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DIGITAL PHOTOGRAMMETRY: A STANDARD APPROACH TO CULTURAL HERITAGE SURVEY

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ABSTRACT

Digital photogrammetry offers an easy and economical approach to the metric survey of cultural heritage. New software able to manage all photogrammetric procedures (orientation and plotting) are now offered at low cost. They run on standard PC and offer user-friendly interfaces allowing them to be used even by unskilled operators. Photogrammetric survey of cultural heritage can be managed by two different specialists: a photogrammetric expert who plans and executes the image acquisitions, the control point survey and the orientation of the images and an architectural surveyor who interprets the 3D model in order to extract all the necessary information considering the goals of the survey.

The paper describes a standard metric survey organisation considering the two different skills with which to build the 3D model and to extract the traditional representations required to understand the object and to plan a correct restoration procedure.

1. INTRODUCTION

The research activities in the field of geomatic applications in cultural heritage concern both the proposal of innovative techniques (e.g. digital photogrammetry, true digital orthophoto production, laser scanner, information systems, etc.) and the practical application of them to real cases.

The study of new methodologies is an interesting topic for surveying researchers but the information and the suggestions coming from the application of surveying technologies by the end users (e.g. conservationists, architects, etc.) have the same importance.

One of the main goals of C.I.P.A. is to offer the possibility of sharing experiences between those who know the geometric survey techniques and those who know how to survey cultural heritage.

The best way to carry out this objective is to perform real and complete applications in order to highlight the degree of satisfaction and the real applicability of the survey proposed techniques.

The present work shows an application of digital photogrammetry to the survey of the remains of a church which will be converted into a conference hall for the University.

The survey of a cultural heritage object, in order to support a restoration project, is not only a simple recording of the geometric aspects: there are many ways to record and represent the geometry depending on the different intended uses of the results.

In the application here presented the classification of the decay, both structural and decorative, and its correct location in a given reference system have the same importance as the purely geometric aspects.

While geometric problems can be correctly understood by photogrammetrists, the other aspects of the survey must be performed by specialists; in fact the knowledge required is not

covered by the engineering skill typical of photogrammetric researchers.

2. DIGITAL PHOTOGRAMMETRY

Digital image processing has simplified the practical approach to photogrammetric survey in such a way that even non experts can perform the plotting and interpretation phases.

The distinction between acquisition and plotting units in digital photogrammetry can help to make the different rules in a photogrammetric survey process clear.

The digital photogrammetric acquisition unit is the combination of hardware and software dedicated to:

- the acquisition of the required images;
- the acquisition of the necessary coordinates in order to orient the acquired images;
- the execution of the measures and computations in order to estimate the orientation parameters.

Once all the orientation parameters are known, the geometric survey is yet performed in a potential way: in fact by using stereoscopic viewing the operator has just to select those points needed to represent the aspects under examination.

The digital photogrammetric restitution unit is the combination of hardware and software dedicated to:

- finding the homologous images of the interesting points;
- classifying the collected information in logical levels;
- representing the results in an efficient way.

The only difficult step in the previous topic list is the homologous images identification, but digital photogrammetry has developed automatic procedures useful to solve the problem (e.g. autocorrelation) in a user-friendly way.

It is clear that all the topics of the acquisition unit require a specific technical expertise and can be correctly designed and

executed only by photogrammetrists. In the same way it is clear that all the topics of the restitution units can be correctly performed only by the end-users of the survey which can operate independently from the acquisition and orientation phases.

3. THE CONFRATERNITA DELLA MISERICORDIA

The ruins of the church *Confraternita della Misericordia*, also called *Croce Nera*, form an area of decay in the historical centre of Savigliano, a city of ancient origin in southern Piedmont. The historical centre of this town developed inside the medieval fortified walls, and it is mainly composed of complex buildings of religious origin, now used for cultural and educational purposes (like the St. Peter's, St. Chiara's and St. Francisco's convents) or abandoned, like the St. Monica's convent and the *Confraternita della Misericordia*.



