SURVEY AND REPRESENTATION OF THE VILLA REALE DI MONZA TO SUPPORT OF THE INTERNATIONAL DESIGN COMPETITION

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ABSTRACT

In April, 2004, the Lombardy Regional Government and the Monza Municipality, pro-quota owners of the Villa Reale in Monza complex, with reference to the contents of the Program of Agreement, signed the "Refurbishment and Enhancement of the Villa Reale in Monza and of its Gardens", and decided to announce an "International Design Competition for the Refurbishment and Enhancement of the Villa Reale in Monza and its Gardens" (http://villarealemonza.regione.lombardia.it).The survey has got the aim of generating materials to support the restoration and enhancement plans for the Villa Reale.
This work is an example of digital photogrammetric survey for the architectural restoration of monuments belonging to the Cultural Heritage. The work, in particular, implies the realization of dimensioned drawings of the Villa and of the buildings, of digital rectified images of historical buildings indoor and outdoor prospects, together with the vectoralization of relevant elements of the surfaces and with the creation of 3D orthophotos and prained and vaulted surfaces.
The case study of the Villa Reale in Monza has contributed to the development of different information that are structured on various levels: architectonical local nets, geodetic nets, horizontal and vertical profiles at a 1:50 scale, digital rectified images at a 1:50 scale and 3D models of complex parts at a 1:50, 1:20 scale.
Digital rectified shots have been taken with the new Rollei DB44 Metric digital metric camera with a 16 megapixel sensor. The topographic survey has been realized with no-prism laser theodolites. The survey is the requirement for an effective activity of conservation and valorization of the Villa Reale.

1. INTRODUCTION

The work illustrates the realization steps of a topographic and digital photogrammetric survey as a means of support to the refurbishment and enhancement project of the Villa Reale in Monza [*] (Figure 1). 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 the entire set of buildings. Once the proceedings are completed, the work will start in 2006 with a 106 million euros investment.
The survey of historical buildings having great dimensions presents representation problems linked to the reference and generalization of information system, that have to merge in order to better support a multi-purpose finalization.
The process starts from the topographic survey network, architectonical nets, indoor detail nets, to the design of the horizontal and vertical profiles, of digital rectified image and of 3D models on the complex parts. The honour halls of the Villa have been represented by means of 3D digital models with a photogrammetric mapping of the surface.
This survey has contributed to the knowledge recognition of the problems in developing and studying information which are structured on different levels.
For this reason the survey has been simultaneously realized by two groups[**]. The first group has dealt with the topographic and photogrammetric survey, while the other has dealt with the direct survey and the deterioration mapping with unified methods and with coherence in the topographic references.
In this way, the final result coming from the maps, the sections, the mappings is not the sum of elaborations done in different moments, with different aims and methods, while it is the unification of a coordinated and coniugated job, which has the aim of realizing a complete piece of work with integrable and complementary data, inside a unified whole project.

[*] The Villa Reale in Monza was founded as a symbol of the prestige and the greatness of the Asburgic family. Maria Teresa, the empress, decided to have it built when she named his third-born child Ferdinand General Governor of the Austrian reign of Lombardy.
The work started in 1777 and was directed by the court architect Giuseppe Piermarini, who had it built in three years.
From the central body, two equally high wings spread out from it and end with the two front bodies of the Cappella di Corte and the Cavallerizza. The stables and the kitchens were located in the rural parts where, later on, Luigi Canonica built a Court Theatre – the Serrone and the Rotonda delle Serre, painted by Andrea Appiani.
When Napoleon became emperor, Eugenio di Beauharnais moved to the Villa, which, from that moment on, was called 'Reale'.
A 750 hectare enclosed park was built and used as a hunting preserve and as an agricultural estate.
When Napoleon was defeated, the Austrians went back to the Villa and when Lombardy was enclosed to Piedmont, the building became part of the Savoy estate.In 1921 the Villa management passed to the Monza and Milan Municipality and, until 1929, lived a florid period thanks to the two "Biennale delle arti decorative ed industriali moderne" exhibitions.During Word War II it was invaded by troops and homeless people who here responsible of the raids. In 1996 the Villa and the gardens management passed again to the Monza and Milan Municipality.

