment. The data were taken by the digital photographic survey.

This phase required the real-time interaction between Adobe Photoshop, a two-dimensional image editing software, and 3dsMax, the software used for 3D modelling.

For each geometry we created a bidimensional texture using the edit UVW command.

Figure 5. Comparison between the digital reconstruction (image on the left) and the digital image of the actual chapel (image on the right)

UVW mapping is a mathematical technique for coordinate mapping in computer graphics. It is most commonly used to map, it is suitable for associating a 2D image (a texture) to a three dimensional object of a given topology. The name "UVW"- like the standard Cartesian coordinate system - means that it has three dimensions; the third dimension allows texture maps to wrap themselves on some irregular surfaces in complex ways. Each point in a UVW map corresponds to a point on the surface of the object. The graphic designer or programmer generates the specific mathematical function to implement the map so that the points on the texture are assigned to the points (characterized by XYZ coordinates) on the target surface.

One of the more complex parts to model is represented by the four statues placed inside the church.

Figure 6. Print screen of Poser interface: on the right the digital mannequin. On the right the final results that can be exported into 3dsMax

The organic nature of the geometry required the use of an additional software called Poser, a 3D software package for modelling three-dimensional human figures.

The software provides users with a vast library of human figures to be used as a basis for modelling. Each part of the body –

from the length of the limbs to the physical features - can be modified through parametric changes.

Figure 7. Virtual model of the church organ placed at the end of the central nave

Once you reached the right level of similarity between the set template and the subject you want to reproduce, you will need to set up the right posing of the digital mannequin; fortunately, all the templates are already rigged so it is not necessary to create a system of bones and the subsequent link to the model through skin operations as occurs using 3dsMax.

After having completed the posing phase, we exported the achieved geometry, no longer editable, in to the 3dsMax environment, for the subsequent mapping phases. This technique was pretty satisfying because it also decrease the modelling time.

In order to add more details without increasing the number of polygons we used another software package, called Zbrush - a sculpting software - developed by Pixologic.

The software allows you to import low poly models for adding details managing millions of polygons.

The detailed mesh can be exported as displacement or as normal map, in order to be used in the low poly version of the same digital model.
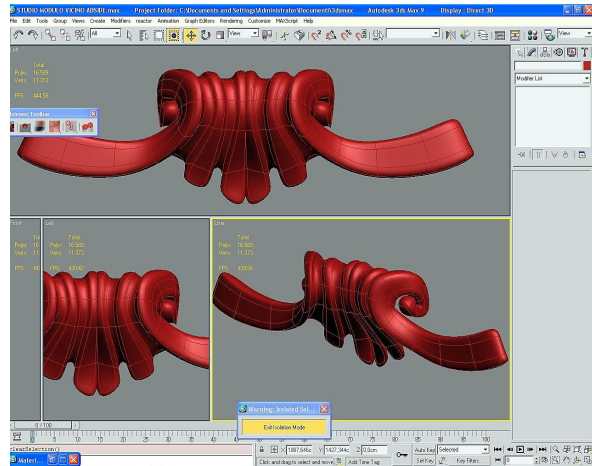

Figure 8. Some decorative parts are modeled with a high level of detail and a particular attention to the number of polygons (low poly way of working)

4. CURRENT USES OF THE STATIC MODEL

We created the static 3d model for two purposes:
- restoring the original condition of things of the degrades clear over the frescoes and the plasters;
- simulating the subsequent restoration interventions for the rehabilitation of the degrades previously described.

Figure 9. Lateral chapel on the left, without material application: clay render

5. THE DYNAMIC MODEL

The subsequent stage foresees the production of an interactive real-time model of the interior of the church but we are still working on that.

We are using a software called Quest3d version 4.0, developed by Act-3D. This program allows you to import polimesh (in 3Ds format) into a graphical programming environment in which the algorithms are constituted by flowcharts.

This kind of approach - similar to the concept maps - makes the setting phase more intuitive and fast. This software also offers you the possibility to use the interactions previously calculated i.e. the virtual walkthrough: in order to get a walkthrough model in a few steps, we need simply to connect the model to the routine inspection of the virtual camera.

Figure 10. Lateral chapel on the left, after the material application: final render

The software recognizes the imported volumes and calculates the interaction and collision between the camera itself and the 3D model previously texture. The recognition of the volumes avoids the crossing of the volumes by the virtual camera, but allows you to interact with them: for example we can give the possibility to climb stairs and letting you feeling the differences in height virtually simulating the user-environment interaction. The output file is a stand-alone executable one, almost like the game entertainment environments (first person shooter).
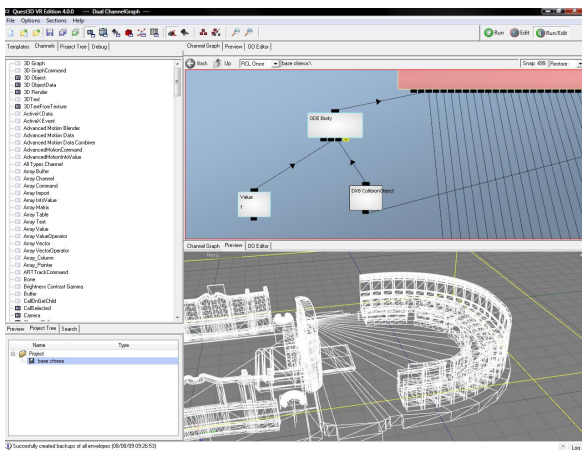

Figure 11. Quest 3D interface: the software works using flowcharts

This technology allows the user to be deep in a virtual model choosing the path in real-time using the keyboard and the mouse.

We believe that this interactive approach should be applied to architecture, to allow a broader knowledge of spaces and volumes of the interiors than using 2D digital images or renderings. The simplicity of the instructions ensures also to widen the catchment area to no-expert users.

6. CONCLUSIONS AND FUTURE DEVELOPMENTS

At the end of this complex work we can draw some conclusions:

- the simultaneous use of different software allowed us to optimize some procedures for modelling and mapping: the use of specific software packages dedicated to certain procedures were more functional than 3dsMax, which is able to absolve the same functionality but spending more time;

- the case study's originality and complexity represent an added value for the final balance of the whole work, which now becomes particularly interesting for the improvement and the subsequent adoption of innovative procedures and instruments in the field of computer graphics;

- this work will be a good practical example for Architecture courses: the authors of this paper are faculty members at Politecnico di Torino, Italy and teach courses like "Representation Technique and Automatic Drawing" at the I year of the Architecture Degree Program. in which the digital modelling constitutes theoretical and operational topics of the teaching;

- from a strictly working point of view, future developments concern the completion of the interactive model, incorporating the possibility of monitoring in real time changing the lighting system parameters connected to the natural and artificial lights using several configurations.

Figure 12. Final render of the interior of the church, in order to evaluate different design and restoration proposals

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