LASER SCANNING AND TRADITIONAL SURVEY INTEGRATION TO BUILD A COMPLETE 3D DIGITAL MODEL OF "SAGRESTIA DELL'ARCHIVIO DI STATO A MANTOVA"

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ABSTRACT:

The main tasks of this work consisted of the look for an integration between methods of traditional survey and laser scanning technique in the 3D architectures survey.
The intentions to build a model that is able to satisfy the demands of precision, for example, to planning an intervention of recovery and therefore to editing architectural plates, but also those of aesthetical quality and representative effectiveness, they have conditioned the choices that have driven this work. In other words has been estimated the effectiveness and the potentialities of this new survey method , which in this case was supported and assisted with traditional methods that have also allowed to test the model obtained from laser scanner.
During this work we have realized how this new method of survey, that allows a quick acquisition of million points, that allows the description of even very complex geometries, imposes many evaluations beginning from the fitter tool until the choice of target points and about the method of textures mapping, which are very important for the quality of final digital model.

1. INTRODUCTION

The Sacristy of State archives in Mantova, is an architecture that allows to appraise the effectiveness of this integration: inside the Sacristy there are many decorations and plasters that would require a long and hard-working traditional survey. The Sacristy has an octagonal plant, 15 meters high and about 12 meters wide.
There are many ways of creating 3D model of a building and many technologies can be employed to record the spatial and visual complexity of real word environments. The work described in this paper, wants to underline the necessity to integrate these different techonolgies to optimize the costs, accuracy and visual quality of the final 3D model. Another important thing is the approach to create a complete 3D not limited to an internal or anyway partial reconstruction but a full 3D composed from an internal end external surface to create the as completed as possible representation. In this way is also possible to give a more realistic perception about the building volumes.
The 3D model obteined is not only a photo-realistic representation of the reality building but is also dimensionally rigorous so it has also an important metric value which makes it a powerful tool of investigation and study of the architecture.
Is important to underline how from such product is possible to obtain a series of graphic useful results for the planning and design of interventions to the building safeguard.

2. LASER SCANNING SURVEY

The laser scanning survey was made with *Cyrax 2500* laser sensor, that has single point accuracy equal to ± 6mm. The scanning procedure took up 1 working day, using 15 different viewpoints. In some of these the scanner was mounted on a tri-pod while for the other it was just leaned on the floor. The scanning survey has been articulated in the follow steps.

- Planning the distribution of laser viewpoints.
- Laser data acquisition.
- Images acquisition by digital camera.
- Scans merging and orientation in an absolute reference system.
- Meshing to produce a triangulated 3D.
- Editing operations on the 3D model.
- Texturing the photograph images on the geometric model.

In the most cases it is not possible to have complete 3D representation from data acquired at a single viewpoint. Indeed, to resolve occlusions in the scene or to reconstruct large scenes, it is required to have 3D data acquired from multiple viewpoints. So it was necessary to locate the sensor at several positions inside the sacristy, since all surfaces may no be visible from a single point or will data be acquired at sufficient resolution.
The problem of determining the next capture point depends on how much a priori information about the scene is available. The selection of the next capture point should consider both the resolving occlusions in the already extracted model and the acquiring additional views of the non-modelled environment. The latter are required to have a sufficient overlapping region between two scans so to aim their integration. Is easy to see that the quality of the final model depends highly from the planning strategy and in particular from the distribution of the viewpoints inside the architecture. Another important thing to consider is that the number of these points, from where the data is acquired, should be minimised to reduce the time needed for a complete scene reconstrucion. These considerations are important also for the points where photograph images are taked. The problem to chose the viewpoints position represent an important phase of the survey, in particular for a complex architecture like this one. Recently have been proposed some algorithms that allows to determine the best viewpoints position considering many

scanning parameters (occlusion detection, accuracy, time optimisation...)
All these reasons underline how is important to use digital instruments during the survey that allow to verify on the field, in real time, the data transferred on a portable PC and evaluating the best position of the point of view for the next scan or intensity image acquisition.

