DSM AND DIGITAL ORTHOPHOTOS IN CULTURAL HERITAGE DOCUMENTATION

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ABSTRACT

The research has been addressed to the production of digital surface models (DSM) and ortophotos of the internal fronts in the "Oratorio del SS. Rosario in Santa Cita" in Palermo. The Oratory has been built between the end of the XVIIth century and the start of the XVIIIth; it is regarded as the higher expression in the work of the sculptor and stucco-worker Giacomo Serpotta.
The internal fronts, whose architectural partition is almost conventional, are characterized with a rich sculpturesque decoration, made of statues and three dimensional perspective scenes named "teatrini". The contextual presence of architectural and sculpturesque forms makes the internal fronts a good subject to experiment with the integration and comparison of photogrammetric and laser scanning tecniques of surveying.
Surface models of one internal front of the Oratory have been produced using heterogeneous data coming from digital photogrammetric processes and laser scanning acquisitions; surface models have then been compared to value the differences between each other.
Surface models generated from point clouds triangulation process have been refined using CAD models and breaklines coming from photogrammetric restitution. Refined surface models have then been used to produce one digital orthophoto.

1. INTRODUCTION

Laser scanning technology has deeply modified the approach to surveying architecture; great amounts of metric data are collected rapidly, and surface modelling is apparently easy.
Still few years ago partition of architectural surfaces in elementary components was one of the most important phases in surveying and measuring process. This phase seems today obsolete, and so it seems that traditional instruments and techniques -i.e. contact surveying- are not useful any more. Scanner laser metric data are actually particularly effective in surveying and modelling sculpturesque and smooth surfaces, but they sometimes fail in capturing and detecting sharp edges and lines of intersection, which are essential for a correct representation of architecture.
Such problems can be solved using several devices in scanning process, such as time of flight (TOF) scanners for wide surfaces and optical triangulation 3D scanner for details; cloud points could be then joined and used in polygonizing phases. Yet this solution increases the cost and the duration of data collection phase and produces an excessive amount of points.
A different solution is achieved integrating point clouds and metric data collected with photogrammetric or traditional contact measures. The investigation means to prove that integration between different techniques of measuring and modelling is still a proper praxis in surveying and representing architecture.
The internal fronts of the "Oratorio del SS. Rosario in Santa Cita" in Palermo are appropriate to such experiment, since their architectonic structure is enriched with sculpturesque decoration. Metric data of the entrance front have been collected with photogrammetric restitution, laser scanning acquisitions and contact measuring of detail elements.
Surface models have been produced both with photogrammetric correlation and polygonizing processes. In order to improve the correspondence between virtual and real forms, surface models have been refined introducing breaklines and CAD surfaces.
Surface models have finally been used to produce and compare different ortophotos of the front.

2. DESCRIPTION OF THE "ORATORIO DEL SS. ROSARIO IN SANTA CITA"

The Oratory dedicated to the Holy Rosary has been built between the end of the XVIIth and the start of the XVIIIth century, near the church of Santa Cita, in the ancient centre of Palermo.

Figure 1. Photoplane of the entrance front.

The Oratory is an introverted edifice with richly decorated internal fronts and absolutely bare external fronts. A rectangular

hall is lightened by eight windows in the long sides; one of the short sides is interrupted by a triumphal arch that leads to a square apsis; the opposite front is the entrance front, with two symmetric doors opening at his ends.
All the internal fronts are richly decorated with allegoric sculptures of virtues or characters from the Old Testament. Fifteen three-dimensional "teatrini" represent the episodes of the life of Christ and Maria evoked in the prayer of the Rosary. An oversized "teatrino" at the centre of the entrance front represents the battle of Lepanto (Figure 1).
Giacomo Serpotta has realized all the sculptures and phytomorphic decorations in the period from 1685 and 1717 with one only low cost material: white stucco.

