Photogrammetry and Laser Scanning in Surveying and 3D Modelling of Architectural Heritage

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SUMMARY

Using the most recent survey techniques of an Architectural or Monumental Heritage, this study investigates problems on three-dimensional modelling.

It is plain that the achievable accuracy, with specific characteristics of every single technique, determines a considerable variety of attainable products that vary from navigable three-dimensional models for tourist and popular aims to 3D Informative System for Architectural Heritage conservation and restoration.

As a first approximation, it is intuitively remarked that Laser Scanning and Metric Cameras Photogrammetric survey products will be addressed to precious Monumental Heritage, in which accurate control operations of spatial information, with perfect metric object knowledge for conservation and restoration, it is necessary.

Recent instruments with minor accuracy achievable (digital cameras, etc.) can certainly be utilized for three-dimensional models, also with 3D Modelling and Virtual Reality techniques, in order to permit public knowledge and fruition of monuments. In this case we want investigate in such situations, and with what accuracy they already are a valid alternative in the field of Monument metric description.

We have studied an Italian Church, situated in Conversano (Bari), in the Apulia region, realizing a survey campaign with Laser Scan Cyrax 2500, Photogrammetric instrumentation: UMK – Zeiss Jena Metric Camera, with frame size of cm. 13 x cm. 18, and Nikon D100 reflex digital camera with 6 Mpixel CCD.

The survey process had permitted three-dimensional coordinates identification of scattered points that consent three-dimensional model realization of the Church exterior surface.

With this work we attempt investigate the utilization of different architectural survey instruments in order to obtain a complete metric documentation of Architectural Heritage.

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1. HISTORICAL AND ARCHITECTONIC NOTES

The S. Catherine's church in Conversano, in the province of Bari, has a singular "quadrilobata" plan of unsure origin.
However, several studies assume Byzantines, Greeks, Armenians or Syrians influences.
The construction of the Church has an uncertain temporal collocation because it oscillates between the XI and the XIV century due to the lack of precise probative documents.
The Church is placed less than 1 km from the city of Conversano in the countryside of Apulia region.
It has a plan made of four semicircles welded in a life edge. The radius of the semicircles corresponds approximately at the half of the circumference that circumscribes all the plan of the church. Even in the cross-section is a correlation between the dimensions, finding in the radius of the cupola curve, the same dimension of the radius in each lobe of the plan.
The masonry is made of blocks of calcareous stone arranged in a thick plot of concentric rings for each lobe. The masonry closes with a frame that divides the superior level, constituted by an octagonal cupola drum, which is closed by shed roof and dominated by a quadrangular little steeple covered by a spire.

The inside is completely perusal and realizes a very interesting space just because of the relationships elapsing among the dimensions of the single elements both in the plant that in section.
The current aspect of the church is due to the restoration made in 1935 which altered the original aspect by modifying several parts in an arbitrary way.
The choise of this particular type of Architectural Heritage, with many kinds of curved walls, is intentional in order to investigate several methodology of survey.

2. TOPOGRAPHICAL SURVEY

The planning of survey has previewed the location of a network constituted by four stations around the monument, and one on the entrance threshold with consequent materialization and a monographic card for each station.
The network of control points has been realized using the Total Station NIKON NPL-820 equipped with laser without reflecting prism. From every station, the positions of the single stations and an high number of points have been surveyed for the photogrammetric models.
All control points have been referred to the same local reference system with opportune procedure of bundle adjustment.

The monument had been preventively equipped of affixed targets in all the lower part of the Church. For the other ones easy recognizable points of the same monument for the photogrammetric survey have been found.

3. LASER SURVEY

A higher number of targets which supply a better reflectance have been used for the Laser Scanner survey.
The survey has been carried out by placing the Cyrax Laser Scanner 3D in four points around the Church setting the instrument in order to acquire a grid of points with equidistance of 2 cm with a vertical angle of 40° and with the necessary amplitude to frame the Church according to the software of the instrument management.
After a few minutes of surveying the Scanner has pointed out a dense cloud of points so that it has been possible to see the result of acquisition in the same countryside.
On the Notebook screen it is possible to visualize the acquired cloud of points in several modalities, which give the perception of the building shape in all the three dimensions. The same software exports the survey in different kinds of files such as the DXF and ASCII format with X,Y,Z coordinates which we have used in the following elaborations.

