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Project Presentations

The Geometric Documentation of the Asinou Church in Cyprus

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Abstract

The Asinou Church, devoted to the Virgin Mary, is a wonderful 11th c. Byzantine Church built up in Troodos Mountain on the island of Cyprus. This Church has been recognised as a World Heritage Monument by UNESCO. A joint effort between the Laboratory of Photogrammetry of NTUA and HTI had as main goal the geometric documentation of this monument, using a combination of modern digital techniques for data acquisition and methodologies for data processing. Digital surveying and photogrammetric instrumentation, as well as a laser scanner were employed, in order to collect the necessary data for producing digital colour orthophotographs for the four exterior facades and six interior crossections of the church.
The methodology is briefly described and assessed for its adaptability to the special requirements of this monument. The results of the data processing are presented and evaluated for their usefulness. Moreover a 3D visualisation of the church is attempted based on the accurate measurements performed. The paper concludes with an appraisal of the products in view of their inclusion in a Monument Information System, which could include all monuments of the particular area of Cyprus.

Categories and Subject Descriptors (according to ACM CCS): I.2.10 [Vision and Scene Understanding]: Representations, data structures and transforms, H.2.8 [Databases Applications]: Spatial databases and GIS

1. Introduction

Monuments are undeniable documents of world history. Their thorough study is an obligation of our era to mankind's past and future. Respect towards cultural heritage has its roots already in the era of the Renaissance. Over the recent decades, international bodies and agencies have passed resolutions concerning the obligation for protection, conservation and restoration of monuments. The Athens Convention (1931), the Hague Agreement (1954), the Chart of Venice (1964) and the Granada Agreement (1985) are only but a few of these resolutions in which the need for geometric documentation of the monuments is also stressed, as part of their protection, study and conservation.

The geometric documentation of a monument may be defined as the action of acquiring, processing, presenting and recording the necessary data for the determination of the position and the actual existing form, shape and size of a monument in the three dimensional space at a particular given moment in time [UNE72]. The geometric documentation records the present of the monuments, as this has been shaped in the course of time and is the necessary background for the studies of their past, as well as the plans for their future. Geometric documentation should be considered as an integral part of a greater action, the General Documentation of the Cultural Heritage. This comprises, among others, the historical documentation, the architectural documentation, the bibliographic documentation etc. The Geometric Recording of a monument involves a series of measurements and -in general- metric data acquisition for the determination of the shape, the size and the position of the object in the three dimensional space. Processing of these data results to a series of documents, i.e. products, at large scales, which fully document the geometric -and other- properties of the monument. Usually such products include two dimensional projections of parts of the object on horizontal or vertical planes, suitably selected for this purpose.

Technological advances in recent years have spectacularly multiplied the variety of sources for collecting metric information at such large scales. In order to fully exploit these data special techniques should be developed. Moreover, the advancements in computer industry have enabled the three dimensional visualizations of the monuments in a virtual world. The compilation of 3D models of historical monuments is considerably facilitated by the use of dense point clouds, which are created by the use of terrestrial laser scanners. Their combined use with photogrammetric procedures, such as the production of orthophotos, allows the realistic 3D representation of complex monuments such as sculptures. In this context virtual reality tours have been created for simple or more complex monuments. This ability has greatly contributed to the thorough study of the monuments, as well as to the creation of virtual visits.

2. The Asinou Church

2.1. Historical issues

The famous Byzantine painted church of Panagia Phorbiotissa of Asinou lies about five kilometers to the south of the village of Nikitari in the pine-clad of the Troodos range of mountains, at an altitude of approximately 450m (Figure 1). The church is dedicated to the Virgin Mary and is considered to be one of the most important Byzantine churches in Cyprus. The main church is the only surviving part of the Phorves monastery from which the name Panagia Phorviotissa originates. The church is dated from the early 12th century AD and the murals inside range from the 12th century through the 17th century [HM02] . The church is recognised as a World Heritage Monument by UNESCO, as it is home to perhaps the finest examples of Byzantine Mural paintings of the island.