3. DATA ACQUISITION

3.1 Photogrammetric survey

A mobile iron structure with five elevations has been arranged to lighten the entrance front and take photos with axis direction orthogonal to its mean vertical plane.
Photogrammetric images have been taken at a distance of 6 m from the front using an analogic semimetric camera Rollei 6008 with a 50 mm lens. The scale of the photos has therefore resulted nearly 1:120. The entire front has been covered with 4 horizontal strips of 5 photos (Figure 2).

Figure 2. Photogrammetric coverage.

A proper number of 4x4 cm adhesive targets have been placed on the wall and have been measured with topographic instruments. Targets have been used as control and check points in the exterior photogrammetric orientation. Targets coordinates have been referred to a local reference triad having *xy* plane parallel to the front.
Photos have been digitized with a film scanner Nikon Coolscan 8000 ED at the resolution of 2000 dpi. Pixel in digital photos has the dimension of 13 µm, that is equivalent to 1,5 mm. on the object.
Photogrammetric restitution and orthorectification have been carried out with the software SOCET Set 5.2. External orientation process has been performed using 15 control points, and has produced the following residuals:

RMS x ==> 0.003 m
RMS y ==> 0.002 m
RMS z ==> 0.007 m
Total RMS ==> 0.008 m

In order to check the accuracy of the orientation process 14 check points have been used. Check points residuals are listed below:

RMS x ==> 0.003 m
RMS y ==> 0.003 m
RMS z ==> 0.009 m
Total RMS ==> 0.009 m

Sharp border edges of the mouldings surrounding the "teatrini" have been drawn using stereoscopic photogrammetric restitution. Photogrammetric restitution has been restricted to the main border lines of the mouldings and the edges of the truncated pyramid with perspective scene. Such lines have been used in surface and CAD modelling phase (Figure 3).

Figure 3. Photogrammetric restitution.

Photogrammetric restitution has been used also to generate a DSM of an area corresponding to the "teatrino" above the right entrance door. DSM has been calculated by image matching (Figure 4).
Generating precise models of architectural surfaces with photogrammetric autocorrelation is not easy. Complex geometries, sharp edges that break the surface, sudden changes of z-coordinates, are often simplified or smoothed.

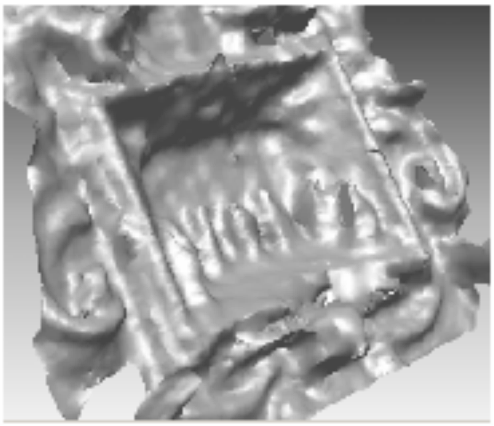

Figure 4. Photogrammetric DSM of the "teatrino".

3.2 Laser scanning survey

Two scans of the entrance front have been taken using a laser scanner device Mensi GS100; the scanner has been placed in two distinct points sited at different distances from the front (Figure 5). First scan has been performed from the furthest point with an angular step corresponding to an average grid of 10 mm on the object; a more accurate scan, restricted to the lower part of the front, has been taken from the nearest point with a mean step of 3 mm. (Figure 6).
Both scans have been taken positioning the device on the floor; that's why point clouds have several holes in the areas above elements that stick out of the wall – i.e. cornices – or behind sculptures.

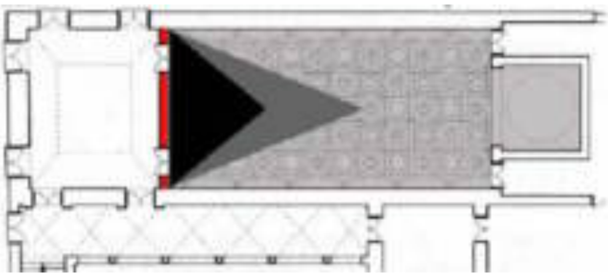

Figura 5. Laser scanner placement.

