# INTERNATIONAL DESIGN COMPETITION FOR THE REFURBISHMENT AND ENHANCEMENT OF THE VILLA REALE IN MONZA. THEMATICAL MAP: FROM CLOUDS POINT TO SURFACE ANALYSIS. CASES STUDY: SALONE D'ONORE, SCALONE AND SALA DEL TRONO

R. Brumana[a], C. Achille[a]

[a] DIIAR, Politecnico di Milano, P.za Leonardo Da Vinci 32, 20133 Milano, ITALY- Laboratory of  Survey, Digital Mapping, GIS - raffaella.brumana@polimi.it, cristiana.achille@polimi.it

**KEY WORDS: 3D, Digital Surface Model, Conservation, Laser Scanner, Orthoimage**

**ABSTRACT**

The geometric complexity, the relevant dimensions, the rich decorative apparatus of the peculiar interiors, have mode the traditional survey difficult in terms of times and costs, because of the difficult geometric restitution of the architectonic morphology. The photogrammetric survey is insufficient for stereoscopic restitution even if it is rigorous from the metric point of view. Experimentations based on the use of advanced methodologies of survey, such as modern laser scanner instruments integrated with photogrammetric techniques (high resolution camera), require the acquisition of cloud points and their georeferencing in unique reference system by means of topographical method or similar points. From these opportunely generate clouds (algorithms of decimation, cleaning and filtering) it is possible to extract profiles and sections, whose geometry is not automatically extracted (algorithms and sw of interpolation, extraction of breakline, simplified model and surface interpolation integrated by discontinuities breakline, border lines). The availability of these clouds makes it easy to reconstruct knowledge and the analysis of geometric and morphologic genesis of the architectural elements (arch, vault, dome or other), and their constructive technologies. The digital 3D orthophotos of the vaults are generated from the acquisition of photographic taken whichever is their orientation and topographical support, and are oriented are by means of the Aerial Triangulations. This technique of multiple shots orientation by using a specific photogrammetric software, can be also used in absence of calibration, element of fundamental importance in the case of multiple superimposition of digital taken acquired in the visible and invisible range (not calibrated and with important distortion: for example termographic and multispectral camera). The integrated use of digital photographies and 3D modelling enables to obtain a measurable and geometrically interpretable understandable result, but also a high possibility of 'semantic codifyng' tied to the content of the same images. The management and the use of 2D-3D orthophoto is similar to the management of rectified images, because it implies the generation of a metric support to the operations of thematic mapping done by specialists and technicians of the restoration. The orthophotos are georeferenced by GIS standards and are managed directly in low cost GIS or in traditional graphical CAD.

## 1. INTRODUCTION

### 1.1 Villa Reale in Monza[*]: the survey of indoor spaces

The work illustrates the realization steps of a topographic-photogrammetric digital survey and the use of laser scanner as means of support to the project of conservation and restoration of structural and decorative elements, located in representation rooms of noble floor of Villa; the halls were chosen in according with the indications of Soprintendenza (Figure 1.).

The geometric complexity, the size and the rich decorative apparatus of the peculiar environments sometimes make the traditional survey difficult as regards to times and costs, because of the complex geometric restitution of the architectonic morphology; they also make the photogrammetric survey difficult, because of the insufficient manual stereoscopic restitution, even if rigorous from a metric point of view. The test on some of the indoor spaces of the Villa Reale in Monza have been performed with advanced survey technologies both with the modern laser scanner instruments and with the traditional topographic and photogrammetric techniques (high resolution cameras).

The models, obtained by using together different techniques, and more and more perfect in shape and colour, bring back the subjectivity model matter, which is always not only influenced by the 'position' of the observer, by the person who realizes the model and the reason why he does it, but also by cultural and cognitive level of constructive techniques and transformations in act.