Figure 1. Urban hand made 3D model (M. Nicolosino, 1815) showing the church and the surrounding religious buildings (Local Museum of Savigliano)

In the last year the recovery of St. Monica's convent as future centre of the University has been decided; as a result the Town Council is going to finance the restoration of the *Croce Nera* church by means of a conversion to a multifunctional hall.

The church, designed by A. Rusca and F. Piazzola, was erected between 1614 and 1616, but only in 1655 it was completed.

The construction of the bell tower started in 1664 and finished in 1711 with the construction of the upper addition designed by Lorenzo Barattà.

After the Second World War the decline of the church began: as a result of the bombings, extraordinary maintenance works were necessary in 1947-1949.

In 1960 the church was closed for religious ceremonies. The church was judged unsafe, and in 1967 the Town Council requested a demolition order from national authorities: the response was an order to restore the church.

In 1968 a portion of the nearby St. Domenico's convent was demolished, and in 1971 the church's adjacent buildings were pulled down too. On 29 March 1984, a decree by the Mayor ordered the demolition of the church but the works were stopped once again.

Since then *Croce Nera* church has been a ruin: the roof, the vaults and part of the flanks and the apse have collapsed. The area where the church stands is still off-limits (see Fig. 2).



Figure 2. The church before and after the damage of 1984

After twenty years of abandon, the new Town Council of Savigliano started the procedures for the restoration plan of *Croce Nera*. Preliminarily (April 2002) it ordered the architectural survey, that ended on August 2002.

4. THE SURVEY REQUIREMENTS

Considering the state of the ruins, the survey operations have to meet certain requirements:

- necessity of an urban survey of the surrounding area;
- representation of the decay geometry: the state of the ruins is determined in substantial way from the decay of the structures;
- metric survey of the volumes with executive and homogeneous degree of precision for all the buildings;
- tight three-dimensional correlation among the metric information by using several views of the buildings.



Figure 3. Rests of the vaults

The urban survey of the fronts of the surrounding area was considered necessary by the surveyor even if not required by the Council, because the ruin, beyond its physical disrepair, is an element of a more general question of decay in the town. So it was also necessary to document the disrepair of the nearby buildings; in this case lower performing techniques can be used.

The architectural survey of the church required methods able to give metric data with homogenous precision concerning two aspects:

- from the geometric point of view, even for the inaccessible parts, such as the bell tower and, above all, the remains of the vaults;
- from the point of view of decay analysis, determining the geometric conformation of the ruins at the same level as the original structure.

These requirements will influence the acquisition and restitution procedures.

The survey rises from the building's intrinsic characteristics and from the extrinsic purposes of the plan.

In addition it is necessary to consider that the mixture of architectural elements, structural damage and superficial decay will require a choice of the representative elements.

5. THE SURVEYING PHASES

The survey has been developed in the following steps:

- urban survey of the fronts of the adjacent buildings by means of digital rectification of photographic images;
- architectural survey of the church using digital photogrammetry.

The use of rectified images allows the creation of a three-dimensional model with the representation of all the fronts. Such a model therefore contains a lot of geometrical information about, chromatic characteristics, materials and state of disrepair of the surrounding fronts. The creation of the model is possible at a low cost, due to the lower degree of precision needed.

The use of photogrammetry for the architectural survey allows:

- the acquisition of the data related to the top portions of the building, in particular of the currently inaccessible bell tower and of the remains of the collapsed vaults;
- sufficient metric precision for an executive project, also and above all for the collapsed high portions;
- the acquisition of the data related to the structural and superficial decay;
- the creation of a 3D model of the whole ruins, more helpful in understanding this building in addition to the traditional orthographic representations.

As described in the previous paragraphs digital photogrammetry facilitates the work of the architectural surveyor, even if not specialized in photogrammetric restitution.

The survey runs in two separate steps:

- the creation of the photogrammetric model (control point acquisition, orientation of the images) realized by a photogrammetric expert (in this case from the Laboratory of Photogrammetry of the Department of Georisorse and Territorio of the Politecnico di Torino);
- the restitution (plotting and interpretation) realized directly from the architectural surveyor specialized in

the interpretation and the knowledge of the building patrimony, after brief training. The variety of elements to be represented requires a continuous selection of the data based on a specific architectural background.

