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Giuseppe Amoruso *Editor*

Putting Tradition into Practice: Heritage, Place and Design

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Communicating Through Digital Tools

The Digital Documentation of the Florentine Complex of Santa Maria Maddalena De' Pazzi

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Abstract. The theme of the Documentation for the Conservation of Architectural Heritage is more current than ever on the international scene. The text speaks of the documentation project of the religious complex of Santa Maria Maddalena de' Pazzi, located in the historic center of Florence; this is a subject on which to test protocols for making reliable digital three-dimensional surveys, with laser scanners and S.f.M. technologies, which could be used as a basis on which to return the necessary analysis to the preservation and restoration of the monument. Towards the hypothesis of an integrated survey the intent is to define methods of management and use of models in order to obtain processed two-dimensional useful to the preservation of architectural heritage.

Keywords: Laser scanner survey · S.f.M. survey · Santa maria maddalena de' pazzi · Drawing

1 Introduction

The documentation project of the complex of Santa Maria Maddalena de' Pazzi began in 2015 as a research topic within the academic class held by Professor Bertocci and Professor Minutoli[1]. The topic is important for the Superintendent of architectural heritage which is monitoring the preservation of this monument, especially due to the significance of the monument within the artistic and architectural heritage of the city of Florence. From the thirteenth century the church was born and grew more and more, collecting works of art by artists and projects of the greatest Florentine architects such as the fresco by Perugino, the cloister of Sangallo and the fresco on the ceiling of Chiavistelli[2].

The church of Santa Maria Maddalena de' Pazzi hosted a monastery of nuns founded in 1256–57; it was dedicated to St. Maria Maddalena La Penitente and still stands today along the medieval street called Borgo Pinti, which at the time was outside the perimeter of the city walls. The Gothic building, which at that time had a rectangular hall, forms the core of the present church: its pointed arches are still visible on the southern exterior wall of the church. In 1321 the monastery passed to the Cistercian

[1] The data acquisition campaign began in April 2015 as a seminary within the architectural survey course held by Professor Bertocci and involved 20 students coordinated by the writer; after completing the survey students have continued to study the monument inside of restoration exams held by Professor Minutoli integrating the diagnostic, structural and deformation analysis.

[2] Many works were stolen by Napoleon and are now in France.

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order and changed its name in Santa Maria Maddalena of Cestello[3]. After 1481 the complex had a big renovation: they built a new main chapel with behind it a chapel of the choir and twelve chapels distributed to the sides of the nave, as well as a dining hall, two dormitories and a porch that gave access to the church. The porch was probably designed by Giuliano da Sangallo. In 1628, under Pope Urban VIII pressure, Cistercians moved in the current Cestello church in San Frediano, while in the complex, which was dedicated to Santa Maria degli Angeli, settled the Carmelite nuns. After the canonization of the nun Maria Maddalena de' Pazzi, which occurred in 1669, the complex was renovated with a new main chapel and the ceiling painted by Chiavistelli like a quadrature. When Florence was the capital, part of the monastery was destroyed to allow the widening of Via della Colonna; the preserved part was converted into a school. Since 1926 it became the official church of the French colony in Florence and after the flood of 1966, the French Government has contributed to the restoration of the complex.

2 Objectives

The church and the complex have been the subject of numerous studies in the University of Florence; The recent restoration, which affected particularly the covers and attics, have necessitated an update of the surveys, which have however been conducted only with direct survey tools. The technological development in the field of survey and documentation, which occurred over the past decade, led to seek further progress on the morphological study of the complex, creating three-dimensional digital surveys that fully describe the building.

The research aim is to provide a database of documents and drawings that are useful for the preparation of all the analysis, diagnostic and structural one: a morphological data therefore to base the knowledge of the monument. The survey in this case stands as the first approach necessary to the understanding of the object in analysis; since the project's aim is to describe the state of materic and structural conservation, in order to pursue a coherent research, it was necessary to comply with methodological protocols, that would guarantee the metric reliability in all of the digital survey phases, and process a large number of drawings order to describe all the architectural surfaces (Fig. 1).

This documentation project was an opportunity to continue a line of experimentation aimed at achieving a three-dimensional model of reliable points[4] (in the order of centimeters) even in the absence of topographic control points, but using only one laser scanner instrument, speeding up this way the phase of data acquisition.