[**] The surveys and the restitutions to the 1:50 of the indoor spaces of the Villa were generated by the work group directed by Prof. Stefano Della Torre (Dipartimento B.E.S.T. Polytechnic of Milan).
The work done by the Polytechnic of Milan has been coordinated by the Agenzia del Territorio of Milan.

2. COMPLETED WORK

In order to get a general map of the Villa Reale di Monza, it has been necessary a highly precise topographic and photogrammetric survey. The prospects of all the fronts of the building, the horizontal profiles of each single façade and several vertical sections have been surveyed. After that, digital rectified images of flat surfaces have been generated by means of the usual technique of hyper determined homographic straightening, while 3D orthophotos have been realized for three-dimensional surfaces.

Figure 1. Picture of the Villa Reale in Monza

The aim is to reach a metric resolution to the 1:50 scale but with a radiometric-photographic resolution compatible with the 1:20 scale, that is with a more than doubled intrinsic resolution, which will support the geometric, building, thematic and morphologic knowledge and the interdisciplinary analysis.
The so-elaborated survey will enable the mapping of the materials of the finished work and of the degradation and ruin, with a concrete help for the paper and video reading of the architectonic and decorative details.

2.1. The topographic networks

After an accurate survey the position of the 27 vertexes around the buildings of the Villa has been chosen in order to realize the main network and improve the measurement processes.

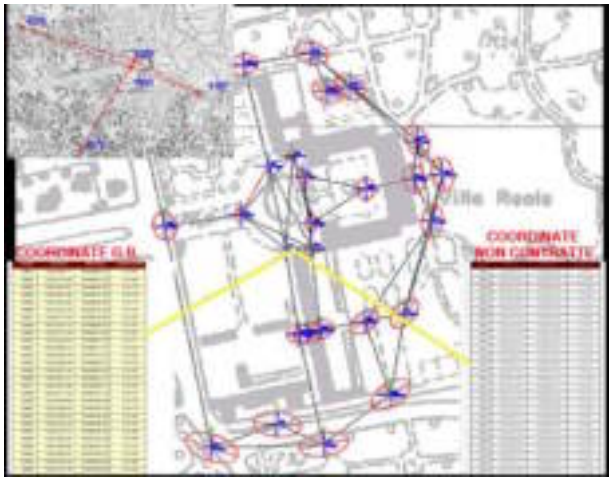

Figure 2 Main topographic network. Above the GPS network plan, tables with the vertex coordinates in the two systems, GB and uncontracted. The Villa is about 250 m wide and 350 m in long

The vertexes location choice has been made according to the criterion of an almost uniform distribution and has been preceded by a simulation in order to verify the error distribution and to optimize the geometry. Thanks to this operating method, the realization of secondary nets for the survey of indoor spaces and for the photogrammetric support has been eased.
The vertexes have been built in three different ways:
- dedicated content (1 hafts chambers) with cast iron or CLS (manhole covers);
- inox allen screws and brass expansion wedge, inserted in the floor without the protection chambers;
- inox topographic nails.

The topographic network has been connected to the national system by means of GPS measurements; therefore all the net points are in Gauss-Boaga coordinates. Anyhow, because of the Villa size and of the final restitution to a 1:50 scale, the vertex coordinates have been recalculated and, for the survey of the profiles and of the support points, non-contracted coordinates have been used (Figure 2). The tools that have been used are the total Leica station no prism TCA 2003 and the GPS Trimble 4000 (a static survey of two vertex of the local net has been performed using three vertexes of the Milan Province).