Surveying the shape of an object involves, first of all, the recognition of the geometric shapes that compose it. After having considered the building genesis of the different composing shapes, it is possible to determine 'what' has to be

---

[*] Lombardy Region has started the reliefs of Villa Reale in Monza, with the technical support of Politecnico di Milano and Agenzia del Territorio; the aim is to realize a support for a  the politic of care, which is the correct presupposition for activities of conservation and valorisation. The Lombardy Regional Government, in agreement with the Monza Municipality, announced an international competition for the refurbishment of the whole Villa building and of its gardens. The aim of this competition is the future evaluation and fruition of the Villa, a way of giving back life to entire set of buildings. Cfr. the article 'Survey and representation of the Villa Reale di Monza to support of the international design competition', inside here proceeding.

measured in order to get the useful information and to reconstruct the surveyed object with a model.

From the moment that it is possible to consider volumes to surfaces, and surfaces to lines, and to describe lines according to the assumed behaviour of same points; it is possible to affirm that, approximatively, the survey activities (traditional topography) lead to the identification of same relevant points, which are used to describe more and more complex geometric elements (Figure 1-2).

If it is assumed that the model tries to be similar to reality as possible it is also true that, in some specific cases such as this one, the model should make it possible to check an interpretative hypothesis (for example: does a cloister vault based on a circular or elliptical section?) and thus be the most 'veritable' model.
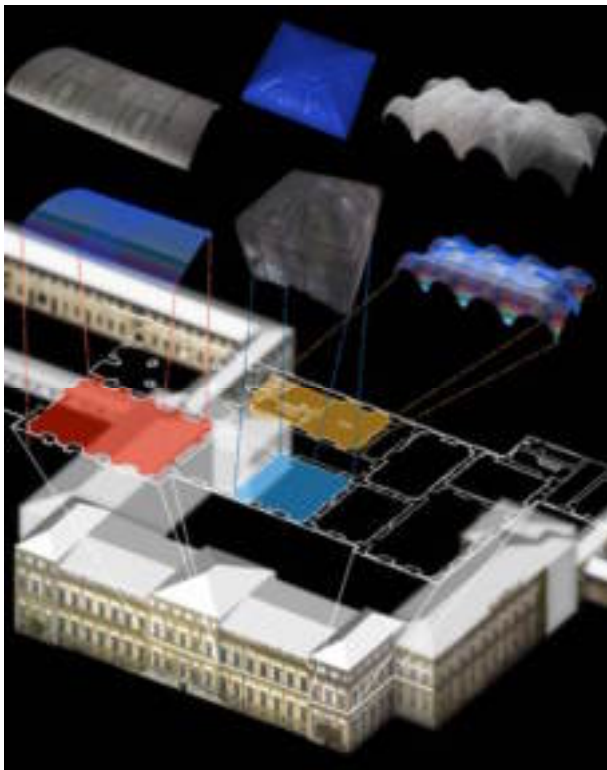


Figure 1. The models and orthophotos of different indoor spaces of Villa Reale; in particular the models and the orthophoto to the 1:50 and 1:20 scale of the Salone d'Onore, Scalone and the Sala del Trono have been realized

### 1.2 Model and orthophoto of the scalone

The survey of the most meaningful and the delegation indoor rooms of Villa, such as the Scalone, has been realized by means of the topographic survey of several important points, in order to get the editing of three section: horizontal one and two vertical ones (longitudinal and transverse).

The complex geometry of the vaults of the spaces has been restituted thanks to the generation of 3D models, to their edition according to the topographic survey and to the location of a sufficient number of points, able to describe the border lines for such simplified models, deprived of decorative apparatus (Figure 2).

The 'box' of the indoor of the Scalone has been built beginning from the topographic survey of horizontal and vertical sections at different heights (software Autocad).

Once the model has been generated as a whole, its composing parts (wall, pilaster, strips, steps, …) have been 'covered' with the straightened images and orthophotos as a texture (software 3D Studio Max) (Figure 3-4).

