ICOA1814: PHOTOGRAMMETRY AND INTERACTIVE 3D VIRTUAL TOUR TO THE OUTREACH OF CULTURAL HERITAGE. THE CASE STUDY OF THE CHURCH OF PANAGIA EPISKEPSI, TRIKALA, GREECE

Subtheme 03: Protecting and Interpreting Cultural Heritage in the Age of Digital Empowerment

Session 1: Relevance of Digital Tools & Technology in Documentation, Conservation and Safeguarding of Heritage & Community Engagement
Location: Silver Oak 2, India Habitat Centre
Time: December 13, 2017, 11:45 – 12:00

Author: Athanasios K. Moysiadis

Athanasios Moysiadis is a Surveying Engineer (TEI of Athens, Greece). He also holds an MSc in Photogrammetry with Remote Sensing (UCL, UK) and a PhD in Surveying and Geomatics (University of Thessaly, Greece). He has worked as a freelance surveyor. Currently he works as a surveyor in the public sector and as an adjunct professor and researcher. His research interests mainly focus on the use of surveying and geomatics to the cartography and documentation of cultural heritage while he has contributed to over forty scientific publications.

Abstract: Cultural heritage management involves a range of methodologies, from data acquisition, recording and visualisation to information management, technology interchange and communication. Close range photogrammetry provides completeness, precision, uniform accuracy, texture and three dimensional data, while interactive 3D virtual tour is used to present a full cover of monuments of cultural heritage, in immersive "lively" appearance. The Church of Panagia Episkepsi built in 1867, located in the traditional settlement of Varousi, is one of the oldest and most historic cultural heritage monuments in the city of Trikala, Greece. It is a monument of significant architectural elements, with rich traditional decoration and splendid wood carvings. Close range photogrammetric techniques are used to create a 3D model of the monument, while a series of panoramic images made of stereoscopic images to embed 3D modelling in virtual tour. Accuracy considerations with respect to image overlap, luminosity, projection and filtering are taken into account. Photographic and descriptive characteristics are also embedded at the virtual tour to provide a historical and technical overview of the monument. Both the 3D model and the virtual tour are uploaded to the official site of the church for dissemination and outreach purposes, from visitors and tourists to theoretical and technical scientists.

Key words: photogrammetry, virtual tour, cultural heritage, outreach

The church of Panagia Episkepsi

The church of Panagia Episkepsi built in 1867, located in the traditional settlement of Varousi, is one of the oldest and historical ecclesiastical cultural heritage monuments in the city of Trikala, Greece. The church is dedicated to the Visiting Virgin Mary (Panagia Episkepsi) a rather common name in Byzantine iconography. The old icon of Panagia Episkepsi, was silver-plated in 1896, by the painter Anastasios Tsinaridis. According to the ktitoric inscription, Panagia Episkepsi is honoured both on August 15th (Dormition of the Virgin Mary) and on November 21st (Presentation of the Virgin Mary).

The church is characterised as both a majestic and a dignified monument, a three-aisled basilica with a dome, with significant architectural elements (Fig.1). On the eastern side of the church a nine-sided conch is featured, decorated with stone-carved representations (double-headed eagles, birds, hexapteryga, angel figurines, crosses). A stone-carved door appears at the west gate of the church. Rich traditional decorations such as splendid wood carvings appear at the pulpit, the despotic throne, and the shrines as well as at the iconostasis of Metsovian art, dated back to 1869, made by the woodcarver Georgios Petris (Fig.2); flowers, birds, deers, lions, the Apostles Peter and Paul bearing a church, the bird in his nest, etc. In 1959, at the southwest corner of the building a stone bell tower was built (Fig.1).

During the period 2007-2008, with the blessings of His Eminence Archbishop Alexios of Trikkis and Stagon, a restoration of the church was made.

Fig.1– The church of the Visiting Virgin Mary (Panagia Episkepsi) in Trikala, Greece.

Until August 24th, 1967, the church of Panagia Episkepsi was also the Metropolitan Church of Trikala. In 1881, the thanksgiving praise of the liberation of the city of Trikala took place at the same church.

A wealth of information of the church, the priests, the commissioners, the property, the utensils and various activities are written at the Code of Trikki (no 1471) and Code of Varlaam (no 287) <http://panagiaepiskepsi.gr>[1].

