#### INTEGRATION OF DIGITAL TECHNIQUES FOR THREE-DIMENSIONAL SURVEY: THE CASE STUDY OF THE BAROQUE CHURCH OF "SAN GIOVANNI DECOLLATO" IN TURIN (ITALY)

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#### **ABSTRACT:**

This paper describes an experience of survey (baroque church of San Giovanni Decollato in Turin - Italy) that focused on the search for a useful integration of several techniques in a digital data stream from data capture to the final model. In order to respect the scheduled time and constraints, the project is characterized by: a) the use of different techniques for the optimization of equipment, human resources and working time; b) the systematic use of remote sensing techniques: total station, 3D laser scanners, 3D ortho photo, solid image. c) testing the functionality of a new software (beta release) for the vectorial transformation of the solid image. The survey operations have been characterized by the cooperation of researchers associated with two different disciplines: Topography and Representation. In fact, the complexity of the baroque architecture required a careful consideration of the decorative details to be represented. On the basis of this experience, it is possible to come to the following considerations:

- especially in presence of external constraints, typical of real cases, the time required to human engagement for the integration of different procedures outclasses the time of automated acquisition and processing;

- the vectorial transformation of solid images is effective for continuous surfaces, while it is difficult to apply to discontinuous surfaces. In case of an architecture with complex decorative details the solid image should be integrated with other systems.

#### 1. THE CASE STUDY: CHARACTERISTICS AND CONSTRAINTS

#### 1.1 Introduction

The information revolution in the field of architectural survey brings a rapid developments of techniques for data acquisition and processing. The surveyor has a wide choice of procedures and instruments, which need to be integrated with each other, sometimes with a dose of empiricism.

Therefore, it is symptomatic of this issue the survey of the baroque church of San Giovanni Decollato in Torino (Italy) performed in 2008 by a group of researchers from the Politecnico di Torino and of which we want to illustrate the main features. This survey, in fact, needed the integration of various digital techniques in the flow of digital data, from the acquisition to the final model.

The case study in question is not so much the paradigm of a standard procedure, but rather it is symptomatic of the need to search for better integration of different techniques to optimize the result with respect to constraints and changing real-life situations (such as costs, time, accessibility of the house).

This essay is meant to describe the case study, that is significant for:

- the application and testing of innovative techniques and software for the metric measurement, in particular for the twoand three-dimensional graphical modelling;

- the application of procedures typical of university research to a real case study;

- the application of advanced instrumentation and procedures to optimize results, time and costs;

- the completeness of case study, from metric survey to modelling.

## **1.2** The object of the survey: summary of the characteristics of the church

Before the description of the phases and problems of measurement, it is necessary to describe the characteristics of the building.

The survey covers the inside of a Baroque church located in the historical center of Turin. In 1720 the Confraternita della Misericordia (Brotherhood that was devoted to bring spiritual and moral support to prisoners condemned to death) buys and install in the convent that previously was property of the nuns of Santa Croce.

The Church was rebuilt in 1751 by Filippo Nicolis di Robilant. Particularly valuable is the vault over the altar that is inspired by the famous Baroque architect Guarino Guarini.

From a geometric-constructive point of view, the church has a nave of 36 meters long and 15 meters wide. The interior of the Church consists of three areas covered by masonry vaults. The height of the three main domes is respectively 16.5 meters, 23 meters, 14 meters. A continuous ledge runs along the entire perimeter inside the hall.

The baroque decorations are obviously very rich; we can find stucco decorations in relief, and paintings with a *trompe l'oeil* effect. Before the recent restoration, wall surfaces showed different types of degradation, in particular efflorescence, caused by infiltration of rainwater and rising damp, which caused detachment of plaster; the building showed a significant structural lesion in the north-east corner wall.

Even in other towns there are churches owned by Confraternita della Misericordia; it is interesting to make a comparison with the photogrammetric survey of the church Confraternita della Misericordia in Savigliano made by researchers of Politecnico di Torino (Lingua, Rinaudo, Piumatti, 2003).



Figure 1. The interior of the hall of the church, showing a rich baroque decoration.



Figure 2. The complex masonry vault above the altar (inspired by the vaults of the great baroque architect G. Guarini). The surface shows different types of decoration.