The orthophotos and the rectified images have been realized at a final nominal restitution scale 1:20. The surveys and all the models have been georeferenced in the Villa net system (in GB coordinates) and are thus in agreement with all the other existing surveys. A new movie of the model as a whole has been generated with the 3D Studio software.
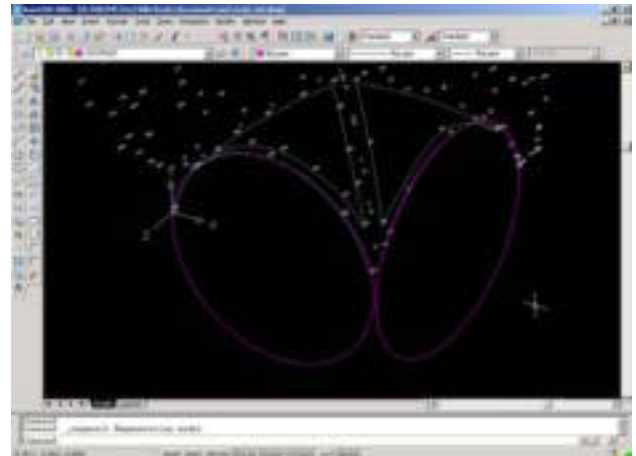


Figure 2. Building of constructive lines for the model of the vault of the Scalone. The topographic points, 650, imported in Autocad, contain the information about the shape of the surface. The shape has been first extracted by building the different sections. The border lines formed in this way enable to elaborate the shape of the object as a whole
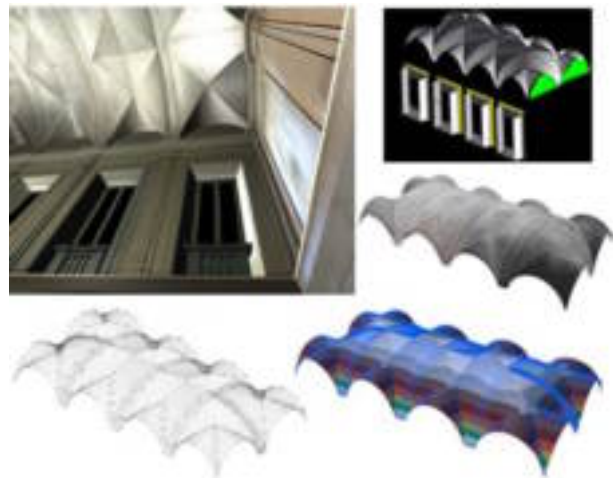


Figure 3. The orthophoto of Scalone. To the topographic survey (Total Station Leica TCRA 1103 no-prism) the interpretative analysisi has followed, with the reconstruction of the axis and the genesis of the shape, in an effort of reconstruction in order to realize the model. The whole model (7240 mesh) has been generated with the ArcInfo and ArcGIS 8.3 software and it has been used to realize the orthophoto to the 1:50 and 1:20 scale (118 MB, software PCI Geomatica 9.0). The orthophoto constitutes a digital metric and measurable result, natural support to the metric evaluation of non-flat surfaces (from the model) and a sudden support to the mapping of the materials, to the classification and location of the deterioration and instability. Therefore it represents a qualifying support to costs analysis of the interventions
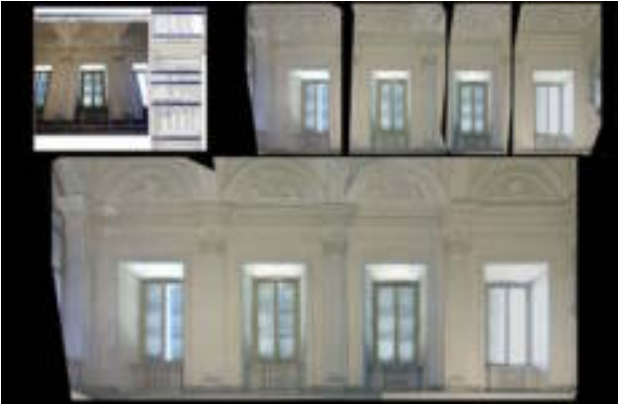
Figure 4. The rectifying photographic techniques (rectified images) are so called simplified photogrammetric techniques and can be used with almost flat surfaces. The indoor walls substaining the vault have been restituted thanks to the generation of rectified images (sw OrthoEngine; camera a Rollei DB44-Metric - Sensor Phaseone, CCD-Chip 4080 x 4076 pixel an a 36,720x36,684mm format). The size of the images without losing resolution, RAW format, till a 48 bit colour hue is 32 MB per image (48 MB in the TIFF format).The camera has calibrated interchangeable f/40 mm, f/80 mm e f/150 mm optics
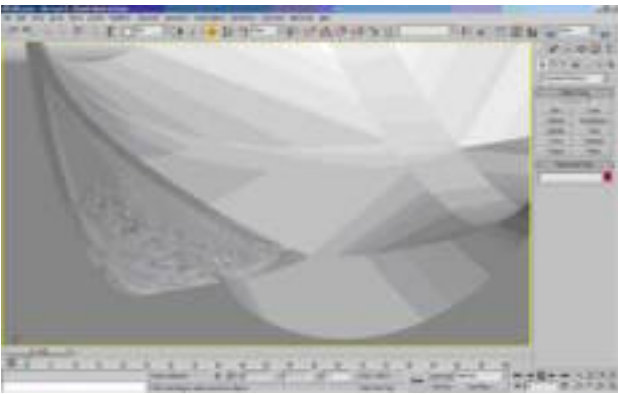