Three reflecting targets, positioned in the lower part of the front, have been used to register the scans. Target coordinates have been calculated through topographic measurement; target and point clouds coordinates have then been referred to the local coordinate system used in photogrammetric processes.
Using an unique coordinate system for heterogeneous metric data allows comparison and integration between them; in this work laser scanning and photogrammetric data have been joined to refine surface models.
Point clouds pre-processing has been performed in the following steps:

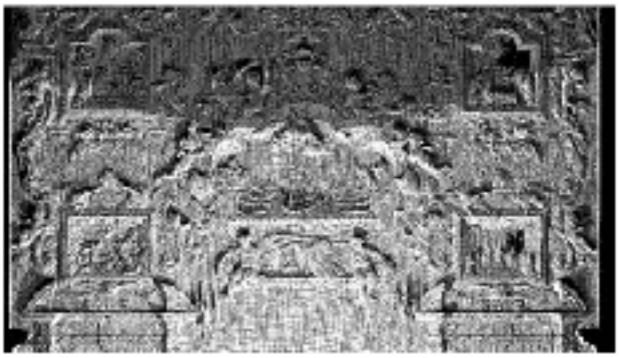

Figura 6. Point cloud of an horizontal strip in the entrance front; different resolution scans are overlaid.

- curvature based point sampling to reduce points in low curvature areas;
- noise reduction to eliminate redundancies due to errors in the scan process;
- rejection of the outliers - i.e. points that statistic computation find not to be part of the surface.

Polygonizing operations have then converted the point cloud into a triangular net model of the surface.
In the areas where points are sparse or lacking, such as the higher part of the front, polygonizing process has failed leaving several holes.

3.3 Contact measurement

Architectural mouldings are complex elements composed of surfaces intersecting in lines and curves close to each other. Surveying mouldings requires therefore an high level of detail; measurements can be executed with dedicated laser devices or, in a simplier way, considering mouldings as the result of extrusions of profiles along rail lines. This way, it is enough for their rapresentation to get plane sections of mouldings profiles and then extrude them along rail lines. Plane sections of the mouldings have been collected with a quite simple instrument that is pushed over the profiles and retains the imprint of it.

4. MODELING AND SURFACE REFINEMENT

Surface reconstruction and refinement has beeen executed with RapidForm 2004. Microstation 8.0 and Rhinoceros 3.0 have been used to produce surface CAD models.
Surface refinement has been achieved in the following steps:
- edges sharpening;
- integration of polygonal and CAD surface models;
- holes filling.

4.1 Edges Sharpening

Edges sharpening is usually achieved introducing breaklines generated directly from the surface model with automatic processes of edge extraction; triangular net is then modified so that triangles do not cross the breaklines. This process is strongly conditioned by surface model accuracy.
The investigation has been addressed to define techniques and procedures to insert in the surface model three-dimensional breaklines plotted with stereoscopic photogrammetric restitution. Breaklines have been exported as IGES and then attached to the surface model; sharpening process has

Figura 7. Detail of the “teatrino”.

succeeded in generating triangles having a vertex or one side on the breakline. (Figure 7-8-9-10)
Sharpening process obviously depends both on the accuracy of photgrammetric restitution of the breaklines and on dimension and density of triangles.
We have concluded that good sharpenings are achieved when continuous surfaces surround the edge; if several edges are close to each other, such as in mouldings, sharpening processes to not produce good results.

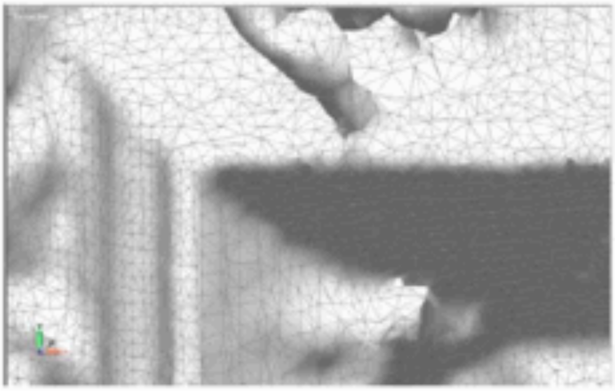

Figure 8. Surface model from laser scanner data.