## 2. THE DESIGN OF THE SURVEY AND GRAPHIC PROCESSING

The integration of different techniques and procedures for acquiring and processing data, the different format of data and especially the testing of innovative and still elaborating techniques and tools, have required careful design of the survey operations.

The design of the survey had to take into account the constraints and performance requirements, such as:

a) the detail level of graphical information and metric precision consistent with the proper content of scale 1:50;

b) the preparation of 2D drawings to contract out the design of restoration;

c) the scarcity of archival documents because of the ongoing reorganization of the archive of the "Confraternita della Misericordia";

d) the inaccessibility of high shares of the Church (especially of the lantern);

e) the delivery of the drawings in accordance with a preordained scheduling:

- 15 days for the plants of the ground floor and the level below the ledge;
- 20 days for the first longitudinal sections (below the inside ledge);
- 15 days for the cross sections and to end the longitudinal sections;
- 7 days for the vaults, drawn through an orthogonal projection from the bottom;
- 7 days for the details in scale 1:20 (portion of longitudinal section corresponding to a structural lesion in the side of the facade).

The timing was rather tight and mostly characterized by an unfavourable time allocation for the best use of the various specialists of the research group.

In order to respect the time, optimizing the use of equipment and human resources, the design was characterized by:

a) use of several important techniques in the different phases;

b) systematic use of remote sensing techniques:

- Total Station
- 3D Laser Scanner
- 3D Orthophotos
- Solid photography

c) testing of software for solid photography (Bornaz, Dequal, 2003) developed from a spin-off of the Department of Land, Environment and Geo-Engineering (DITAG) of Politecnico di Torino;

d) creation of data model for 3D virtual modeling.

## 3. SUBDIVISION OF THE SURVEY IN OPERATIONAL PHASES

The design of the survey and the graphic modelling ask for several stages, differentiated from one another by a chronological point of view (different and subsequent times) and from an operational point of view (chronologically overlapping phases but with different personnel and operations involved). The operations were organized on the basis of a Gantt-type design, essential for compliance with the assigned scheduling.

The operating elements of the graphic restitution of the survey are represented by a set of models - in particular the conceptual model of the Church - a series of tangible and intangible components (human skills, infrastructure, tools, procedures) and a flexible organization of the interpretative and operational phases of the drawing. References taken into account in the documentation of the survey are:

**The conceptual model of the Church.** The conformation of the Church can be thought as a result of several components:

a) structural, that is, all the system elements that have a lead function of the building, that is understood not only in a static sense, but mostly geometric: they are the formal frame of the first level, the pure geometry of the inside framework of the church;

b) functional and decorative, formalized through:

- juxtaposed apparatus in relief (stuccoes, ledges, mouldings);

- frescoed coating features;

- items of movable and fixed furniture.

The elements of the metric survey/graphic restitution system. The metric survey/graphic restitution system is characterized by efficiency features and a number of factors that promote its effectiveness for future use of processed products.

In terms of efficiency, the features that characterize the process are:

- the skills involved (people);
- the geometrical survey and graphic restitution equipments (hardware);
- the computer science tools for data processing (software);
- the set of operating procedures adopted as a reference by the working research group (immaterial infrastructure).

The effectiveness of the produced elaborations mainly resides in the quality and reliability of the geometric data collected, properly and promptly documented and geo-referenced (metadata). The graphic language used for communication of the metric survey guarantees the permanence of the quality information of directly and indirectly measured data - through the appropriate critical interpretations that have guided the measuring and drawing phases - and allows the unambiguous reading of the graphic signs used according to the widespread conventional praxis.

The elements of critical interpretation and of its subsequent graphic restitution. The transition from a discrete model to a continuous one (open or closed linear geometric entities) was supported by the critical interpretation of the geometries. Auxiliary documentation and apparatus and specialist skills and experiences of the involved Departments have been usefully employed to select the information to be used. The auxiliary documentary apparatus is primarily composed by photographic surveying, preparatory sketches and schematic drawings of total or specific part of the building, usually made by hand free, aimed at architectural survey and containing morphological and dimensional information of the Church, with an indication of the sequence of points taken with the total station.