Figure 5. The texture of the voult superimposed on the model: with the solid model of the object and the orthophoto another kind of representation rich of information can be obtained with the help of known and sudden operations of texture mapping of the solid model
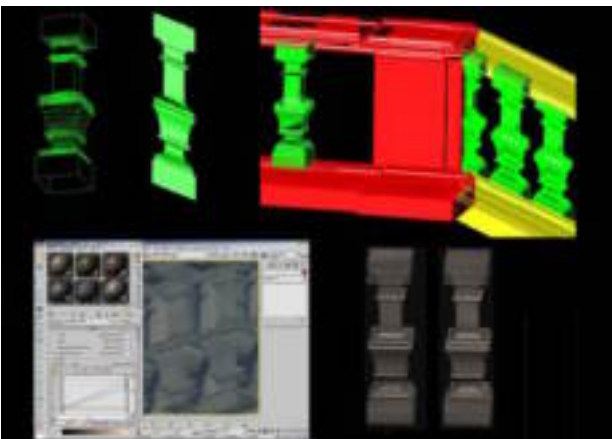


Figure 6. An example of the building of one of the Scalone details. From the modelling in Autocad to the 'dressing' of the model in 3D Studio Max



Figure 7. The model of the Scalone realized by means of the photographic sections and texturized with the rectified images and the orthophoto



Figure 8. The use of digital photos, together with a different kind of digital images, metrically integrated to 3D modelling of different elements, enables to get a measurable and geometrically understandable result, but also a great chance of codifying semantically the content of the images

## 2. THE SALA DEL TRONO

The new laser scanner survey technologies enable to recreate the 'original status' of what exists – the surveyed object in a significally starter time and for some reasons also more accurate – than that of traditional topographic or photogrammetric survey. They enable also to insert in the model simulations and analysis able to wholly illustrate problems, analysis and solutions with precision once improbable. All this in a non-

automatic way. The survey of the cloister vault of the Sala del Trono has been realized by acquisition of clouds of points with the laser scanner LEICA HDS3000 instruments, with a 4 mm a 6 m resolution (Figure 9). From the cloud of points and from the model the aim is extracting those information that describe the structures and the building genesis of the examined object (Figure 10-11).
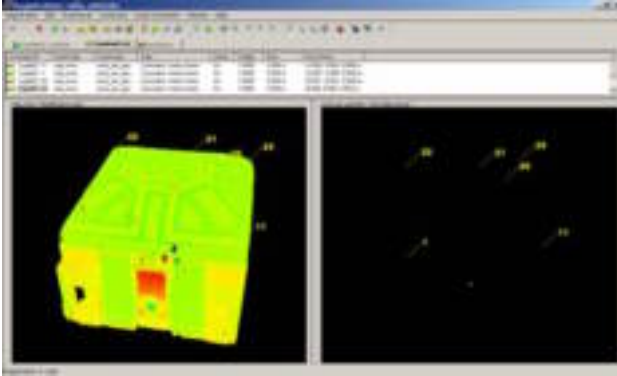


Figure 9. Georeferentation of the cloud of points in the net system of the Villa Reale (Gauss Boaga uncontracted coordinates) with topographically surveyed architectonic points

## 2.1 Genesis and building models

A typical pavilion vault is generated by two barrel vaults with an identical guiding curve. By cutting the barrel vault on a square plant with two vertical and diagonal planes, four two by two identical parts of a vault are the result.