2.2 Topographic survey of the profiles

In order to integrate the rectified images, the external horizontal profiles of the factory building have been generated. These profiles have been obtained thanks to the location of remarkable points where the doors are and of points able to describe the lines of the walls, of the encumbrances and of the main architectonic elements (pilasters strips, frames, …).
A direct systematic and precise survey has integrated all these elements. For the realization of the maps of the different building plans, the survey of the outdoor profiles has been integrated with the survey of the indoor points, by means of closed polygons and branch along the hallways and in the rooms. This has been done in order to enable the assembly of the indoor direct survey by the B.E.S.T. group and to edit the final general plan. About 1200 points have been surveyed. The whole topographic survey, as a matter of fact, has been the backbone of the direct geometric survey of indoor spaces, which made it possible the final editing of the 1:50 scale plan. At the same time, 25 vertical outdoor profiles of the buildings have been surveyed, in correspondence to approved and significant section lines; relevant points, doors and the vertical course of the walls have also been located. For each surveyed network point, each prospect or section of all the distinct stations, an accurate monograph has been generated (Figure 3).

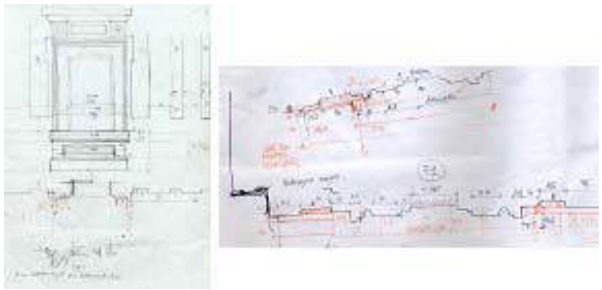

Figure 3. Monography of the prospect of a window detail and a portion of the profile of the wing Nord façade

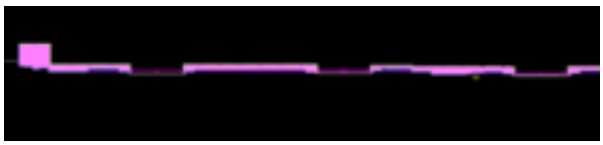

Figure 4. A detail of the profile (sw AutoCad Map 2004)

The profiles (Figure 4) have been useful to help design the sections at a 1:50 scale and integrate them with, at the same time their integration with the rectified prospect has made it possible to check eventual non-alignements.
The survey as a whole has highlighted that under the cover of an apparent modular regularity of the fronts, building and structural anomalies can be found, together with able imperceptible abilities in the morphologic and projectal control. The surveyed sections of the Villa expand for nearly 1800 meters (perimeter).

2.3 Photogrammetric survey of the outdoor prospects: digital rectified images

The survey method used for prospects is based on the realization of digital rectified images by means of an accurate diagram of the shots that had to pay attention to spaces and obstacles around the Villa. The camera that has been used is a Rollei DB44-Metric, with a Phaseone, CCD-Chip 4080 x 4076 pixel on a 36,720x36,684 mm format. The size of the images without losing resolution, in RAW format, till a 48 bit colour hue, is 32 MB per image (48 MB in the TIFF format).

Figure 5. The Rollei DB44 Metric digital camera and the calibration certifications of the different optics