4. PHOTOGRAMMETRIC SURVEY

The architectonic building can be well investigated through photogrammetric means. For this reason we have carried out several photos with different photographic instruments in order to compare results and procedures regarding both the difficulties of execution and allowed accuracy.
The first metric survey has been carried out, using a Zeiss Jena UMK Metric Camera (photograms 13 x 18 cm), by 5 couples of photograms (Fig. n. 1) for the realization of stereoscopics models: 4 models in axis with the lobes of the plant and the fifth one in adding for the main façade.

Figure 1: UMK 13 x 18 Photogram

In the same time another survey has been carried out, using a Nikon D100 digital Camera 6 Mpixel previously calibrate in our laboratory, obtaining 4 couples with 28mm focal length.

Nikon D100 digital camera has been calibrate with Photomodeler Camera Calibrator that use 8 different photos of a panel with 111 target points.

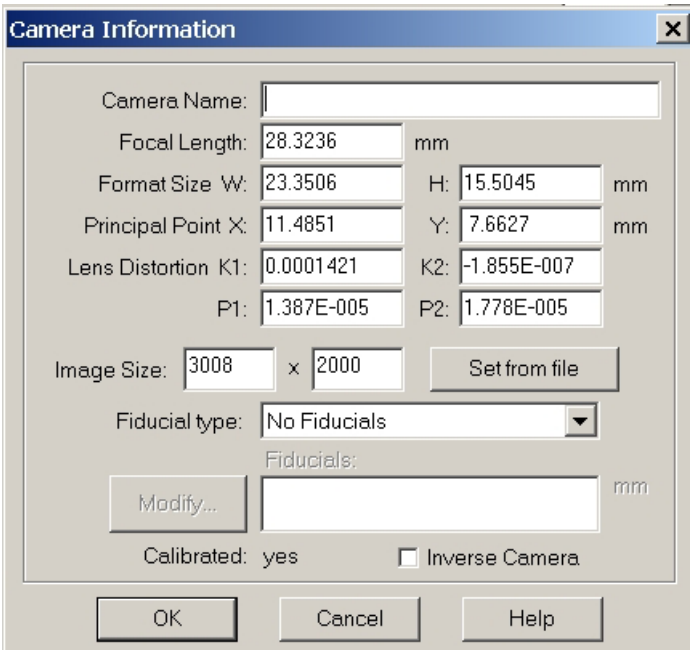


Figure 2: Camera calibration information

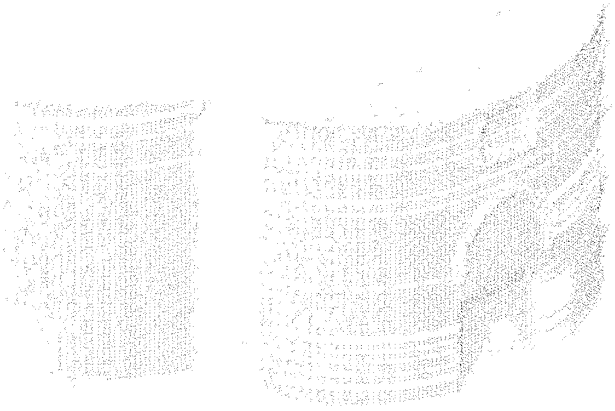
The images recorded at the maximum resolution allowed by the camera firmware have produced 17 MB files for each one in TIFF mode.

5. IMAGES DIGITIZING

The photograms realized with chemical film cameras have been digitized with the Wherli RM3 digital photogrammetric Scanner by 20 micron resolution, obtaining Tiff files of about 200 MB for the UMK photograms.