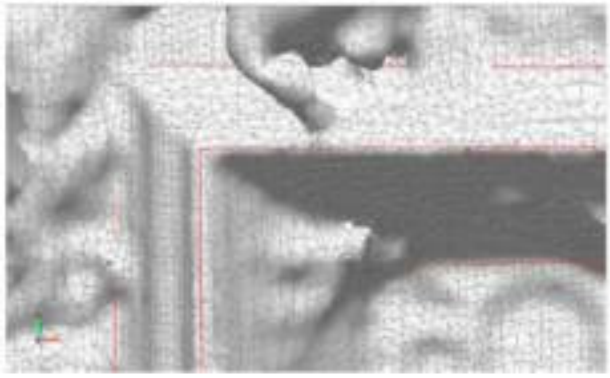

Figure 9. Superimposition of photogrammetric breaklines on surface model of triangles.

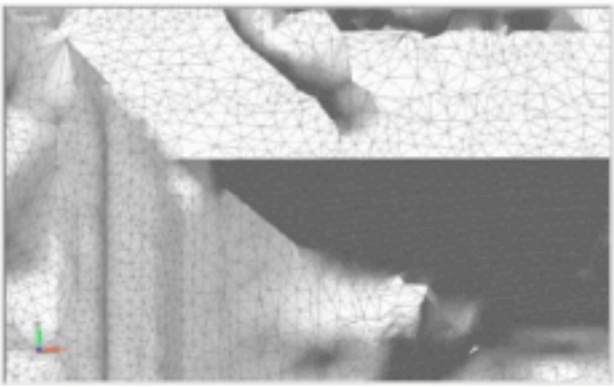

Figure 10. Edges sharpening

4.2 Integration of triangulated and CAD surface models

Another way to refine surface models is substute parts of the mesh with CAD models. In order to achieve a good result CAD models must be dimensioned and positioned properly.

We have tested the substitution of the cornice of the entrance door and the moulding of the "teatrino" above it. Both of them have been modeled in CAD environment using processes of extrusion, sweep of section profiles along rail lines, lofts and ruled surfaces (Figure 11). Rail lines can be determined with photogrammetric restitution or extracted from the polygonal surface model generated from point clouds. Rail lines are particularly important since they determine the dimensions and the position of the CAD model.

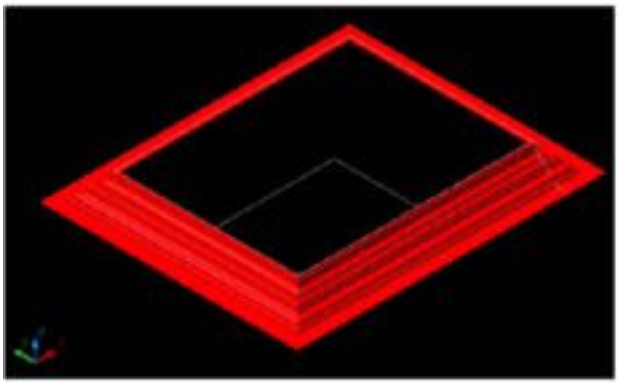

Figure 11. CAD model of the "teatrino".

In order to extract rail lines from the polygonal model we have determined several reference planes; vectors have been produced intersecting planes and comparing them with section curves of the model (Figura 12 13)