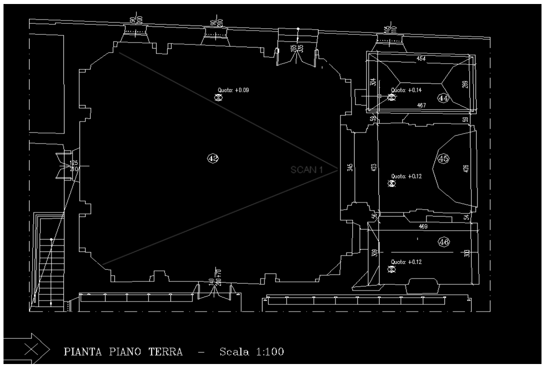


Figure 1. Scan field of view on sacresty plan.

The distance, between the center of the sensor and the points on the surfaces, has remains between 10 and 15 meters, so considering that the laser mesh was composed from 1000x1000 points with an aperture of 40°x40°, the distance between the points, in the cloud that describes the 3D model, result included between 1cm and 1,5cm. The whole process of evaluation to create a 3D model took about 7 days, fairly divided between geometrical mesh construction and textures application.
A reconstruction algorithm based on polygonal meshes was used to produce a triangulated model.

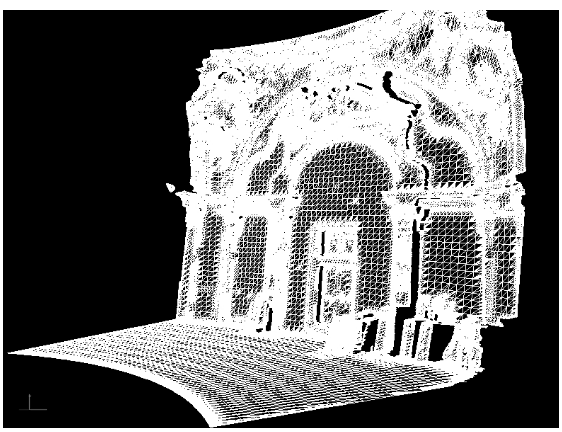


Figure 2. Triangulated model of a scan.

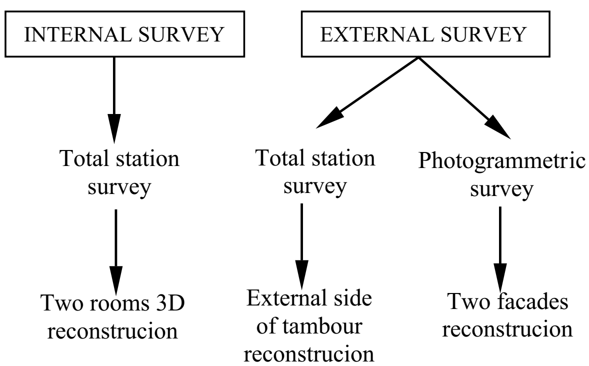
To map the texture upon the surface covered from a single scan, has been necessary two photographic images taked from a position close to the laser scanner viewpoint. The digital camera adopted is *CANON Powershot PRO 90 IS* with CCD 3,34 Mpixel sensor.
One possible solution for determining the relationship between range and color images is through calibration using the calibration board and fixtures. However, this method requires that the range and color sensors be fixed on the fixture once the relationship is calibrated. But usually a color camera is much handier than a range sensor so is better to take color images freely without having to transport a heavy and fragile range sensor.
As side product of range images, range sensor often provide reflectance images that represent a collection of the strenght of returned laser energy at each pixel. This image is aligned with the range image because both images are obtained through the

Figure 3. Reflectance image of a scan.