Figure 1: *Location of the church of Asinou on the map of Cyprus.*

The church is a rectangular vaulted, humble-looking building with arched recesses in the side walls and transverse arches supporting the vault. It is built with local volcanic irregular stones originally covered with plaster in such a way as to imitate marble revetment. The church is covered with a steep-pitched roof and flat tiles. The original pies with the transverse arches where strengthened with additions at a later date. The apse of the church was also reinforced with additions at a later date (Figure 2). A narthex, with two semi-circular apses and calotte and a drumless dome, and apsidal north and south ends, was added at the west end at about the end of pitched roof with flat tiles, which appear in the model of the church in the donor composition, and therefore is original. The structure was built in the 12th century by the Greeks, who also built the nearby ancient city of Asinou.

Figure 2: *North-western view of the Church.*

It appears that the church suffered great damage at the end of the 13th, or beginning of the 14th century as the result of an earthquake. The apse was then rebuilt and the apse semidome and nave were redecorated. The narthex was redecorated in 1332/3. Thus the frescoes surviving in the church of Asinou today vary in date.

Fortunately, two-thirds of the original decoration of the church of 1100's survive today. Through these murals we are able to determine that the church was probably originally constructed as a family chapel for Nicephoros Magistros (who later died here in 1115 AD). One inscription found in the south-west recess records that the church of the holy mother of God was painted through the donation and great desire of Nicephoros Magistros the Strong, when Alexios Comnenos was Emperor in the year 6614, indiction

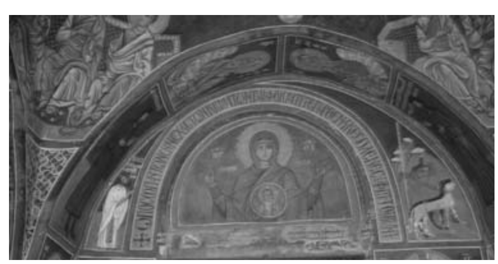

Figure 3: *Mural including the oldest inscription of the church.*

14 (Figure 3). This probably means that the church was constructed some time between the year 1099 and 1105.

Another inscription mentions that the founder was also nick-named ”the Strong”, an appellation most probably given to him by the people for his power and severeness as a judge, or taxation officer. Neither of the inscriptions mentions a Monastery, or the appellation ”Phorbiotissa”.

2.2. Specifications

For the proper geometric recording of the Asinou Church it was decided to work towards the production of the minimum necessary 2D and 3D products, which would contain the geometry of the monument, both inside and outside. Hence the final drawings include:

- a horizontal section of the building at a height of approx. 1m, which would, of course, include all necessary details above and below this section,
- the four outside elevations,
- a longitudinal vertical crossection ”looking” at both sides
- two N-S crossesctions, again ”looking” at both sides.

In order to do justice to the wonderful murals inside the church, but also to the unique outside structure, it was decided to produce colour orthophotography for the above drawings, instead of the more traditional and, in any case, quite abstract line drawings. 1:50 was chosen as the scale of the drawings, since it is the most commonly used scale for geometric documentations. This scale requires an accuracy of 15mm for all points and details recorded on the monument, a task which is not that easy. In addition to the above, it was decided to attempt a 3D representation of the Church, in order to convey to the observer part of the majestic impression that the visitor gets, when looking at the monument itself.

3. Geometric Documentation

3.1. Methodology

The Geometric Recording of Monuments at large scale, i.e. larger than 1:100, presents several difficulties and peculiarities, which call for special attention by the users. The need for large scale images, the presence of extremely large height differences compared to the relatively small taking distances and the multitude of details usually present on the surface of the monuments combined with the high accuracy requirements are the main sources of these difficulties for the production of the conventional line drawings. The production of orthophotographs presents even more special problems, as it usually is a case of a highly demanding true orthophoto. Special techniques have been developed to address these problems in the best possible way [DL01], [MPK02], [Wie02].