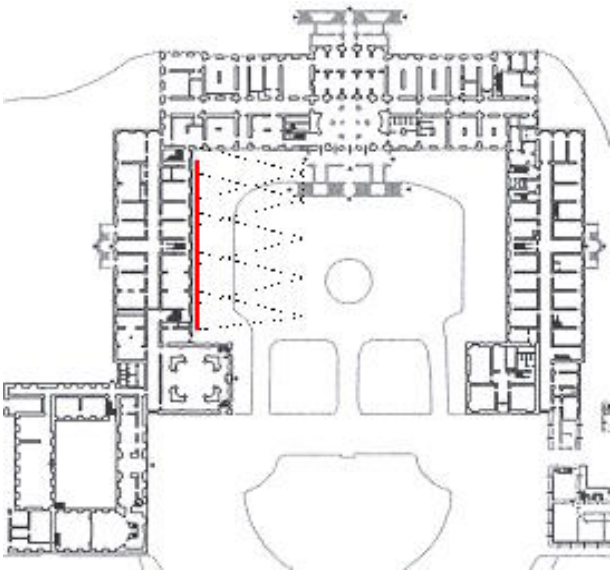

Figure 6. Exemplary of one of the stripe diagrams, made of different stripes

The camera has got calibrated interchangeable f/40 mm, f/80 mm e f/150 mm optics (Figure 5-6). From the net vertexes, about 2000 supportive points for the models have been surveyed; they have been pointed out in some areas with architectonic points, in other areas with 10x7 cm targets on the walls. The tools that have been used are Leica no prism TCA 2003 Total Stations and the new TPS 1200.

Figure 7. Visualization of the supporting points, architectonic and target, on a complete rectified image of the fronts of the Ala Nord

The rectified images have been generated with the photogrammetric software OrthoEngine PCI Geomatica 9.0 (Figure 8 –9). The orthophotoprojection module has been used degenerating the real DTM to an array of definite plane surfaces. In the processing phase must be consider that a façade is irregular and can't be approximate with a single plan but required a set of parallel planes with different quotes along z-direction.
The digital rectified images have been obtained putting each single image together into a mosaic in order to build a continuous image of entire front.
The mosaic image was subsequently digitalized using the vertical and horizontal sections like support and control information.
The rectified image (figure 10-13) lets give both the geometry and the semantic characteristic of the photograph. Together with the characteristic of prospects created with traditional methods, the rectified photos supply a natural support to the subsequent operations: mapping, classification, estimative metric calculation, decay location on the materials.

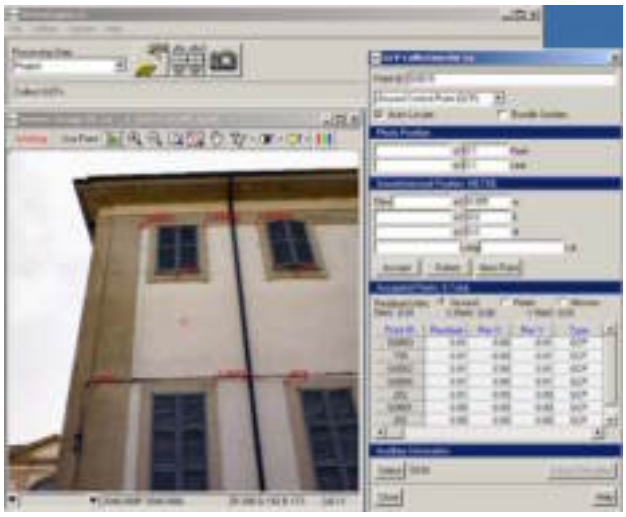

Figure 8. The procedure for the realization of a rectified image. The coincidence of the support points with the OrthoEngine software and the table shawing the error residual in mm (maximum error 1 mm)

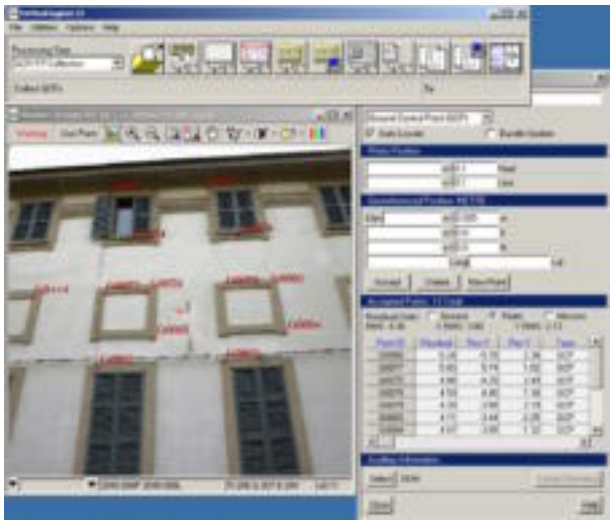

Figure 9. The Procedure for the realization of a rectified image. The coincidence of the support points with the OrthoEngine software and the table shawing the error residual in pixel (maximum error 6 pixel)