The historic, constructive and architectural value of this type of ecclesiastical cultural heritage appraises the choice of modelling for both documentation and outreach purposes. This involves the exterior photogrammetric surveying of the church using both mono and stereophotogrametry, while the rich decorative features and the precious property (icons, wall paintings, utensils etc.) of the interior make the creation of a 3D virtual tour an ideal methodology for outreach purposes.

Fig.2– Panagia Episkepsi (Trikala, Greece). The old icons of Panagia Episkepsi and Megas Archiereus (Christ the Great High Priest) and decorative wood carvings of the iconostasis and the pulpit.

Close range photogrammetry

The very first measurements ever made using photogrammetric analysis were made in the middle of the 19th century. The term photogrammetry was introduced by the architect Albrecht Meydenbauer, who has had the idea to use photographic images for geometric documentation[2]. Since then, photogrammetry has provided completeness, precision, uniform accuracy, texture and three dimensional data in monuments of cultural heritage documentation[3]. New photogrammetric techniques have been developed[4], [5] and still develop, while digital photogrammetry and use of non-metric cameras have been widely used[6], [7].

The west, north and south facade of the church mainly consists of planar surfaces. Thus, the image orthorectification was used to create an orthographic projection of the facades. Image acquisition was made early in the morning in order to achieve the best illumination conditions and avoid shadows. However, at the west facade of the church, poor illumination conditions, strong shadows at most time of

---

[1]panagiaepiskepsi.gr, 2017
[2]Albertz, 2001
[3]Baltsavias et al., 2006
[4]Ogleby & Rivett, 1985
[5]Luhmann et al., 2006
[6]Patias et al., 1998
[7]Ogleby et al., 1999

the day, as well as the lack of space for photo acquisition made the surveying demanding and time consuming.

The process of image orthorectification requires measurements on a single image in order to create an orthographic projection of the area being surveyed, rather than a stereopair used in stereophotogrammetry. The geometric distortions between the initial and the orthorectified image are the image rotations ω, ϕ, κ and the change in scale. Therefore, a projective transformation (Eq.1) is needed to incorporate these two distortions and create a new orthorectified image. At the following equations the coefficients are computed of the coordinates of each point in the initial image x, y at the coordinates of the rectified image X, Y.

$$X = \frac{\alpha'_1 x + \beta'_1 y + d'_1}{\alpha'_3 x + \beta'_3 y + d'_3} = \frac{\alpha_1 x + \beta_1 y + d_1}{\alpha_3 x + \beta_3 y + 1}$$

$$Y = \frac{\alpha'_2 x + \beta'_2 y + d'_2}{\alpha'_3 x + \beta'_3 y + d'_3} = \frac{\alpha_2 x + \beta_2 y + d_2}{\alpha_3 x + \beta_3 y + 1},$$

Eq.1 – The projective transformation.

The equations of the projective transformation include eight coefficients since each known point on the initial and the rectified image forms two equations. For the computation of these coefficients, at least four control points with known coordinates are required, uniformly distributed at each facade, also identified and measured at the initial image. The projective transformation converted the image coordinates of each point at the initial image to the respective coordinates of the rectified image (Fig.3).

Fig.3– Before (left) and after (right) the orthorectification on part of the south facade.

For the 3D surveying of the nine-sided conch featured at the eastern facade of the church, with stone-carved representations, a convergent multistation imaging geometry was established. Image acquisition was made early in the morning, to avoid shadows and create an accurate photogrammetric model. Stereophotogrammetry involves the interior and exterior orientation of the images. The interior orientation describes the internal geometry of the camera and the lens distortion. These parameters are needed for the regeneration of the light beam of the object from the corresponding points in the image. The parameters of the interior orientation are the focal length c of the camera, the position of the principal point x_0, y_0 at the level of the digital sensor and the lens distortion. The process of camera calibration compensates for the lens distortions as well as assesses the stability and the operation of the lens system[8], [9]. The position of the projection centre X_0, Y_0, Z_0 and the image rotations ω, ϕ, κ of the object coordinate system in order to be aligned with the image coordinate system describe the parameters of the position and the orientation at the time of the image's acquisition at the object coordinate system. The calculation of these six parameters is called exterior orientation, described by the co linearity equations[10].

$$x = x_0 - c\frac{(X-X_0)R_{11} + (Y-Y_0)R_{12} + (Z-Z_0)R_{13}}{(X-X_0)R_{31} + (Y-Y_0)R_{32} + (Z-Z_0)R_{33}}$$

$$y = y_0 - c\frac{(X-X_0)R_{21} + (Y-Y_0)R_{22} + (Z-Z_0)R_{23}}{(X-X_0)R_{31} + (Y-Y_0)R_{32} + (Z-Z_0)R_{33}}$$

Eq.2 – The co linearity equations.