6. PHOTOGRAMMETRIC MODEL WITH METRIC CAMERA

The files have been used to realize stereoscopic models through a digital plotting station constituted by SISCAM STEREOMETRIC plotting software with a suitable stereo polarized screen.
Once realized the stereoscopic model we have obtained the Digital Elevation Model of the Church through the automatic correlation.
The system has been set it in order to obtain a grid of 5x5cm obtaining thus a very interesting cloud of points but with very long times of elaboration.
The obtained points have been exported in DXF files in order to investigate the features.
The following images display the result of the cloud of points extraction with the automatic correlation of image in digital photogrammetry (Fig. n. 3) and with Laser Scanner (Fig. n. 4).
All the four model by Laser Scanner will be linked in only one reference local system that involves all the Church with the software Cyclone provided by Cyrax.



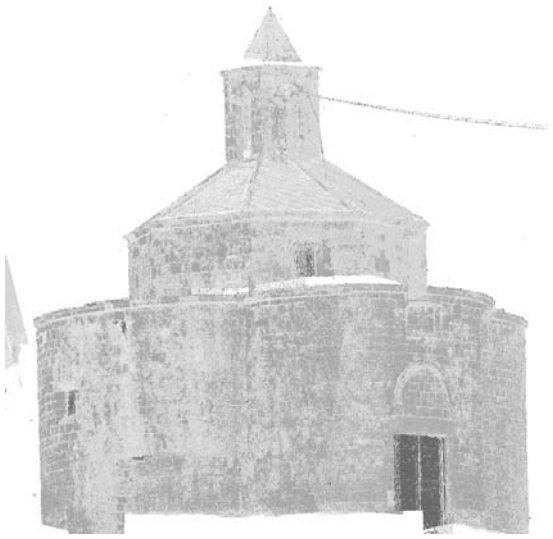


Figure 3: Photogrammetric cloud of points **Figure 4**: Laser Scanner cloud of points

These different files have been treated in GIS enviroment (Arcview 3.1 with 3D Analyst) to obtain three-dimensional models (DEM) with the typical instruments of 3D analysis, like shows in the following images: results of photogrammetric survey (Fig. n. 5) and results of Laser Scanner (Fig. n. 6).
Later we have compared the results of the two techniques of DEM production by pointing out the qualitative characteristics and verifying the usability in order to extract metric informations by digital representation of the architectonic building.
In spite of remarkable problems concerning the corrected definition of suitable breaklines and difficult extraction, the first DEM by photogrammetric survey with 5 x 5 cm grid of acquisition, gives a very interesting result.

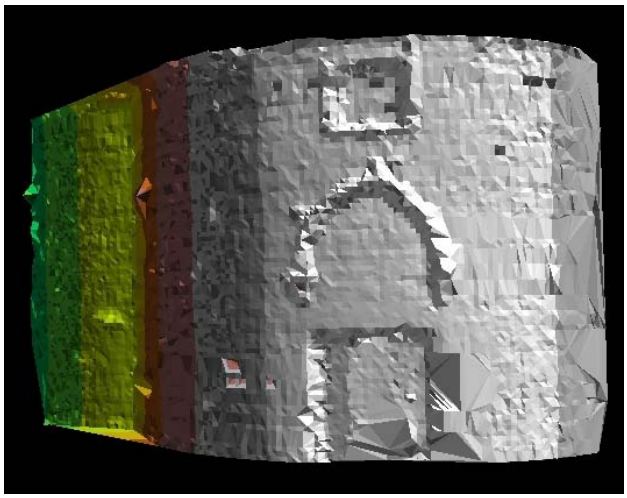


Figure 5: Photogrammetric DEM

The second DEM produces a more detailed model than the previous one, thanks to the denser grid allowed by the Laser scanning methodology.