Figure 10. Rectified image realized with OrthoEngine

Figure 11. The North annex in AutoCad Map of all the single images straightened before putting then together in the mosaic

The rectified images have been georeferenced in a unique reference system, becoming immediately the basis of a manageable and updatable GIS information system.
To each TIFF rectified image corresponds the related TFW georeferred file that can be automatically read by AutoCad Map and by the information system (ArcView/ArcGIS), support to the object structuring for the quantification and metric calculation of the surfaces mapped by different users.
About 1000 shots have been taken, so 50 GB uncompressed TIFF images.

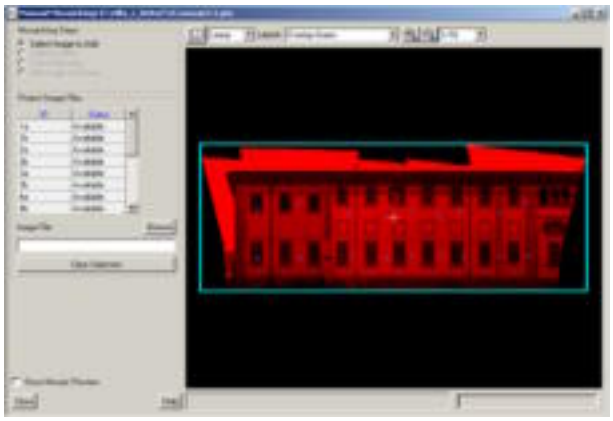

Figure 12. The realization of the mosaic with OrthoEngine

Figure 13. The takens, the corresponding rectified images and the mosaic realization. The images present for each front the rectified image, the horizontal and vertical profile, the dimensions of the tables, manageable with sw AutoCad, from a minimum of 30 MB for the smaller front to the maximum of 1,2 GB for the bigger fronts. For these ones, rectified images in different resolutions have been realized in order to help the files management

2.4 The prospects

The TIFF format of the rectified images together with the TFW file format has enabled the import of the rectified image in AutoCad Map 2004 (Figure 14).
This has been useful to realize the digitalization of the different fronts of the Villa Reale.
The vectorialization restitutes the view in the orthogonal projection of the different fronts (Figure 15-17). In order to vectorialize all the ports putting or recessing from the middle plane of the rectified image, the horizontal and vertical surveys have been used, for example for the frames.

Figure 14. Rectified image of a ISA façade (Istituto d'Arte Superiore inside to Villa Reale)

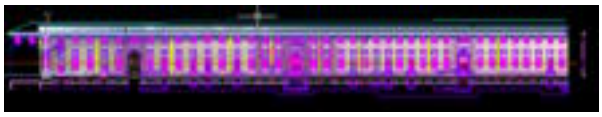

Figure 15. Rectified image of a ISA façade superimposed with the vectorialization. The front is 147 in long, the rectified image is about 1790 mq and the TIFF is 430 MB

Figure 16. The vectorialization of the entire façade

Figure 17. The detail of the vectorialization of the previous facade

3. THE MODELLING

A 3D model of the whole Villa Reale has been realized using the horizontal and vertical profiles and rectified images by means of the sw AutoCad Map 2004 (Figure 18-22).
This will guarantee an almost complete accessibility for the future users first of all the winners of the competition.
The advantage of this simple modelling resides in the potentiality that this integrated raster vector model gives in the projectual support, in the contextualization of new interventions, in their simulation and in the highlighting of the future distinctive hierarchies.