The co linearity condition relates the image coordinates x, y of a point at the image coordinate system with the object coordinates X, Y, Z through the parameters of the internal geometry of the camera c, x_0, y_0 (interior orientation), the perspective centre X_0, Y_0, Z_0 of the camera at the object coordinate system and the rotations ω, ϕ, κ between the two 3D coordinate systems (parameters of exterior orientation). The measurement of the image coordinates of a point x, y at two images of a stereo pair formed two pair of equations solved by the method of least square adjustment and the position of the point X, Y, Z at the object coordinate system was calculated. This is called photogrammetric intersection. Therefore, the parameters of the interior and exterior orientation as well as the measurements of a point at the image coordinate system allowed us to calculate the respective point coordinates at the object coordinate system.

[8]Kraus, 1997
[9]Ziemann and El-Halkim, 1982
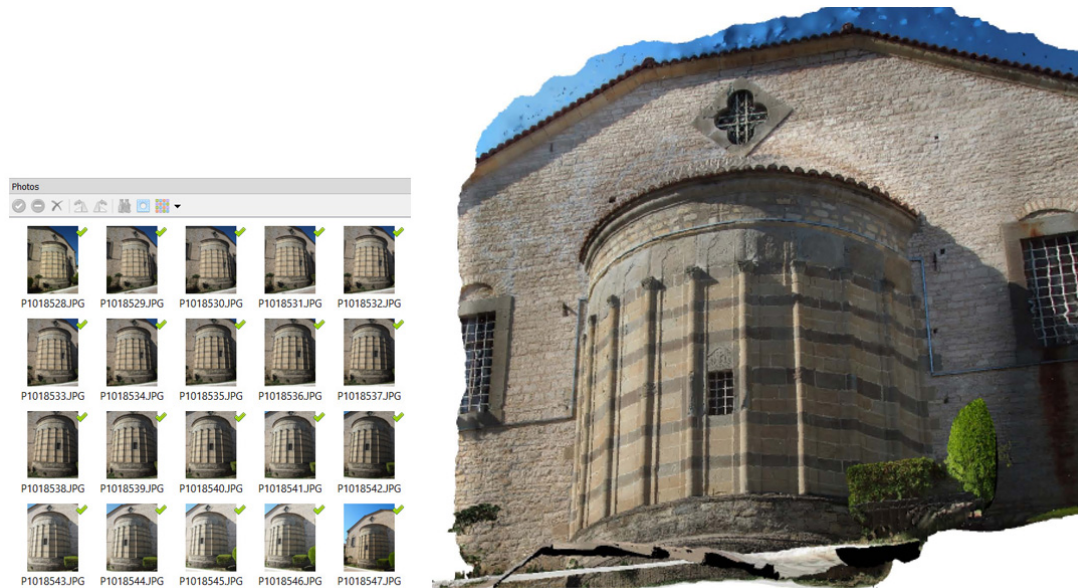[10]Mikhail et.al., 2001

Fig.4– The photogrammetric model of the conch.

3D virtual tour

3D virtual tour has gained much appreciation in various applications since it mainly provides imaging and descriptive information in an interactive way, hence online[11], [12], [13]. It has proved useful for informative and outreach purposes[14], [15]. Especially for cultural heritage (archaeological sites, settlements, historic buildings, museums, natural sites etc), it has been used to present a full view of a monument in immersive "lively" appearance[16], [17]. The historic and architectural value of the church of Panagia Episkepsi, with a fully updated website, the creation of a 3D virtual tour would provide an ideal platform from visitors and tourists to theoretical and technical scientists.