Recording of monuments often demands the production of special products, quite different from those of conventional photogrammetric applications. Among others the 3D visualizations, supported by technological advancements, have added a significant means of representation of the complex monuments. The combination of available data has enabled the construction of highly detailed 3D models, which could convey the accuracy of the original data. Rendering techniques supported by increasing computing power have significantly contributed to the aesthetic appearance of these visualizations. The next step is to enable the performance of accurate measurements on these 3D visualizations.

In the present case a combination of all available technological advances was used for the optimum result. The irreplaceable conventional surveying measurements support the photogrammetric mapping, which provides the detail and the point clouds from the terrestrial laser scanning cater for the detailed three-dimensional information.

3.2. Data acquisition

Instrumentation of the latest technology has been used for the data acquisition phase. A reflectorless total station Topcon GPT-3003, with 10cc and ±3mm ±2ppm accuracy, a Canon EOS 1D Mark II 8.2 Mpixel digital camera with a pre-calibrated 28-80mm f/3.5-5.6 zoom lens, with a pixel size of 8μm and CMOS sensor size of 3504 x 2336 pixels and a Leica Geosystems HDS-2500 terrestrial laser scanner were the basic instrumentation used.

The contemporary idea of multisource data exploitation [GI05] has been applied in this case, hence the fieldwork included -among others- geodetic network and control point measurements, image acquisition and laser scanning. A careful planning of the fieldwork ensures the successful processing at a later stage, minimizing the need to re-visit the site for additional measurements.

Special care has been given to the initial image scale, or equivalently, to the resulting GSD, in order to cover the requirements of the 1:50 scale. Monoscopic or stereoscopic photography has been planned, according to the properties of the various parts of the object. In total 700 ground control points and 1,500 detail points were measured on the object, from ten traverse stations in and around the church. Moreover 116 photogrammetric images were taken, of which 68 for mono and 48 for stereo compilation (Figure 4). Laser scanninig was applied at a later stage, after an initial processing. This enabled the coverage enhancement of areas where there were gaps or omissions from the initial photogrammetric processing. Such areas included the domes of the three apses, the interior of the Holly and other such complicated parts of the object. In addition general scans were also performed, mainly to cover the outside surfaces of the church; in Figure 4 the blue round signs in the internal side of the church symbolize the scanners set-ups directed towards the ceiling.

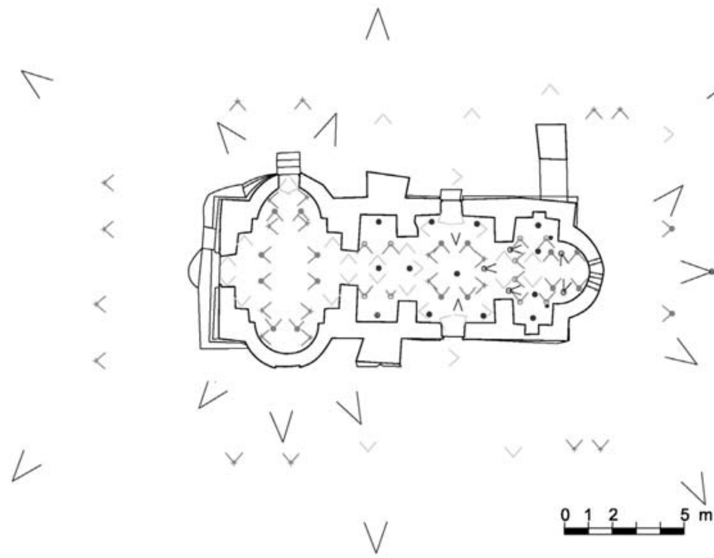

Figure 4: *Plan view of the church, showing scanner set ups (in blue) and camera locations for stereopairs (in red) or monoscopic images (in green).*

3.3. Data processing

Data processing included the individual preprocessing of the various data separately, and later the necessary integration. The geodetic network adjustment ensured the required accuracy in the final products. For the photogrammetric processing, every elevation (Figure 5) should be processed in a separate reference system, which -if desired- may be reversed at a later stage, in order to obtain the final products in a common system.