First, a topographic network has been signalised all around the church and the surrounding area. The angular and range measurements have been carried out by using a total station and the adjustment has been performed by the least squares method.

The survey of the control points necessary for the image orientation and the survey of the building facades has been done by a traditional topographical approach using a reflectorless total station.



Figure 3. Photogrammetric taken of the bell tower

The images have been acquired by means of the semimetric ROLLEI 6008 camera ($f = 40$ mm): the scales of the images range from 1:800 to 1:400. In order to avoid perspective occlusions all the images have been recorded in the normal case of the photogrammetry. The images of the top parts of the buildings have been acquired by using "ad hoc" solutions (see Fig. 3).

The photographic images have been digitised by the RM2 (by Wehrli) photogrammetric scanner at 2100 dpi geometric resolution.

The image photogrammetric blocks have been triangulated by using the SVTRIA software (Menci Software – distributed by LEICA) and the final discrepancies of the control points used are less than 1 cm.

The rectification of the images for the urban survey has been performed by the ARCHIS software (by SISCAM). The facade of the buildings near the church have been composed in single images (one for each front line) by merging all the treated

images. A radiometric adjustment has been performed in order to reduce the different light exposures of the images used.



Figure 4. Semimetric image of the church

30 of the 70 acquired images have been used during the restitution of the church. More than 25 logical levels of information have been used during the collection of the geometric data. Figure 5 shows the results of the plotting executed on the main façade of the church: different colours demonstrate the interpretation and classification performed during the restitution by the operator.

The restitution results have been integrated by using the remaining images and by a field inspection mainly for the perspective occlusions and detailed interpretation of the geometric and structural disrepair improvements.

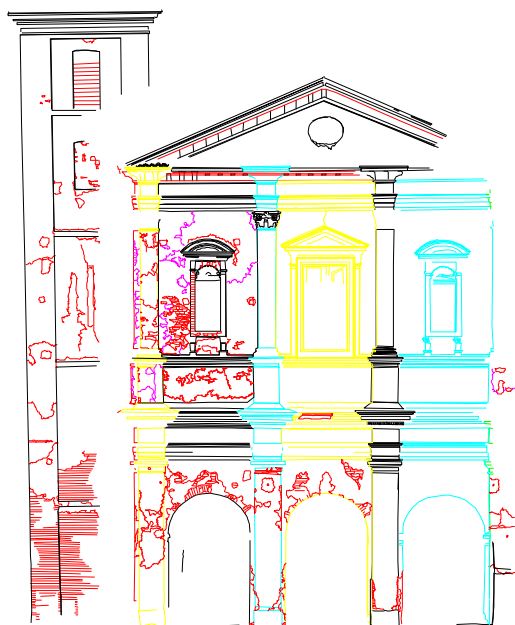


Figure 5. Plotting results of the main façade

6. THE REPRESENTATION OF THE RESULTS

The representation of the results has been done both with digital and analogue (tables on paper) technology (see figures 6 and 7).

During the drawing assembly, both of the 3D and 2D models, different types of lines have been used in order to highlight different aspects: 0.4 mm thick lines for sections, 0.2 mm thick lines for principal visible elements, 0.13 mm thick lines for degradation, fissures, holes, missing bricks and rear elements and 0.05 mm thick black or grey lines for decorations and background elements.

The decay survey has been performed by mainly putting the structural problems of the building in evidence. The following topics have been particularly selected: wall fissures, principal plaster fissures due to the static assessment of the walls, brick placing, holes and missing parts, tie rods and chains, restructured elements, wood elements, signs of ancient adjoined buildings, plaster lacks and main plaster exfoliations.

7. CONCLUSIONS

The results of the survey are now being used by the team of architects who will plan the restoration of the historical complex and its conversion to a multi-functional hall for the University activities.

The acquired experience has shown the real possibility of separation between the strictly photogrammetric competence and the different skills needed for a correct survey of an architectural site. This separation has been made possible by digital photogrammetry and by the new digital photogrammetric workstations which allow a simple and friendly approach to the plotting phase of the photogrammetric survey.