A virtual tour on 360° x 180°, a spectacular presentation of panoramic photography by stitching was created. It offers the user the possibility to interact with the panorama, use the mouse, rotate in all directions, move from the one part of the monument to the other, zoom in different scales and click on point hotspots in specific parts of the church to have access on imaging and descriptive information.
A virtual tour was created by stitching a number of overlapping images to make a panorama and then by creating the virtual tour itself. The geometric projection used to create the virtual tour was the spherical projection during the stitching. A series of images were shot with a panoramic head of a spherical type, with a very wide-angle lens, with a slight overlap between them, in order to be stitched and then a panorama with specific stitching software was created. A complete virtual tour of the church required different point of views (camera positions) to offer a different "camera movement". Even though a very

---

[11] Pan et al.,2004
[12] Roussou, 2008
[13] youvisit.com, 2017
[14] enamecharter.org, 2017
[15] Schmidt and Krone, 2005
[16] acropolis-virtualtour.gr, 2017
[17] chem.ox.ac.uk/oxfordtour, 2017.

sharp lens is good for classic photography, this is not the case for image stitching. A much closed diaphragm was chosen in order to achieve a maximum depth of field even diffraction effects and a slight loss of sharpness was noticed. At the stitching process, due to optical distortions of the camera, straight lines didn't overlap perfectly. Lens distortions lead to various effects that decreased the accuracy and the quality of the panorama such as vignetting, chromaticism, loss of sharpness in comparison with the centre of the photo and geometric distortions.

The output virtual tour (Fig.5) has been exported in HTML5 compliant web standard, also compatible with desktop and mobile formats, modern Android phones, iPhones and iPads, and has been uploaded at the official website of the church of Panagia Episkepsi <panagiaepiskepsi.gr>.

Fig.5 – The main scene of the 3D virtual tour.

Conclusions

The church of Panagia Episkepsi is one of the oldest and historical ecclesiastical monuments of cultural heritage in the city of Trikala, Greece. It is a monument of very interesting architecture and constructive characteristics as well as of unique decorative features of the interior, such as stone and wood carvings, wall paintings and old icons. Close range photogrammetry provides geometric and imaging documentation while 3D virtual tour an interactive way to present a full view of the monument, a virtual tour or 360° photography. Image rectification was used to document the three planar facades of the church, while stereophotogrammetry was used at the east facade to model a nine nine-sided conch with stone-carved representations. Illumination and accessibility issues were taken into consideration for an accurate modelling. Virtual tour offers an online platform of the church with navigation options through a thumbnail stack or navigation through a drop-down list, with image, point and web content hotspots and descriptive information in specific parts of the interior. The selection of the camera positions and the process of photo acquisition, illumination effects as well as the camera characteristics and the images' editing were critical issues for a uniform and accurate visual appearance of the monument. The output virtual tour is available at the official website of the church which aims at providing a step forward the outreach of ecclesiastical cultural heritage in the city of Trikala and beyond.

Bibliography

acropolis-virtualtour.gr. (2017). Acropolis virtual tours. [online][Accessed September 2, 2017].

Albertz, J. (2001). Albrecht Meydenbauer - pioneer of photogrammetric documentation of the cultural heritage. Proceedings of the XVIIIth CIPA Symposium (eds. J. Albertz), September 18-21, Potsdam, Germany.

Baltsavias, E., Gruen, A., van Gool, L. and Pateraki, M. (Eds.) 2006. *Recording, Modelling and Visualization of Cultural Heritage*. London: Taylor & Francis.

chem.ox.ac.uk/oxfordtour. (2017). Virtual tour of Oxford. [online][Accessed September 3, 2017].

enamecharter.org. (2017). ICOMOS Ename Charter for the Interpretation of Cultural Heritage Sites. [online][Accessed September 4, 2017].

Kraus, K. (1997). *Photogrammetry Vol. 1*. 4th ed. Bonn: Dummler.

Luhmann, T., Robson, S., Kyle, S. and Harley, I. (2006). *Close Range Photogrammetry: Principles, Techniques and Applications: Principles, Methods and Applications*. 1st ed. Scotland: Whittles Publishing.

Mikhail, E.M., Bethel, J.M. and McGlone, J.C. (2001). Introduction to Modern Photogrammetry. 1st ed. New York: John Wiley & Sons, Inc.

Ogleby, C., Papadaki, H., Robson, S. and Shortis, M.R. (1999). "Comparative camera calibrations of some "off the shelf" digital cameras suited to archaeological purposes". *International Archives of Photogrammetry and Remote Sensing*, 32 (5W11), 69-75.

Ogleby, C. and Rivett, L. (1985). *Handbook of Heritage Photogrammetry*. Canberra: Special Australian Heritage Publication Series No.4, Australian Government Pub. Service.

panagiaepiskepsi.gr. (2017). The church of Panagia Episkepsi. [online][Accessed August 3, 2017].