same receiving optical device, in other words reflectance and range data are fully registered, considering they both originate with the same echoed laser. The returned timing provides a depth measurement, while the returned strength provides a reflectance measurement. A reflectance image is itself an image of the scene and can be matched to any other image such as photographic images.
Our range sensor *Cyrax* provide reflectance image, so we decided to employ this image as a vehicle for the alignment of range images with intensity images.
Reflectance images are similar to intensity images in that both images are somehow related by surface roughness. Since the reflectance image is aligned with the range image, so to align the reflectance image with the intensity image is much easer task than that aligning the range image with the intensity image.
Corrispondences between the reflectance and the digital images are computed using a semi-automatic system, that align extracted features (edges or points) from reflectance images with those in intensity images. It is possible to guide the system by adding extra points and find further corrispondences. These edges are easy to find in the intensity images, since they are generates from a boundary between two different colors or materials that generates a discontinuity of reflectance. Thus, this method allows to align 3D points on range surfaces with 2D points in the intensity images. This is very flexible in that it allows the model to be texture-mapped using an image taken with any camera, at any time (even historic images can be uesed), from any location. The software used to process the laser scanner data is *RECONSTRUCTOR* realized by 3Dveritas.

Figure 4. 3D edges extraxted from reflectance image.

3. TRADITIONAL SURVEY



3.1 Photogrammetric Survey

For large planar and regular surfaces, like the external two façades of the sacristy, photogrammetric single image techniques has been considered the best solution. It combines true scale geometric measurements with full image information under quite inexpensive instrumentation costs. To make this survey 22 images and 40 control points were needed. The software used during streightening and merging operations is Rollei MSR.The result obteined at the and of this elaboration has required a small intervention of photograph retouch to eliminate sudden changes of contrast or illumination between the images.

3.2 Geometric Survey

Leica total station TPS 1103 was used during the geometry inquiry and the control points measuring for photogrammetric survey.
This instrument has permitted to survey two little rooms enclosed to the sacristy. By this technic the coordinates of many edge points has been measured and referred to the absolute system. After this, they were imported in the Autocad software, where, using the spline command, has been possible to build a three-dimensional wireframe model of the whole locals. This operation was conduced verifying the exact reconstrucion of the geometries as soon as comparing them with the drafts traced during the survey. The following step, always thtough Autocad software, was the construcion of the surfaces that have allowed to complete the reconstrucion from a vectorial point of view of the geometric model. The same procedure was followed for the external tambour side survey.
The choice to use this method instead laser scanner survey is because the geometry of these architectures was very simple and easy to register by a classical topographic instrumentation. It would be useless to describe a planar surface with a cloud of milion points. Moreover traditional survey methods have also allowed to test the 3D model obtained from laser scanner. The inner profile of a decoration along the tambour has been surveyed by both methods. The profiles extracted from two survey technics (traditional with total station TPS 1103 and laser scanning) present a maximum gap equal to 2 cm.

4. LASER SCANNING AND TRADITIONAL SURVEY INTEGRATION

For each position the scanner yelds a point cloud in the sensor coordinate system. The data sets of all the positions have to be orientated relatively to each other so that homologous points have the same coordinates. An absolute orientation can be performed if the coordinates of some object points are known. In this case on the scanned surface was present 10 signalised and measured target points. Their identification on reflecatnce images was very easy because the echos of the retro-reflective targets have much higher intensities than the surrounding area. In a second step other points were mesured to increase the data for scans orientation. These points were generally characteristic parts of the ornamentation.

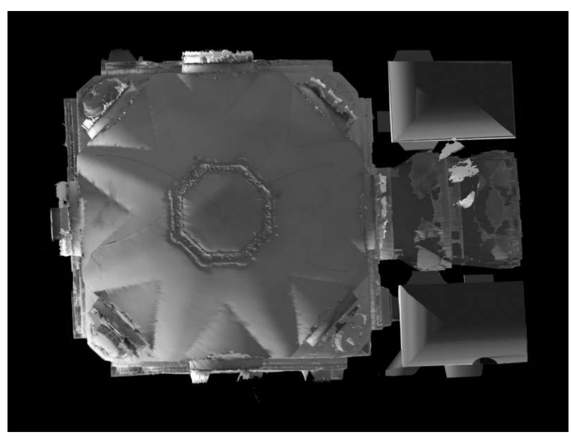


Figure 5. View of two surveys in 3D STUDIO

The 3D model of the sacristy was made from merging the 15 scans in an indipendent coordinate system and then transformed using a 3D coordinate of target points into the absolute coordinate system.