The possibility of, and the need for separation of responsibilities do not mean a separate concept of the entire project. Both specialists must cooperate in all the phases to reach the goals of the survey.

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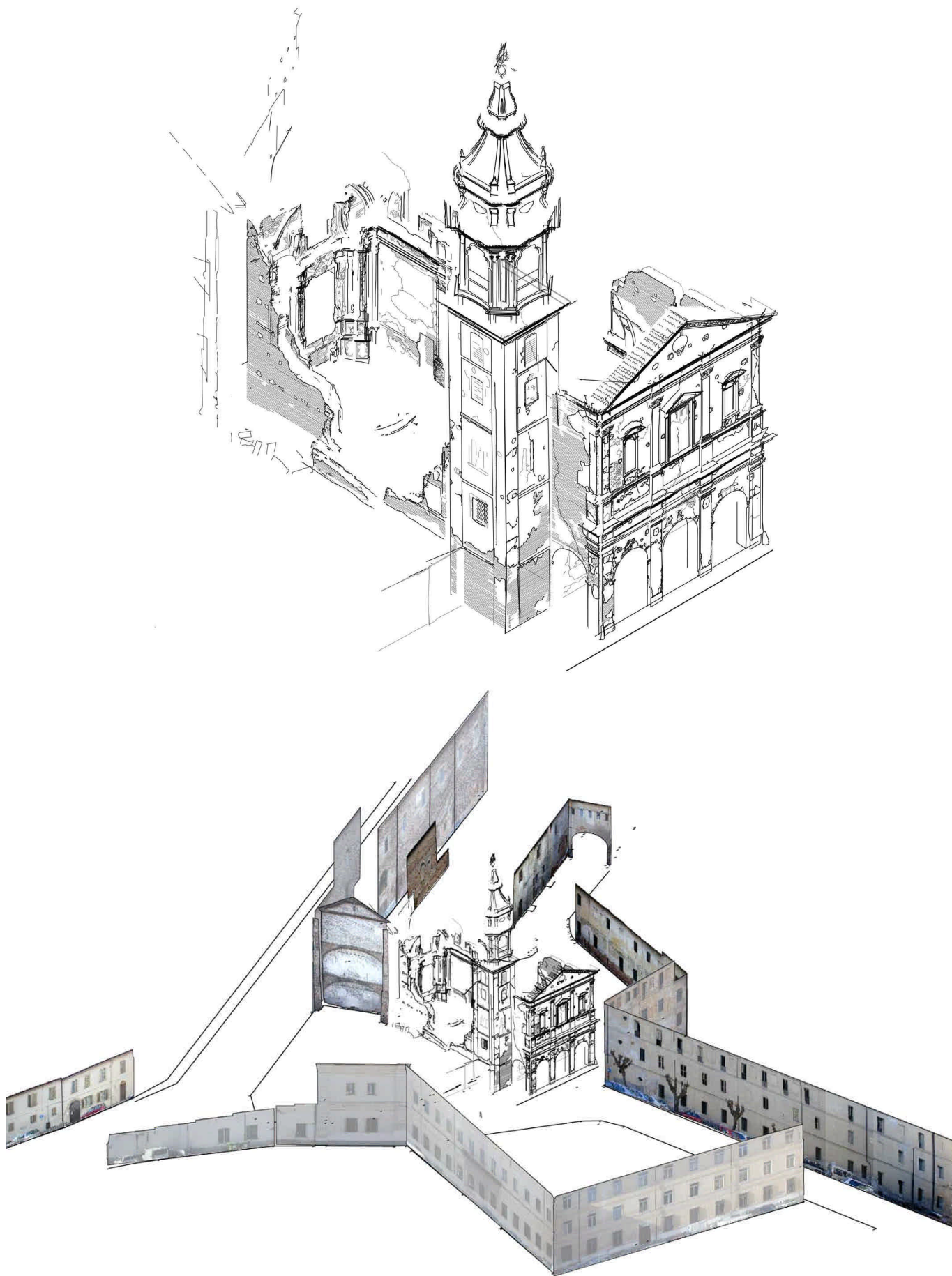