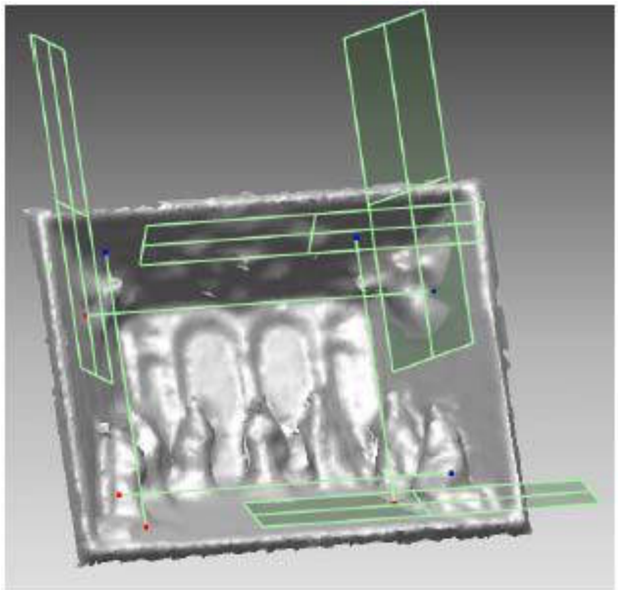

Figure 12. Reference planes and intersection vectors.

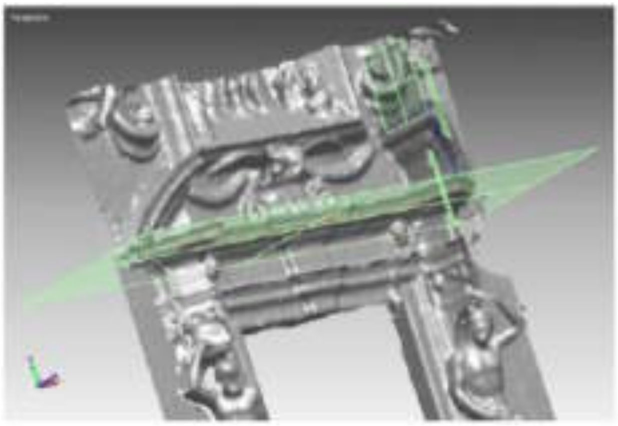

Figure 13. Reference planes and section curves of the cornice over the entrance door.

CAD models have been polygonized to achieve an homogeneous surface model. Portions of the polygonal model overlapping cad model have been deleted using boolean operators (Figures 14-15) .

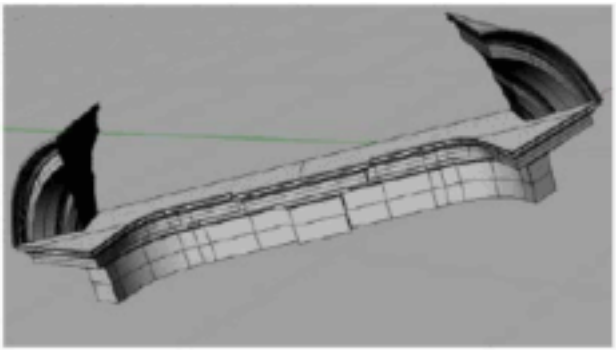

Figure 14. CAD model of the cornice.

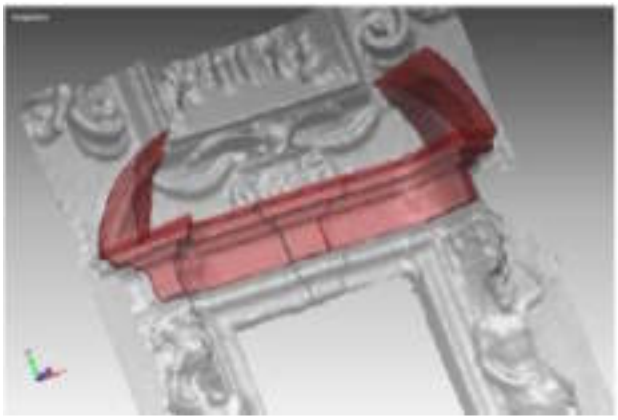

Figure 15. Superimposition of CAD model on polygonal surface

In the last step an alternative method for hole filling in plane areas has been tested. Plain holes in the surface are often transformed in curved surfaces if they are filled with automatic processes (Figure 16). We have created plane patches using a mean vertical plane that approximate the geometry and position of the lacking areas. This plane has been cut projecting onto it boundary curves from the polygonal model. Patches have finally been imported and integrated with the triangular surface.
Finally CAD model of the "teatrino" has been compared to photogrammetric restitution (Figure17).