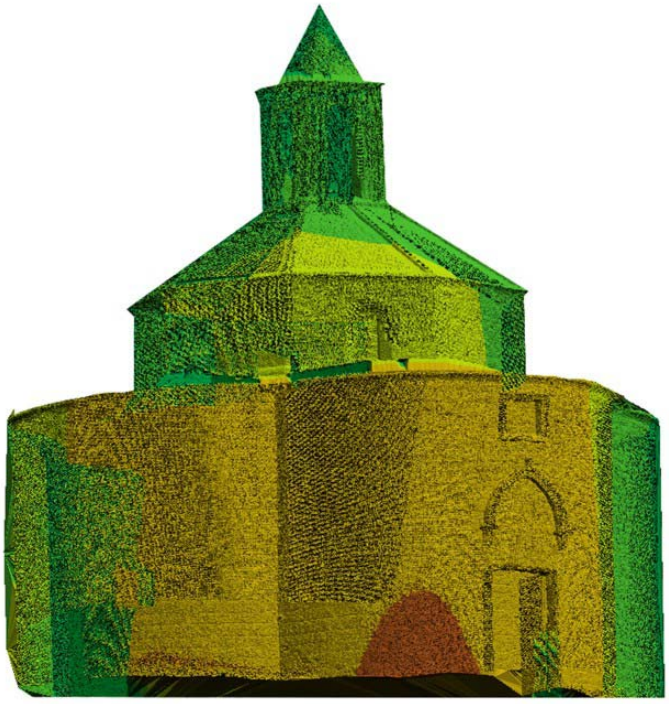


Figure 6: Laser Scanner DEM

7. CONCLUSIONS

Interesting perspectives have been opened in the elaboration and comparison of the various methodologies of extraction of three-dimensional models of the architectonic building.
The experiences produced evidence like the new frontier is constituted by digital methodologies.
In the comparison between the two DEM gains with two different methodologies, for the reconstruction of the geometric shape of the architectonic building the Laser Scanner methodology seems more easy and fast.
The Architectural Photogrammetry remains the best instrument to realize a complete architectonic metric survey, for the possibility to produce graphical elaborates (plans, prospects and sections).
A frontier all to explore will be finally that one of the production of digital models photographic three-dimensional, with methodologies like those we have begun to inquire in this work.
It is possible that in the future there will be other alternative methodologies to represent Architectural Heritage as already today are the “Ortophotomapping” in modern cartography.
In the next works we will analyze the accuracy achievable with different technics considering the Photogrammetric metod as the reference one and controlling the accuracy of Laser technics with many different Scanner and with Digital non-metric Camera.

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BIOGRAPHICAL NOTES

Mauro Caprioli is Full Professor in "Topography and Cartography" (ICAR-06) at the Department of Roads and Transportation of the Polytechnic of Bari, in which he is also Responsible for the "Topography and Cartography" Laboratory.
From 1997 Mauro Caprioli is President of the Degree Course in Engineering of Infrastructures, Polytechnic of Bari.
Since 1985 coordinator of the researches carried out from the local unit of "Topography and Cartography" of the Polytechnic of Bari.
Responsible of conventions of research with public agencies (ASI) and private companies in the field of the land survey also by means of GPS (Global Position System), of Photogrammetry and Remote Sensing aimed to the production of Cartography and GIS projects, of special surveys for environment and territory.
Advisor of Public Administrations (Regioni, Province, Comuni, etc.) for the provision of Standards and Norms in the field of Digital Cartography and Geographic Information Systems, the execution of Cartography and Civil Engineering Great Works' tests and controls.
President of Bari Section of S.I.F.E.T. - Italian Society of Photogrammetry and Topography, of which he is fellow of the National Directive.
Member of A.I.T. - Italian Association of Remote Sensing.
Member of the editorial board of the national scientific review "Bollettino SIFET".
Reference referee on behalf of the review "Terra Nova - Blackwell Science".
The scientific activity, testified from over 70 publications on national and international conferences and journals, has essentially been turned to the sectors: deformations control and monitoring, geodetic and navigational GPS, geodesy, treatment of the observations, applied photogrammetry, cartography, GIS and remote sensing.

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