# 3.1 Phase 1-2 weeks: survey and representation of the horizontal sections, accomplished by integrating topographic survey

The phase 1 required the fulfilment of the following operations:

a) design of the trigonometric network, definition of coordinate system, measurement and compensation of the trigonometric network on the plan;

b) measurement and compensation of the *altimetric* reference network; *project of the survey of points*;

c) detailed *celerimetric* survey of the points concerned with two horizontal planes: the first at 10 cm above the bases of the

columns (horizontal section in succession named "ground floor plan") and the second at 10 cm below the capitals of the same columns (horizontal section in succession named "first floor plan"). Many others points were needed to complete the drawings of horizontal section with the projection of all shapes above and below the section plane;

d) integration of the celerimetric survey with exhaustive manual measurements, especially oriented to the description of the decorative system;

e) import of topographical data in a drawing software;

f) two-dimensional drawings of the ground floor plan and first floor plan: in this phase, as in subsequent stages of the work of representation, from a methodological point of view, particular attention was focused on procedures for data selecting and data processing (instrumental and manual data) in order to produce graphic models in a qualitatively and quantitatively correct way, depending on the scale of representation, the accuracy associated with it, the purposes of the survey.

#### 3.2 Phase 2-3 weeks: survey and partial representation of the vertical longitudinal sections, accomplished by integrating topographic survey and straightening of digital images

Phase 2 is related to survey and graphic representation of two partial longitudinal sections (up to the continuous ledge of the nave), with the plane of vertical section passing through the longitudinal axis of the nave, but opposite direction of projection: one in the west side of the church classroom, the other eastwards.

This phase is characterized by the integration of the following operations:

a) topographical celerimetric survey of points in the inner surface of the nave concerned with the intersection of a vertical section plane passing through the longitudinal axis of the church; many other points of reference are needed to complete the vertical sections with the projection of all projected shapes (galleries, fixed furniture, decorative system, etc.);

b) integration of the celerimetric survey with manual measurements of details, especially oriented to the description of the decorative system (ledge, vaults and detail of the capitals, decorative system, in the portion accessible by the organ balcony);

c) digital analytic straightening of photographic images related only to flat surfaces below the internal frame;

d) import of topographic data in a drawing software;

e) graphic two-dimensional representation of the longitudinal sections below the internal frame: even in this case representation issues are quite sensitive, because they involve important decisions on the degree of detail and on geometric simplification of the decorative system, the fixed furniture and of the main furniture, always remembering the operational purposes of the further interventions.

Introductory to the phase 3 was the survey realized by laser scanner and the subsequent construction of a three-dimensional model of the points, according to the following operations:

- LIDAR survey by 3D laser scanner: using of the laser scanner scans was performed from 4 different positions in order to rebuild in the most exhaustive way the entire three-dimensional model of the analysed church.
- construction of a 3D data model from the four laser scans, after filtering and geo-referencing the scans made by experimenting the software Sirio achieved by the research group of DITAG (Chiabrando, Nex, Piatti, Rinaudo, 2008).



Figure 3. View of the tridimensional cloud of points obtained joining four different laser scanning.



Figure 4. The result of the tridimensional vectorialization of the solid image.

# 3.3 Phase 3 – 2 weeks: survey and representation of the vertical cross-sections and completion of longitudinal section accomplished by integrating topographic celerimetric survey, LIDAR survey and solid image.

Phase 3 is related to the survey and the representation of three cross-sections and to the completion of the longitudinal sections with vaulted surfaces and edges superjacent the continuous internal ledge.

In this phase, the same systems of survey and representation have been used, integrating them with the cloud of point data, generated from LIDAR survey performed with 3D laser scanner, and with data derived by interpretation of the "solid image", as follows.

The contribution of LIDAR survey and solid images are very important results for the geometric interpretation of the vaulted surfaces. The height of vaults, with the complexity of the baroque decoration system (characterized by the simultaneous presence on the vaulted surface of decoration in relief and painted trompe l'oeil decoration), make it difficult to interpret the geometry of vaults and the hierarchy of decorative details.

Starting from the cloud of points, multiple sections have been used, importing it into a CAD drawing software, to identify the superjacent decorative shapes (with section of the point cloud we mean points between two parallel planes distant 2 cm.).

To represent the vaults, the solid image was tested: the solid image is a experimental technique based on the correlation of a laser scan and the photographic images taken by a binded camera on the laser scanner (Chiabrando, Nex; Dishes; Rinaudo, 2008).

In particular, the researchers responsible for the representations conducted trials on vectorial solid images, testing the software "Sirio" (beta version) developed by SIR, Spin Off of the Politecnico di Torino.