Towards the hypothesis of an integrated survey, it was placed as the target to connect the database from the laser survey with three-dimensional models obtained by S.f.M. technologies and to define certain quality standards on the mesh model (Fig. 2).

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[3] The name come from Citeaux, in latin Cistercium.

[4] In this case the goal was to get a reliable survey up to the centimeter.

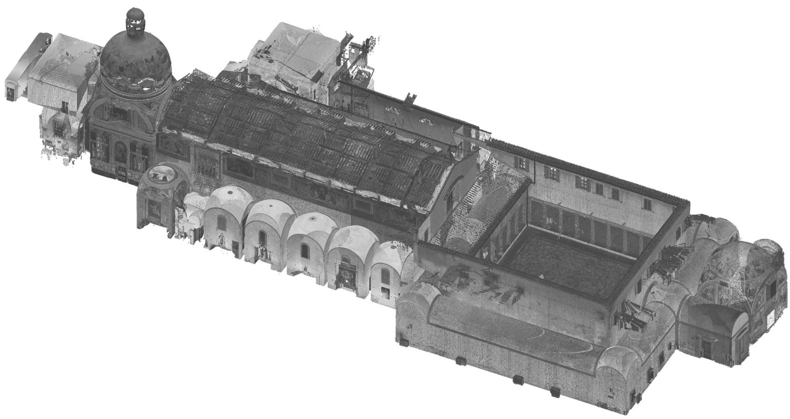

Fig. 1. Recorded total point cloud of the complex

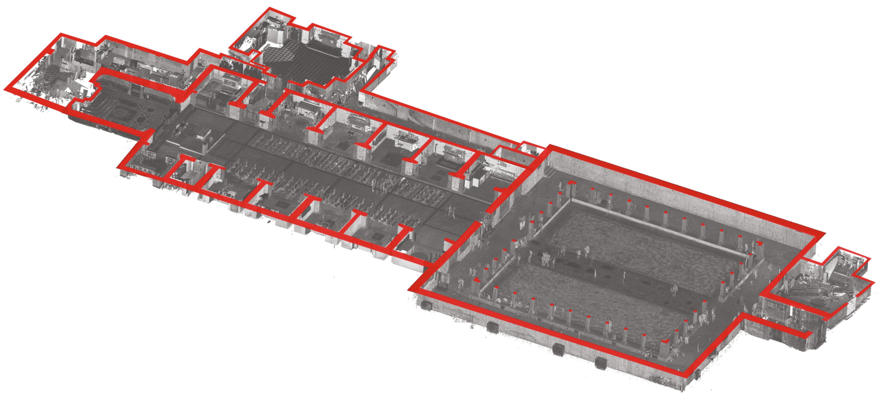

Fig. 2. Total point cloud sectioned at 1.5 m height, used to redraw the planimetry of the complex

3 Methods

The documentation project involved the use of different digital survey methodologies such as the laser scanner survey and the SfM survey. The laser survey was used to provide metrics and morphological information regarding the environments to create a 3D model, made up of points, describing *in toto* the complex; the survey achieved by S. f.M. technologies has integrated textural information of the individual architectural elements, which are essential for further considerations concerning the superficial and structural state of conservation of the masonry walls.

As already said the purpose of the documentation was to provide a set of drawings where to put all diagnostic studies, which is why it was necessary to choose a suitable representation scale. The choice of the representation scale is crucial to determine the density of the information needed to be captured during the survey work: for the restoration of buildings designs must be submitted in 1:50[5] by law. Red during the survey work: for the restoration of buildings designs must be submitted in 1:50 by law. Once it was clear the level of detail to get it was possible to design an appropriate laser survey campaign. The Models Laboratory of the University of Florence has available a scanner Z + F Imager 5006 H, which allows the fast acquisition of point cloud made of several points. About 150 scans were performed within the whole complex that allowed to describe morphologically the church, the cloister, the sacristy, the crypt on the lower floor and the gatter of the church hall. Each scan is not far from the next one more than 7 m and creates a point cloud with mesh acquisition, at the distance of 10 m, of about 7 mm, so as to have each masonry described by at least one point every centimeter; as the only exception some scans were carried out inside the hall of the church: with the intent to properly documenting the quadrature of Chiavistelli, the distance between two points does not exceed 0.5 cm. The acquisition phase has been designed taking into account the subsequent recording phase of the survey: in this case, considering the amplitude of the rooms, the dense mesh of points acquired and the close pitch of the scans, it is preferred to use the combination of black and white target, each identified by its own alphanumeric code, and a well-recognizable architectural points added manually[6]. Where there was narrow links between two rooms reciprocal scans were used in order to maintain the reliability even where there was not to many points in common[7]. During the phase of the detection recording, in the first instance a pre-alignment of the scans was performed on the basis of the target and of the morphological points, afterwards the recording error was improved by adding the cloud-constraint between the contiguous laser stations[8]. The general model obtained was subjected to quality control; despite the nominal error of the instrument on the single scan points does not exceed a millimeter, it has been necessary to cut at several points the cloud, with horizontal and vertical planes, in order to verify that there were no differences between the section wires of different scans[9]. The testing phase of a survey is essential for the reliability of the work: an overall point cloud can apparently seem well recorded, instead it is easy especially in the higher points have deviations greater than those that