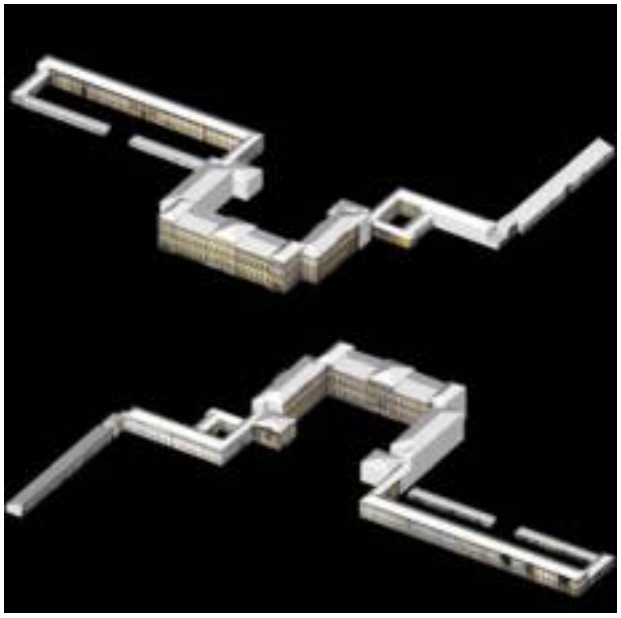

Figure 18. Axonometric view of the Villa Reale complex (software Autocad)

For example the Serrone becomes the stage of the famous Roses garden. The different assemblies of the buildings give a volumetric and semantic dimension to the urban design project, to the amelioration of the environment of the old paths, of the lighting, and, least but not last, to the evaluation of the architectonic-environmental impact of the new project in the different scales.