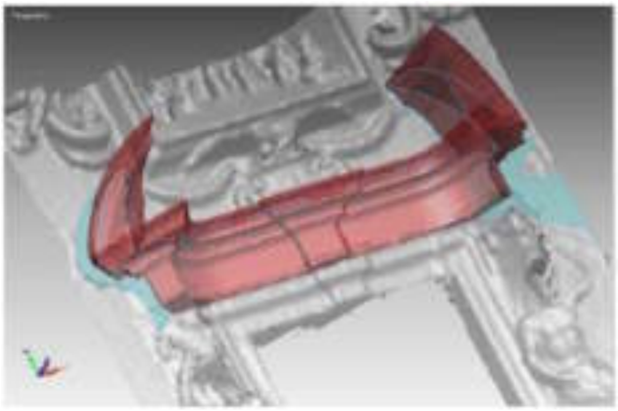

Figure 16. Plane holes filling.

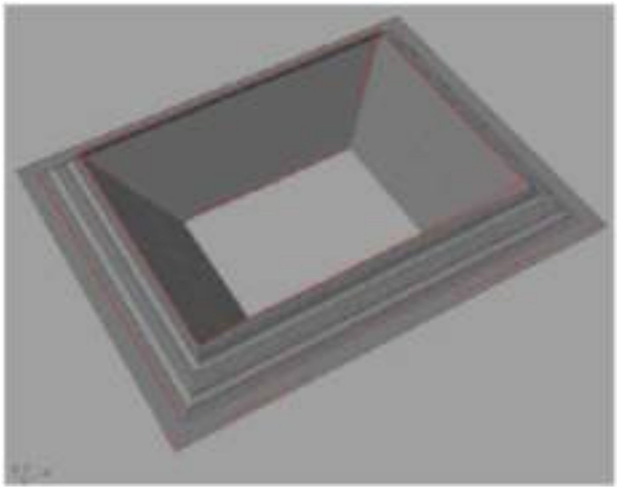

Figure 17. Superimposition of photogrammetric lines on CAD model.

5. DIGITAL ORTHOPHOTOS

Refined and accurate surface models can be used to produce high quality orthophotos; we have made several tests to verify the influence of surface models on orthorectification process.
Initially we have used the surface model generated with photogrammetric autocorrelation; orthophoto image has errors and deformations, particularly in the areas where the surface model does not match the real form of the surface. (Figura 18)

Figure 18. Orthophoto generated with photogrammetric DSM.

Then we have used the model resulting from point cloud triangulation; orthophoto has been improved, but it keeps some deformations.
Further orthorectification tests have been done using refined surface model. This surface model has an heterogeneous density of triangles.
Surface models generated from point clouds have a quite homogeneous distribution and dimension of triangles, while tessellation of CAD models produces non uniform distribution

In order to correct dimensional and distribution differences surface model has been resampled, virtually simulating the scan process.
DSM generated form virtual point cloud has been used to generate one orthophoto of the investigated area (Figura 19-20).

Figure 19. Orthophoto generated with refined surface.

Figure 20. Detail of the orthophoto.

6. CONCLUSIONS

The investigation on DSM and digital orthophotos has tested procedures and techniques to refine surface models through insertion of breaklines or integration with CAD models.
The contextual presence of architectural and sculpturesque forms on the front used for the investigation, makes it difficult to produce good orthophotos.
In the orthophoto produced with refined model several errors and deformations have been corrected; model refining processes have therefore improved orthophoto quality.
Several problems are not completely solved yet, and need further investigations; tessellation algorithms and simulate scan processes should be tested with different CAD and polygonal models.
Partitioning processes and integration of different measurement and modeling tecniques seem to be useful in cultural heritage surveying and representation.

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CREDITS

Arch. Rita Corsale has realized the photoplane of the entrance front.