Pan, Z., Fang, X., Shi, J. and Dan, X. (2004). Easy tour: A new image-based virtual tour system. Proceedings of the VRCAI 2004, ACM SIGGRAPH International Conference on Virtual Reality Continuum and its Applications in Industry, Nanyang Technological University, June 16-18, 2004, Singapore.

Patias, P., Stylianidis, E. and Terzitanos, K. (1998). "Comparison of simple off-the-self and of-wide-use 3D modelling software to strict photogrammetric procedures for close-range applications". *International Archives of Photogrammetry and Remote Sensing,* 32 (5), 628-632.

Roussou, M. (2008). The Components of Engagement in Virtual Heritage Environments. In New Heritage: New media and cultural heritage edited by Y. Kalay, T. Kvan and J. Affleck, Routledge: London and New York. pp. 225-241.

Schmidt, N. and Krone, J. (2005). "Constructing An Efficient And Easily Distributable Virtual Tour". ACM Computing Literature, 3 (1), 43-47.

youvisit.com. (2017). Engage and convert your audience with interactive virtual experiences. [online][Accessed September 3, 2017].

Ziemann, H. and El Hakim, S.F. (1982). "On the definition of lens distortion reference data with odd power polynomials". *The International Archives of Photogrammetry*, 24 (1), 123-130.

List of Figures

List of Equations

ICOA1814: PHOTOGRAMMÉTRIE ET VISITE VIRTUELLE INTERACTIVE 3D POUR LE RAYONNEMENT DU PATRIMOINE CULTUREL. LE CAS DE L'ÉGLISE DE PANAGIA EPISKEPSI, TRIKALA, GRÈCE

Sous-thème 03: Protéger et interpréter le patrimoine culturel à l'ère de l'autonomisation numérique

Session 1: Pertinence des outils numériques et de la technologie dans la documentation, la conservation et la sauvegarde du patrimoine et l'engagement communautaire
Lieu: Silver Oak 2, India Habitat Centre
Date et heure: 13 Décembre, 2017, 11:45 – 12:00

Auteur: Athanasios K. Moysiadis

Athanasios Moysiadis est ingénieur arpenteur (TEI d'Athènes, Grèce). Il est aussi détenteur d'une maîtrise en Photogrammétrie avec télédétection (UCL, UK) et d'un doctorat en arpentage et géomatique (Université de Thessalie, Grèce). Il a exercé comme géomètre indépendant. Il travaille actuellement dans le secteur public et comme professeur associé et chercheur. Ses intérêts de recherche concernent principalement l'utilisation de l'arpentage et la géomatique pour cartographier et documenter le patrimoine culturel, sujet pour lequel il a contribué à plus d'une quarantaine de publications scientifiques.

Résumé: La gestion du patrimoine culturel implique une gamme de méthodologies allant de l'acquisition de données,l'enregistrement et la visualisation à la gestion de l'information, l'échange de technologies et la communication. La photogrammétrie rapprochée permet l'exhaustivité, la précision, l'uniformité, la texture et les données tridimensionnelles, tandis que la visite virtuelle interactive 3D est utilisée pour présenter l'entièreté des monuments du patrimoine culturel, dans une perspective «vivante» et immersive. L'église de Panagia Episkepsi construite en 1867, située dans le village traditionnel de Varousi, est l'un des monuments culturels les plus anciens et les plus importants de la ville de Trikala, en Grèce. C'est un ensemble d'éléments architecturaux significatifs, avec une belle décoration traditionnelle et de belles sculptures sur bois. Des techniques de photogrammétrie rapprochée sont utilisées pour créer un modèle 3D du monument, tandis qu'une série d'images panoramiques faites d'images stéréoscopiques permettent d'intégrer la modélisation 3D dans une visite virtuelle. Les besoins de précision en ce qui concerne le chevauchement d'image, la luminosité, la projection et le filtrage sont prises en compte. Les caractéristiques photographiques et descriptives sont également intégrées dans l'aperçu historique et technique du monument. Le modèle 3D et le tour virtuel sont en ligne sur le site officiel de l'église à des fins de diffusion et de sensibilisation pour les touristes et les visiteurs comme pour les scientifiques théoriciens ou techniciens.

Mots-clés: *Photogrammétrie, visite virtuelle, patrimoine culturelle, rayonnement*