Figure 6. 3D models generated by the use of plotting and rectification results (drawing by Paolo Piumatti)

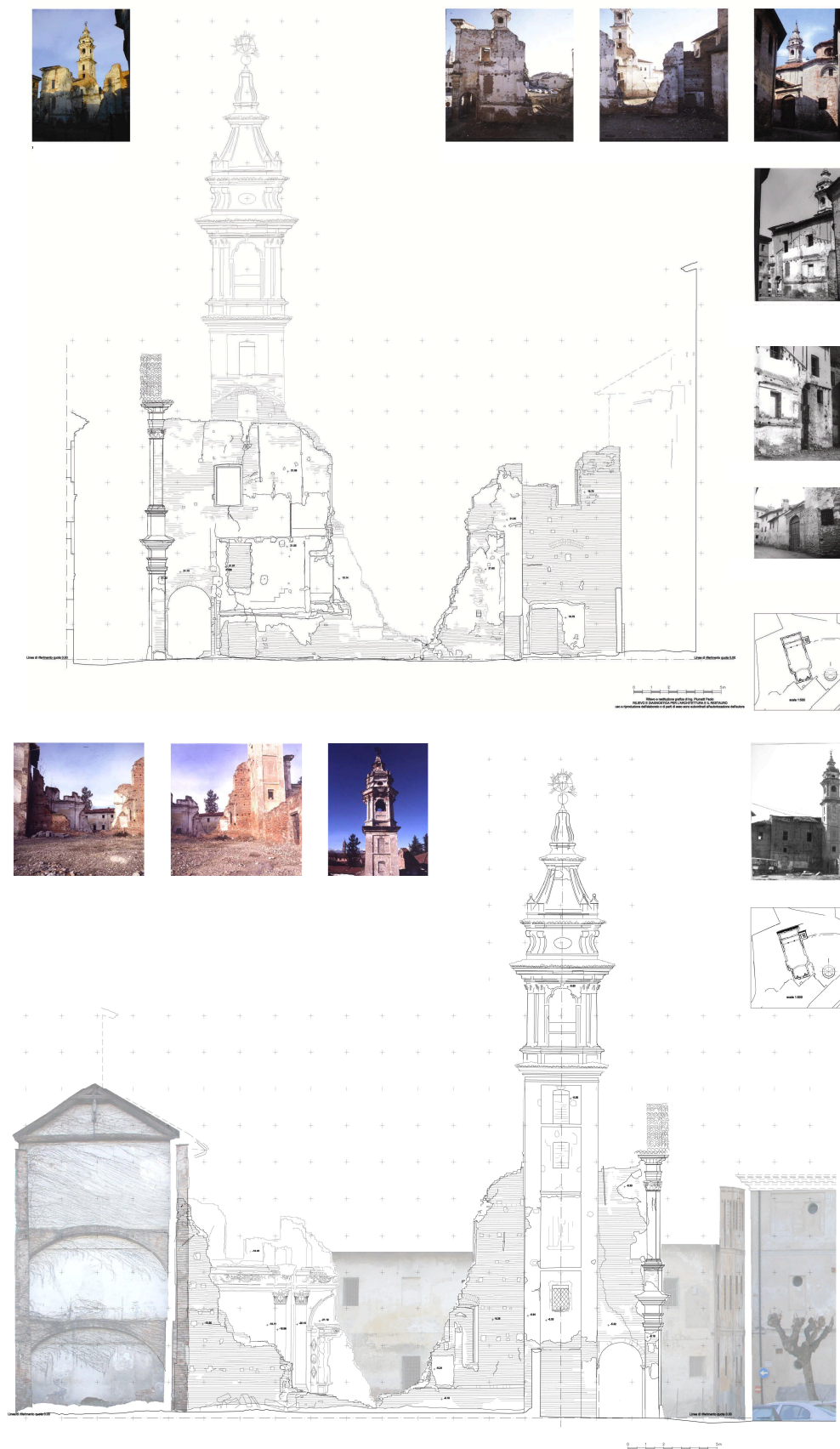


Figure 7. 2D representation of the results: photogrammetric survey, rectified images and photographic documentation (drawing by Paolo Piumatti)