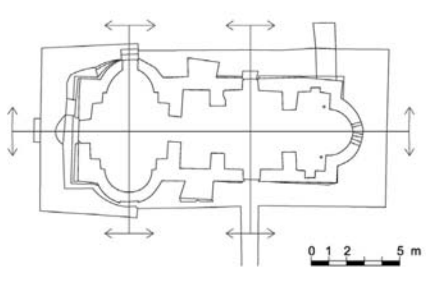

Figure 5: *Horizontal plan of the church showing the positions of the vertical cross sections.*

For the monoscopic processing, i.e. the digital rectification the ARCHIS software by SISCAM was used and for the stereocompilations the digital photogrammetric workstation SSK of Z/I Imaging was employed. DTM, or better, DSM collection was carried out manually on the DPW at an interval of 10cm on the object. In addition all necessary break lines and object edges were also collected, in order to assist the orthophoto production. A GSD of 5cm was chosen for the final orthophotos.

The cloud points from the terrestrial laser scanner were processed within the Leica Geosystems Cyclone software, which provides the possibility of either cloud-to-cloud registration with common points or common features, or the direct reference of a cloud to the desired co-ordinate system. Both possibilities were used and the resulting registrations carried an error of 6mm. The final point cloud (Figure 6) was also exported to dxf format for further exploitation.

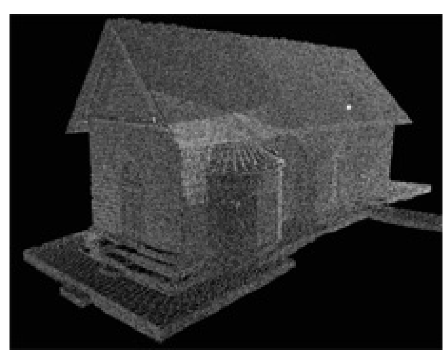

Figure 6: *Registered point clouds.*

4. Products

4.1. Orthophotomosaics

All partial orthophotos belonging to a particular elevation, no matter whether they were produced by rectification or orthophotography procedure, were combined to a unique orthophotomosaic within the AutoCAD environment. For this purpose the measured ground control points were employed. For the radiometric correction and unification of the colours the Adobe PhotoShop image processing software was chosen.

On the resulting orthophotomosaic the inevitable gaps and faults have been located, in order to be completed. (Figures 7, 8, 11, 12)