This kind of vault will be a semi-cylindrical curving one, a flat or raised one, a vault with an elliptical directrix, etc, according to the barrel vault which it comes from (Figure 10).
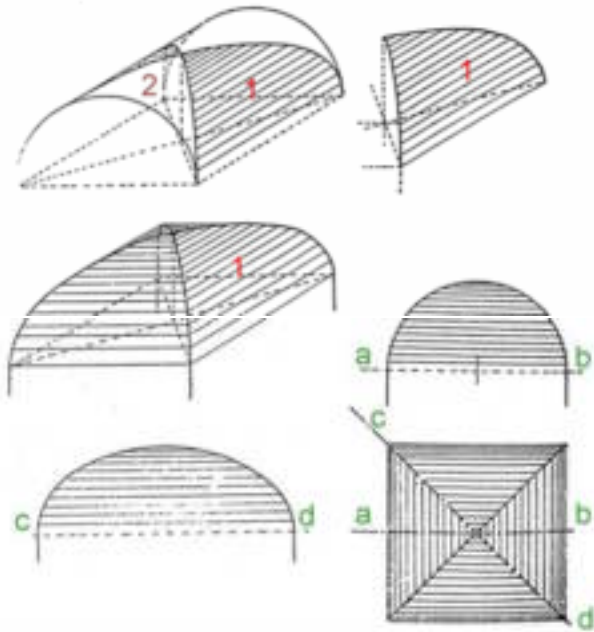


Figure 10. Geometric diagram of the pavilion vault: the parts indicated with the number 1 are called "spindles" and the parts indicated with the number 2 "nails". By assembling four spindles, a pavilion vault on a square plant is generated

## 2.2 3D model realized beginning from clouds

In this case, the aim is to realize a 3D orthophoto model characterized by a metric resolution compatible with the 1:50 scale, but also by a radiometric-photographic resolution compatible with the 1:20 scale. This model may represent a support for the geometric, constructive, thematic and morphological knowledge of the building and a foundation for the required interdisciplinary analysis.

The elaborated model enables to map the materials, the building conditions and the causes of deterioration-instability and it helps the reading on paper and on video of architectonical and decorative details. These data are used by planners and restorers to define the intervention projects and to study the object morphology.

According to this view, an experimentation on distinct fields has begun in order to test different instruments and methodologies able to extract, from clouds of laser points, the structural elements of a surveyed object, such as discontinuity lines, edges, vault guiding lines. From these clouds, after having them opportunely processed with cleaning and filtering algorithms, it is possible to elaborate a digital model of the surface (DSM), extract profiles and sections, where major and primal planes are. The Cyclone and Cloudworks softwares have been used, whose functionalities have been tested:

- extraction of sections as "points stripe"
- semi-automatic extraction of sections as line in the space or plane

These experimentations serve as tests to understand which is the best way to be followed in order to implement the modeling.

In the case of the Sala del Trono, it is better to separate the geometric aspect of the building from the ornamental decorative apparatus represented by the wood *boiserie*, the wall stuccos and the vaulted elements in the intradossal part.

But also simplifying, it has been clear that the genesis of a pavilion is not sufficiently approachable to reality only by means of the guiding sections of the two barrel vaults (in this case elliptical).

This fact is to be attributed to the dyscrasia between the theoretical model (Figura 10) and its factual realization by means of the centerings. This required that, also in the simplified model, the elliptical diagonal sections – lines of discontinuity between the two intersecting models (Figure 10) had to be taken into account.

During the elaboration of laser points, it can also be useful to find not only the structural section, but also, in order to represent also the even simplified decorative apparatus, the curve that approximates the outline of the points without passing obligatorily through all of them.

This because the points given back by the laser instrument are affected by the error caused by the non-uniform response to the signal of the object surface and also because they are not sufficient to represent in a "veritable" form of the discontinuous detail of the stuccos.