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[5] Mario Docci [5] tells us that "it is not possible to delineate and visually appreciate lines in a thickness of less than two or three tenths of a millimeter"; the error of the scale of representation falls in the thickness of the pen, then becomes for the scale 1:50 1.5 cm.

[6] Targets were manually positioned at a height relative to the floor surface that varies between 0.5 m and 2 m, not giving in this way a fairly large delta between the control points along the Z axis: thereby blocking efficiently the rotation in the XY plane but allowing even with small displacement errors of the target large zenith angle rotation errors; the morphological control points serve precisely to block the rotation of the portions of masonry higher, adding additional constraints along the vertical axis.

[7] The concept of reciprocal scanning is derived from the topography, or by the mutual reading or married in the collimation of a point; See [8, 9].

[8] Once added to the target cloud-to-cloud, the weight of the morphological control points and the center of mass changed, whereas a point architecture is less reliable compared to a target recognized by the software, it must be conferred then minor importance and this.

[9] The offset error of the sections for the 1:50 scale must not exceed 1.5 cm; in this case it was possible to obtain a model with less than one centimeter error.

may be acceptable; a misregistration of the model comes at the expense of all the next redrawing (Fig. 3).

Fig. 3. Processing through SFM methodologies: in this case we see the level of detail obtained from the model texture of a vaulted structure richly painted inside one of chapels

To easily manage the database, it was helpful to divide the total cloud layers by assigning a level to each scan; so it was possible to display, from time to time, only the scans that were useful to describe the portions of the monument to analyze. The total model obtained allowed us to extract all the sections needed to describe the surfaces of our building[10].

In parallel to the laser scanner survey it is a photographic survey campaign was carried out finalized to the creation of textured three-dimensional models. The acquisition by S.f.M. technologies has greatly developed in the last few years, far as to propose it as expeditious tool to use instead of the laser scanner for measurements up to 1:100 scale; in our case it has affected all areas of the complex already detected by the laser instrument. Today softwares are able to obtain such high quality 3D models, they could not, however, by their nature, being passive instruments, to confer to the space directly dimensions in metric units. As stated purpose of the research was to obtain the morphological basis to support diagnostic analyzes, which is why the three-dimensional models of the rooms have been made on an appropriate scale[11].

[10] The extraction of the sections takes place through the consolidated process in the years rasterization in orthoimage of the cloud of points to proper definition; See [8, 9].

[11] For the scale of 1:50 is used by convention the ratio of six pixels per centimeter during the acquisition of frames.