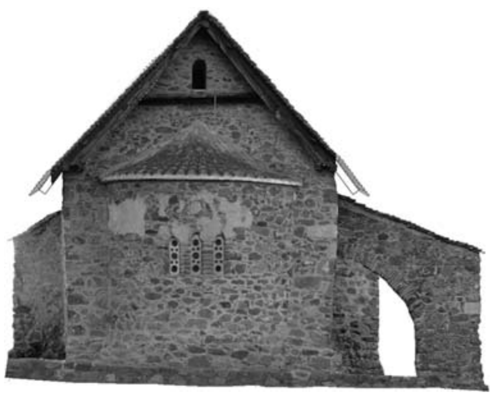

Figure 7: *Ortho-mosaic of the eastern facade.*

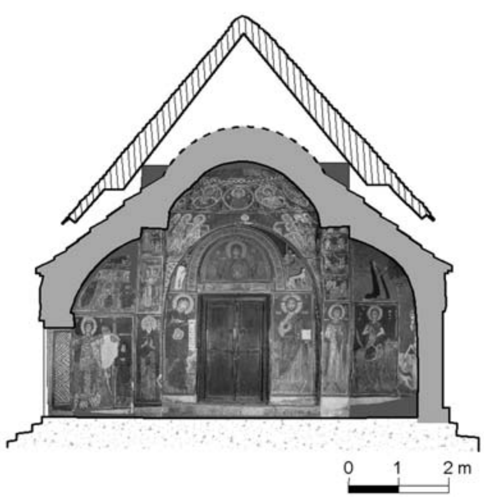

Figure 8: *The N-S cross section "looking" to the west.*

4.2. The three-dimensional model

The creation of a 3D model of the church included first the processing of all dxf files which contain the point clouds, both from the laser scans and the stereo-compilation, for the production of a polygon or triangular network. Geomagic Studio v7 software was chosen for this procedure. The software enables noise removal, as well as data reduction without loss of necessary information. With suitable processing the point cloud was converted to a polygonal mesh, from which the three-dimensional surface model was produced (Figure 9).

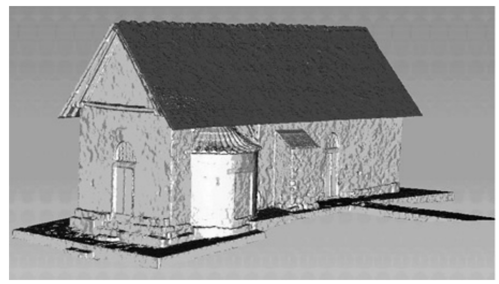

Figure 9: *South-western view of the Church's 3D model produced by the Geomagic software.*

The next step included the production of a 3D textural model of the church. For this purpose the MODO v2.0.1 software was used, which contains a larger variety of more user-friendly tools for texture mapping than the Geomagic software. The orthophotos which had been produced photogrametrically were adjusted to all surfaces of the church instead of using simple images. Thus, an accurate adjustment of raster information on the 3D solid model and high quality results were achieved. Figure 10 shows a view of the internal side of the church with orthophotos as an overlay on the surfaces.

Figure 10: *North-eastern view of the textured 3D model of the Church.*

Figure 11: *Ortho-mosaic of the outer northern facade of the Church.*

Figure 12: *The longitudinal vertical cross section "looking" to the north.*

5. Monument Information System

A Monument Information System (MIS) is required for an integrated documentation of the Byzantine church of Asinou, in addition to the detailed geometric recording. Historic, archaeological, architectural and other information will be integrated in this system together with the above mentioned geometric information, in text, images, vector and raster format, 3D animations, videos.

The establishment of such a MIS is on-going project, and is part of the proposal for establishing an Information System for all Byzantine Churches in the jurisdiction of the Holly Metropolis of Morfu, where there are eight of the 13 churches that exist in Cyprus which are characterized by UNESCO as "World Heritage Monuments". New techniques are been used regarding Informatics, Graphics, Virtual Reality, and Multimedia. The MIS which will be developed will provide for data collection, storage, analysis, processing, management, virtual representation and animation by use of multimedia technology. The user will be able to make a virtual tour of the whole area of the Metropolis, which will be based on the framework of high resolution satellite images and other necessary data. During this tour the churches-monuments will be georeferenced. The system will also provide services for an individual tour by using multimedia and a virtual guide.

The beneficiaries of this project include students, teachers, scientists, researchers, parents, visitors, and any others interested to have an electronic access and would enjoy an e-tour [Tem06].

6. Conclusions

A combined use of photogrammetric methods and laser scanning techniques was applied for the geometric documentation of the Asinou church. The extraction of accurate and detailed DSM of the surfaces of the monument is necessary both for the production of two-dimensional orthomosaics, and for the creation of 3D model. The combined use of those two techniques allowed:

- the completion of the missing parts of the DSM, where the stereoscopic image acquisition was difficult or impossible
- the creation of a three-dimensional textural model which has good geometric accuracy.

In agreement with the Episcope of Morfu, it was decided that a documentation model will be developed for the Church of Asinou, which will be used for the other churches-monuments of Cyprus, as well. For this purpose the produced geometric recording should be completed with more detailed 2D plans at larger scales, e.g. 1:10 or 1:5; videos with detailed three-dimensional textural models of the surrounding area and the inside of the church should be created and a MIS accessible through the Internet should be in operation.

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