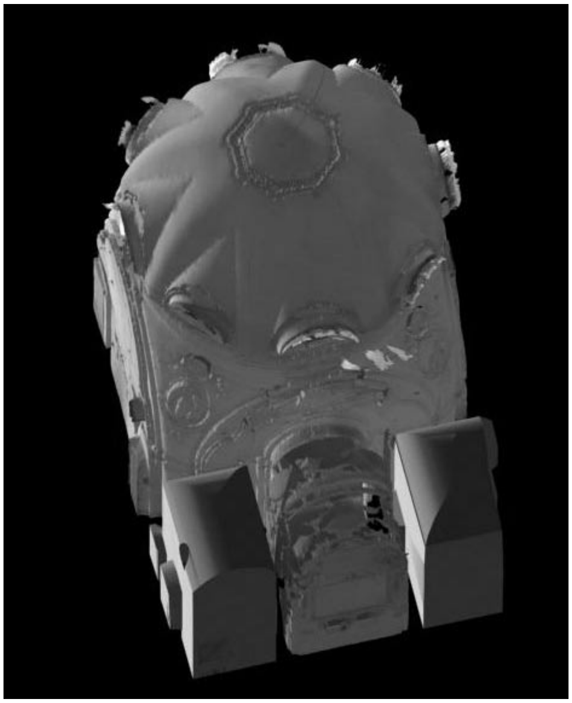


Figure 6. Perspective view of sacresty with two little rooms.

All the survey has arranged in an only one reference system rappresented from a topographical net that develops itself inside and outside the archives. Three vertexes of this net are inside the sacristy and other five around it. This has allowed:

- First of all, has been possible to refer the 3D model, that derived from the laser scanning survey, to the global reference system. That has been possible thanks to the coordinates measure of many target points with classical topographic methods.
- Then, has been possible the integration of the survey realized with laser scanner, with the reconstruction of the side small rooms. This last one has been realized with a survey made with traditional methods and reported to the global reference system.
- Besides has made the survey of the Sacristy's external surfaces, for which was used the photo-straighten technique. So the final 3D is not only an internal view of the architecture.

A topographical net is an important point to start every architectural survey, but in this case where we need to integrate data from different instruments and different technics, it assumes a particular significance. All the survey phases have been referred to an only one reference system thanks to a high precision network, measured by the University of Brescia. Every point of this net, made in 1996, has a monography with the position indicated by a picture and a sketch that allows to find it easy. Besides there are it's coordinates and those accuracies calculated by a least squares adjustment. All these informations are stored in a HTML structure into an interactive CD-ROM, that can be consulted by a common internet browser. The final 3D digital model is composed with 3D STUDIO MAX software, where have been imported all components of survey from different formats (.wrl; .bmp;.dwg.;dxf).