Thus the outline is very unordered, also because of the object actual morphology. These information, which can be defined qualitative, can also be considered and reproduced later on if a detail analysis is required (lower part of the Figure 10).
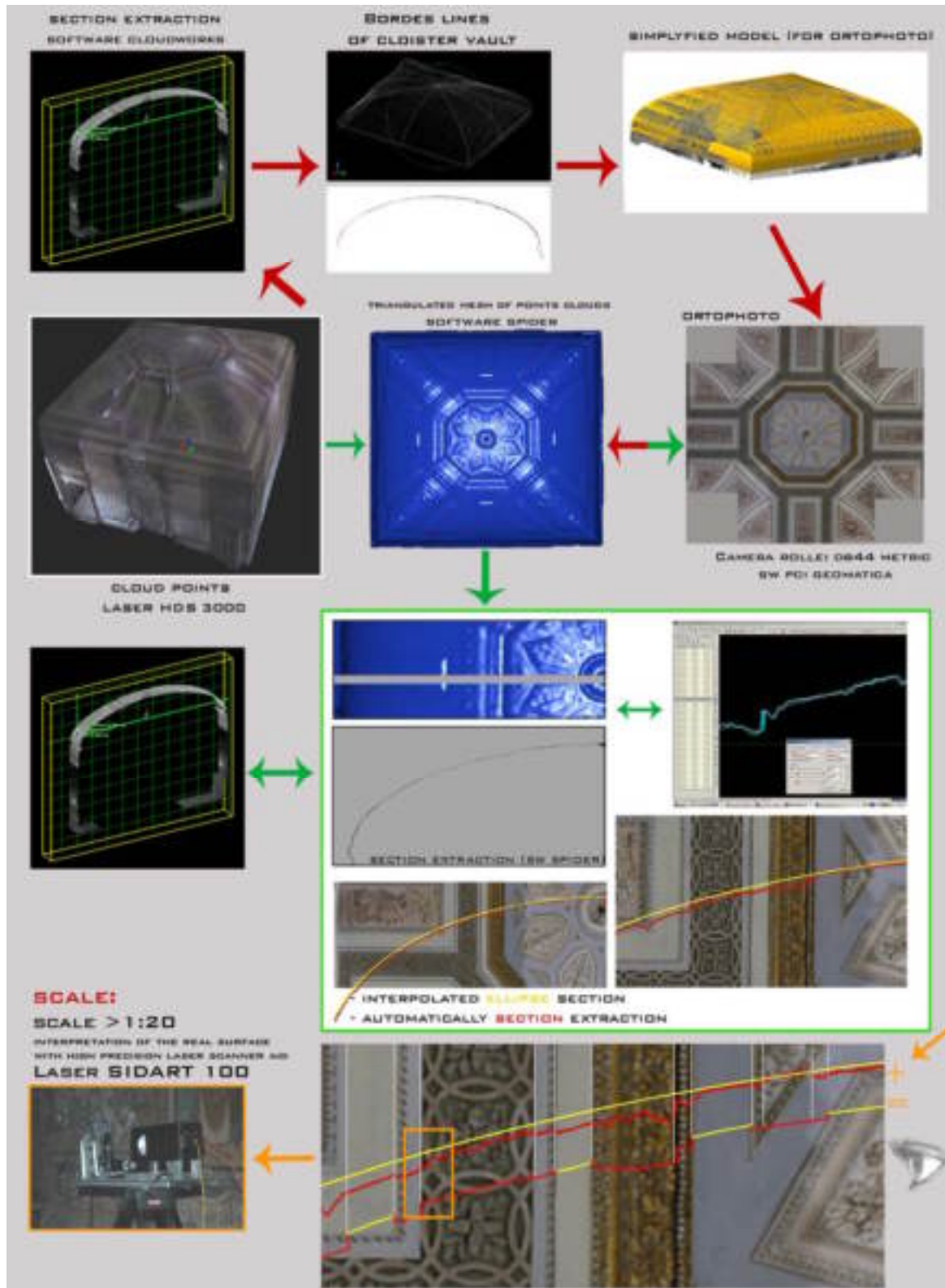
Figure 11. Elaborations realized from the points cloud: the cloud has been elaborated in order to get different information and results. From the filtered georeferenced cloud, the generating elements of the "cloister vault" have been extracted, in order to get a smooth model necessary to build the orthophoto (Rollei DB44 Metric shots, topographically laid down) with a resolutions compatible with the representation and interpretative detail scales. From the same cloud different profiles, where significant sections are, have been extracted – using the cyclone and cloudworks softwares. These sections have been located with the help of the Monuments and Fine Arts Service in order to get, as a first approximation, the position and form of the stuccos and of the decorative apparatus of the vault