## **3.4** Phase 4 - 7 days: plan of the vaulted roof obtained via orthorectified photograph methodology

Data belonging to the cloud of points taken with LIDAR and photographic pictures taken with zenith axis have been integrated in order to obtain an orthophoto projection of the vault. For interpretation and choice of the decorative artistic elements have been used sections of the point clouds.

## 3.5 Phase 5 - 7 days: survey and representation through integration of orthophoto projection, 3D model and direct measurements

A procedure similar to that used to draw the plan of the vaulted roof of the Church (orthophoto projection) has been used for the survey and the graphic restitution (in scale 1:20) of the front internal strip in correspondence of the structural lesion of the North-East corner.

#### 4. CONCLUDING REMARKS

At the end of the architectural survey of the Church of the Confraternita della Misericordia, it is possible to conclude:

- at the present time, the digital data flow coming from the acquisition instruments (total station, laser scanner, calibrated photo cameras) down to the virtual model and to the graphic representation, it is not automatic. Especially in presence of external constraints typical of real cases the time requested to the human operator in order to integrate the different procedures is widely longer with respect to the acquisition and automatic data processing time;

- solid images vectorialization is certainly very efficient for continuous surfaces but strong difficulties emerge in presence of discontinuities. In the case of an architectural building characterized by a complex decorative apparatus it is necessary to foresee an integration of the solid image with the information coming from other system output;

- traditional 2D drawing does not take advantage from the peculiarities of a 3D modelling produced by the modern acquisition instrument and devices.

In order to identify a more efficient way for using 3D data, the research team is going on to experiment new methodologies of virtual modelling starting from the data obtained in the present data acquisition campaign. (Lo Turco, Sanna, 2009).

More over, the methodological approach of this case study has been used also for educational purposes in the academic courses dealing with the management of 3D data to build 3D virtual models. In the present time, within the PhD Program Cultural Heritage, a research about the possibilities given by the virtual modelling for monitoring and testing the restoration yard is in process.

The Politecnico di Torino – Department of Building Engineering and Territorial Systems (DISET) plan, in collaboration with the Confraternita della Misericordia, to develop the research in order to investigate the possibilities given by the virtual modelling to forecast and control different operating solutions proposed by the restoration design. In particular, these procedures will be adopted to test the lighting technologies and for evaluating the characteristics of the surfaces to be restored.

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This article illustrates the survey and representation methodologies used and the results obtained within the consultancy contract between the Politecnico di Torino -Department of Building Engineering and Territorial Systems (DISET) and the Arciconfraternita di S. Giovanni Battista Decollato detta "della Misericordia" di Torino, entitled "Architectural survey and graphic representation of the Church of the Confraternita della Misericordia located in via Barbaroux 41 in Torino - Lotto A: Survey and graphic restitution in scale 1:50 of the inside of the nave of the Church"

The Politecnico di Torino research team belongs to the Departments of Building Engineering and Territorial Systems (DISET) and of Land, Environment and Geo-Engineering (DITAG). It is composed by prof. eng. Secondino Coppo (research director), prof. eng. Fulvio Rinaudo (metric measurements responsible), eng. Maurizio Bocconcino (DISET), arch. Filiberto Chiabrando (DITAG), eng. Elena Marchis (DISET), eng. Francesco Nex (DITAG), eng. Dario Piatti (DITAG), eng. Paolo Piumatti (DISET), arch. Marco Vitali (DISET); eng. Marco Sanna, contract professor at the Politecnico di Torino, has been added to the group as virtual modelling expert.

Software Sirio (Beta version) tested and used for restitution of the solid photography is developed and engineered by SIR (Soluzioni Innovative per il Rilevamento) Spin-Off Company of Politecnico di Torino.

Checking, testing and monitoring the different phases of the restoration yard of the Church of the Confraternita della Misericordia will be the subject of the Ph.D. Thesis of eng. Elena Marchis.



Figure 5. View of the interface of the software for the vectorialization of the solid image; the software Sirio (beta realease) was tested during the survey.





Figure 6. The 3D orthofoto was used to obtain the representation of the vaults.

Figure 7. One of the final drawings: trasversal section (original scale 1:50) of the vault over the altar.



Figure 8. One of the final drawings: longitudinal section (original scale 1:50) of the hall of the Church.