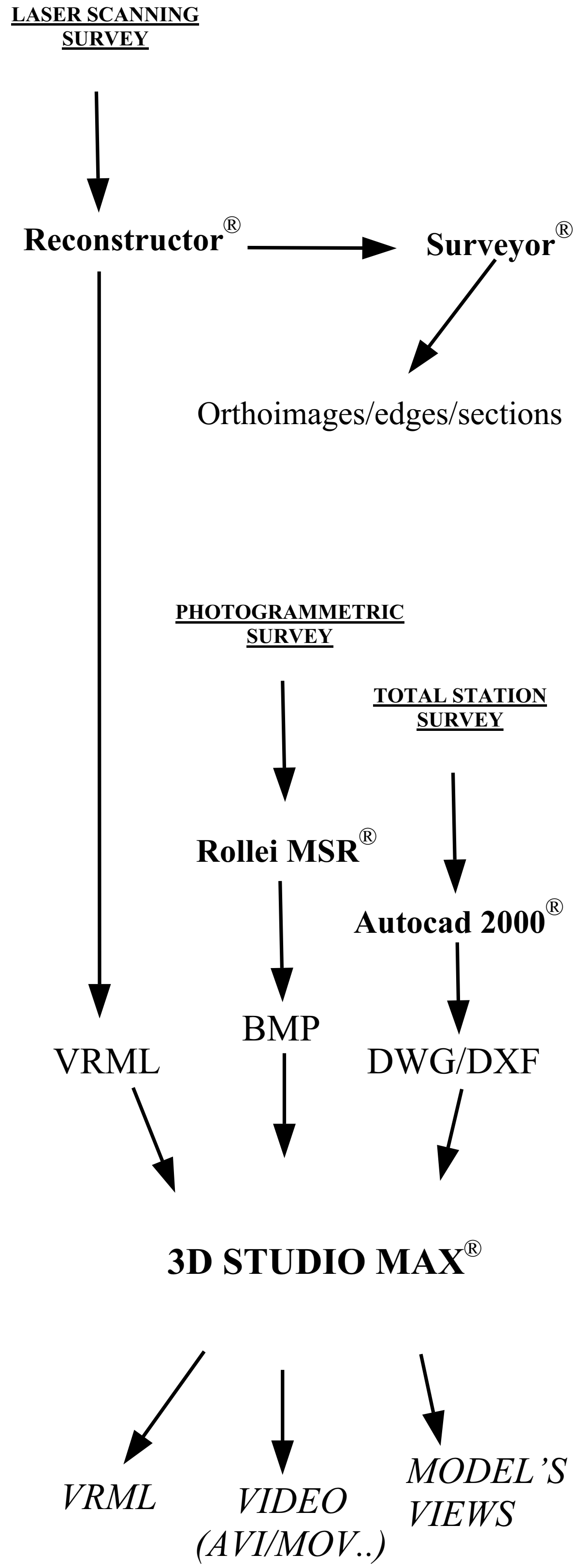


Figure 7. Chart of work procedure.

At this point has began the study about the methods of presentation and investigation of the 3D model, that could be sectioned with specifics tools to produce horizontal and vertical sections complete of orthoimages and 3D edges; otherwise it can be used as a support in the realization of a GIS or to realize a promotional multimedia CD.
An important role is assumed by new format code called VRML (Virtual Reality Modelling Language), that has been selected as the internet format to describe 3D environments. It is supported by most browsers and there are a few public demain plug-ins. VRML allows to study the 3D model in a way really interactive trough a simple instrument. Moreover, several tools, developed in java language, have also been implemented in order to demonstrate the high potential of the 3D models. These tools allow for example the meausurement of distance between points or simplify the 3D navigation by taking the user smoothly along a predefinied walkthrough.
How can be seen in the previous page chart, some important results have been obtained from laser scanning survey using *Surveyor* software. This tool allows to section 3D model and to export edges, orthoimages and section profiles. These informations can be imported in a CAD software to edit architectural plates.
3D studio software, where all the survey is stored, allows to make some interactive products like video and VRML that assume an important role for educational and promotional purposes.

5. CONCLUSIONS

This work wants to represent an example as a method of approach to the survey of a historical architecture, for which is generally very difficult find an only one investigation tool.
Instead, is more effective search for the correct compromise that integrates techniques even very different each other, but however easy to be effectively integrated in a result that covers an ample range of applications and that could be a support for technical staff, studious or simple tourists.
This work is interesting also because this place, during the XIX century, has been used as a barracks from the napoleonic army that has ransacked it and partially defaced: because of these events many decorations, particularly some capitals, has been removed. An interesting application of this survey will be the reconstruction of a comprehensive vision of the sacristy thanks to the introduction, in the virtual 3D model, the missed elements reconstructed on the base of those preserved.

6. ACKNOWLEDGEMENTS

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