In order to understand the genesis of the rich apparatus of the boiserie and of the stuccos, which are considered exceptionally beautiful and unique, it will be necessary to move to a bigger scale (till the 1:1): the work will continue with trial survey, using a higher defined laser (at least a 1/10 of the HDS3000), that is 2÷3 tenths of millimeter[*], in order to extract and recognize some decorative features (Figure 11, lower left part). Trial details selected by the Monuments and Fine Arts Service will be.

## 3. DATA GIS MANAGEMENT

The elaborations have been realized and georeferenced in accordance to the current GIS standards; afterwards the data have been directly managed with more popular softwares (ArcGIS, ArcView,…) and traditional graphical CAD.
The orthophotos will be three-dimensionally mapped in order to guarantee the metric calculation operations of non-flat surfaces (from a 3D TIN model).
The orthophotos will also be an immediate support to the thematic mapping later on realized by restoration specialists and technicians: the materials mapping and their classification (NORMAL indications and other), the interpretation of the building conditions, the individuation of deterioration and of instability (diagnostic outline, cracks analysis, …), even to the planning phase.
A further result, useful for the planning of interventions on the building, is the possibility to connect the metric calculation and the cost analysis in order to evaluate the works of extraordinary and programmed maintenance.
The philosophy implied by the new technologies of data acquisition and representation, give a chance to those analysis, diagnosis and projects, which can be guided by experts of different fields, going from the new digital supports such as the orthophoto.

## 4. CONCLUSION

Next year the research will continue using the 3D laser scanner technique of survey, together with the experienced techniques and the created drawings, with the aim of realizing 3D models, othophotos and models of Villa halls.
The data obtained with the support of these methodologies will be georeferenced in an information system, which will have to manage the planning not only of the future restoration and reuse, but also of the programmed maintenance; moreover the information system will manage all the other not-geometrical data.
The geometrical shape of the cloister vault of the Sala del Trono, will be studied considering the mathematical analysis of the outlines cutting through the principal sections (curve of Bezier, Spline,…) and considering the surface analysis; the surface will be modeled using advanced algorithms (Nurbs,…), which are able to optimize the representation and are useful to create a reliable shape (interpolating ellipse, breakline, borderline, policentic curves, Nurbs models, etc.).
The last aim is to read and to understand the building, its parts and its constructive rules, in order to guarantee, thanks to the

project, the required balance for its restoration and future management.



Figure 12 One of the picture of Sala del Trono. To the right the possible mapping of the degradation realized on the orthophoto (NORMAL indications)

A further step in the research will be to filter clouds of points with 3D simplified model, to separate the points belonging to decorations, in order to model them. The question is still open.

## REFERENCES

Marsh, D., 1999. Applied Geometry for Computer Graphics and CAD, Springer.

Hoschek, J., Lasser, D., 1993. Fundamentals of Computer Aided Geometric Design, A. K. Peters Ltd.

Kraus, K., 1994. Fotogrammetria, Teoria e applicazioni, Levrotto & Bella, Torino.

Eberly, D., 2001. Least Squares Fitting of Data. Magic Software, Inc., 2001

Bonora, V., Chieli, A., Spanò, A., Tucci G., 2003. 3D metric-modelling for knowledge and documentation of architectural structures (Royal Palace in Turin). International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XXXIV, Part 5/W12, pagg. 60-65, Ancona.

Lingua, A., Piumatti, P., Rinaudo, F., 2003. Digital photogrammetry: a standard approach to cultural heritage survey. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XXXIV, Part 5/W12, pagg. 210-215, Ancona.

Vettore, A. (ed.), 2005. Proceedings Italia-Canada Workshop on "3D Digital Imaging and Modeling Applications of: Heritage, Medicine & Land". Padova.

---

[*] Laser SIDART 100 (the laser, still in phase of development, is a phase difference one and works on the band of infrared; theoretically it reaches submillimetric resolutions and measure precisions), realized with the competences of: ENEA Frascati –Artificial Vision Laboratory - FIS-LAS