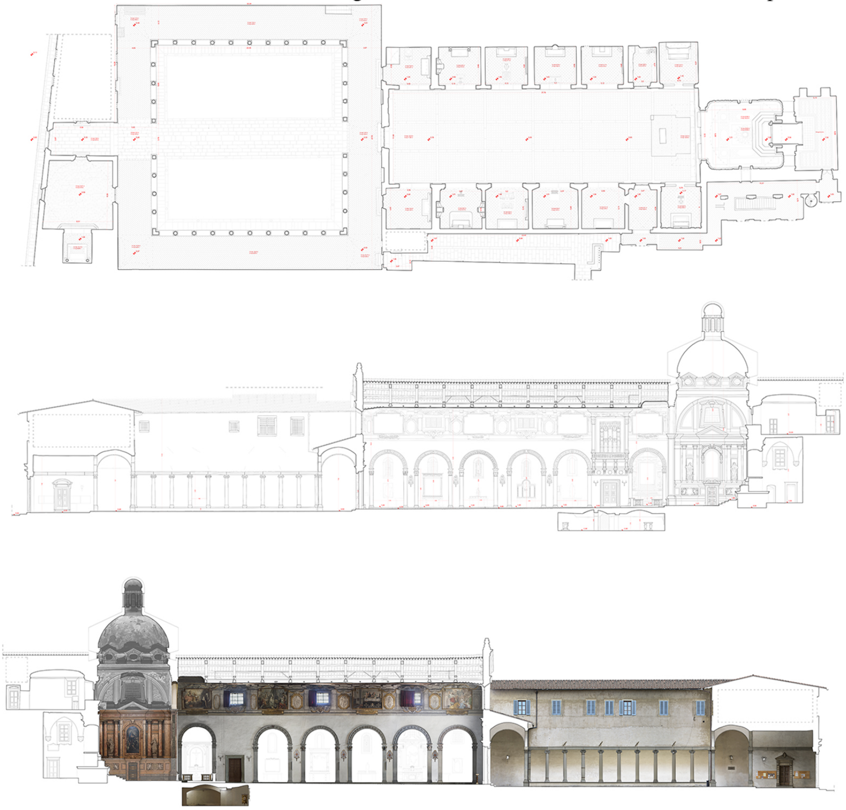

Fig. 4. Final 2D drawings: (Top) general plan of the complex, (Middle) wireframe restitution of a longitudinal section and (Bottom) opposite section with photoplan.

During the acquisition phase, at eye level pictures were taken at an appropriate definition and quality and were aligned within the dedicated software (Agisoft PhotoScan v.1.1.4). After the initial alignment and subsequent densification of data were created meshes, within another model management software (Geomagic Studio 2012): to the point cloud coming out of alignment has been first reduced the digital noise; it was created right after the mesh of triangles that form the model; 3D has been optimized by eliminating spikes, sharp corners, intersections and other imperfections. The optimized model has been re-imported, to be textured on PhotoScan. To verify the reliability of the photographic survey, the 3D model, which was obtained was scaled,: this was possible on the basis of the laser scanner survey, thanks to the identification of easily recognizable morphological points both on the cloud model and on mesh model. The points of a point cloud are described by polar coordinates (x; y; z;) which have been attributed to a homologous points of the model. The photogrammetry software now have a scaled model not based on pixels but as the point cloud on metrical coordinates and can provide the information about the deviation error of the selected points, where error means the deviation of points from the cloud: to fit within the error parameters of

1:50 scale representation are accepted models with less than 1.5 cm error. Each room was dealt on different model in order to allow adequate definition of the texture; after having scaled the model based on the new coordinates of points system it is still hypothesized to bring together the various rooms into a single 3D by simply copying and pasting the various results into a single worksheet.

After the acquisition phase the survey and recording, it began the elaboration of the two-dimensional drawings, by university students. Concerning the wireframe drawing of the sections, the work was designed to be carried out on CAD sheets standardized, divided by layers, created ad hoc for the analysis in building; in this way the main projections and the individual architectural elements were detected with closed polylines. The wireframe drawing has been integrated with the orthophoto extracted from PhotoScan, always verifying the correspondence between photomap, drawing and point cloud (Fig. 4).

4 Conclusions

The documentation project of the complex of Santa Maria Maddalena de' Pazzi has provided another example of how you can create a point cloud without the use of total station and keeping under control the registration error; the study on photographic models has allowed us to understand the importance of working properly mesh model on specific software, in order to have a more reliable 3D on which to place the texture coming from the photographs.

Future developments in the documentation will lead to integration of diagnostic data and structural survey so as to expand the knowledge of the building and to have a general indication of its state of preservation. For the purposes of understanding of the static and structural behavior of the complex it will be important to study the information concerning the evolution of the building through appropriate stratigraphic studies concentrated especially in the areas of the attics where the traces of the preceding plants of the monument are still visible. They have yet to be explored in the survey and in the redesign some environments such as attics, which are hardly accessible, and methods for the detection of the ceiling frescoes by Chiavistelli.

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