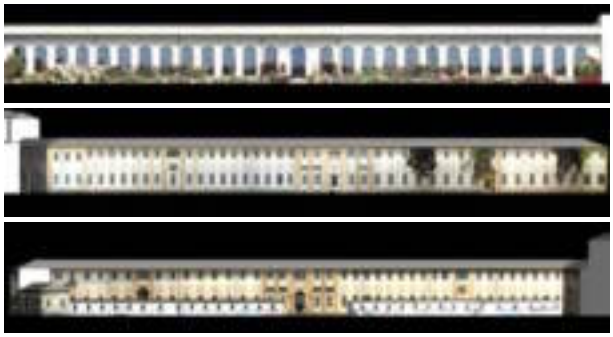

Figure 19. Prospects of the Serrone and ISA

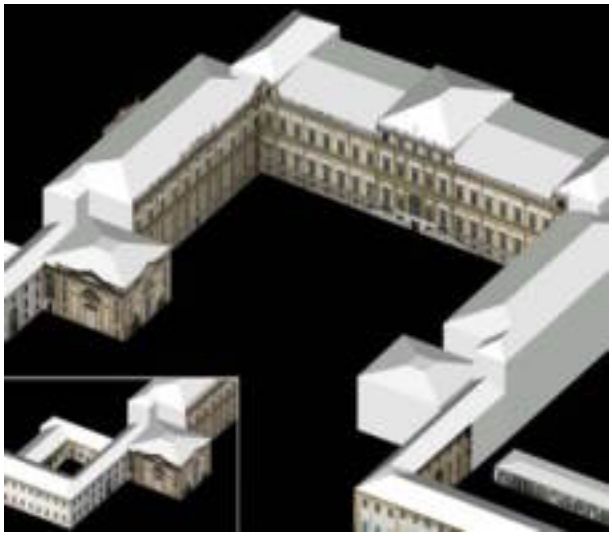

Figure 20. A detail of the North Wing of the Villa Reale

Figure 21. A detail of the ISA

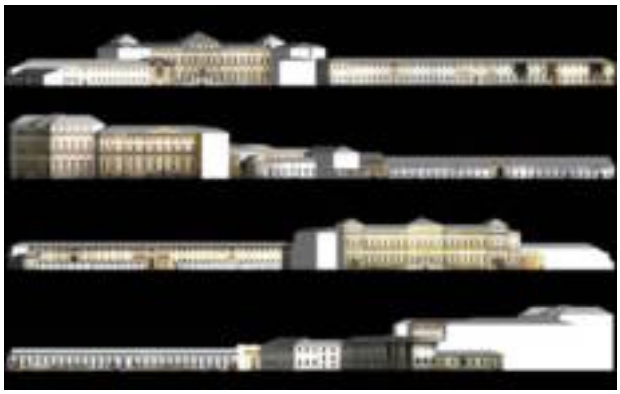

Figure 22. Prospects of the Villa Reale. From the 3D model it is possible to obtain views representing different prospects that have been generated from any referenced flat surface.

The project advantage of this kind of representation is clear. All the grey-coloured parts are those that could not be surveyed because taken up by restoration yards

4. TOWARD THE REALIZATION OF AN ORTHOPHOTO

The digital photographic (rectified image) straightening techniques are the so called simplified photogrammetric techniques and can be used with almost flat surfaces, such as 'to the limit' fronts. The presence of 3D surfaces characterized by rich decorations and by variable geometries where the coverings are (vaults, barrel vaults, cloister vaults, joined to different forms going from the classic rectangles to polygons or festoons, stucco decorations,…) -together with a relevant spread degradation and ruin situation- has suggested to proceed with the integration of the survey with photogrammetric techniques by generating digital orthophotos at a 1:50 scale.

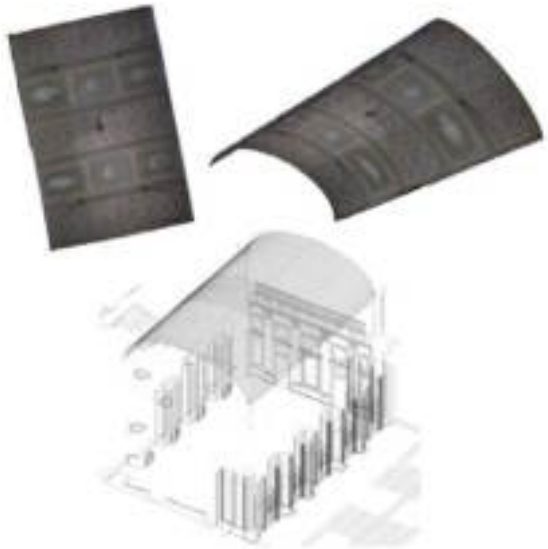

Figure 23. The ortophoto of the Salone d'Onore. About 200 located points. Above: the ortophoto (software PCI Geomatica 9.0.; 103 MB, resolution: 300 dpi). Under: the first simple data elaborations of the Salone Reale in Autocad.

In case of surfaces different from closed planes, in order to generate an orthophoto, it is necessary to create a 3D model of the surface able to restructure the average projection face of the takens. The complex geometry of the vaulted coverings of some indoor spaces (Salone d'Onore e Scalone) has been rendered by means of the generation of 3D models from the topographic survey and the spotting of points sufficient to describe their guiding and origin lines (Figure 23). The management and the use of 2D-3D orthophotos are similar to the rectified images management, because they generate digital photographic results which are metric and measurable and, for this reason, natural support to the metric evaluation of unflat surfaces (from the 3D model) and to the mapping of materials, to the classification and to the ruin location. Therefore, it represents a qualifying support to the cost sanalysis according to the intervention plans (from the orthogonal metric projection of the shots).

5. CONCLUSION

For this year the project has been closed, because the interventions that had been required by the first and second parts of the agreement have been completed (Figure 24).
The survey will go on as a research to generate a complete 3D model of the most important indoor spaces besides that of the whole Villa.

Figure 24. The DVD covers of the complete materials

This georeferenced work will become part of the information system that, together with all the other non-geometric necessary information, will have to manage the refurbishment and reuse phases, but also the future planned maintenance. The final aim is, then, to read and understand the building, its parts, its functioning, in order to guarantee the necessary balance for its revival and its future management.

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