DOCUMENTATION OF CULTURAL HERITAGE MONUMENTS, BY INTRODUCING NEW SURVEYING TECHNOLOGIES

IMPLEMENTATION IN SARLITZA PALLAS, IN THERMI MYTILENE

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Abstract. Visualization in 3D is an effective way to analyze and represent the environment of a building, especially if it's Cultural Heritage. Technology development of standardized methods can be very motivating for researchers of different sciences to integrate 3D modeling in their jobs. A key question is if it is possible for these methods to reach or maybe exceed the accuracy of classic geodetic methods and specifically those that are using total stations. Digital documentation combined with innovative analytical techniques and digital tools can be an effective strategy to support transdisciplinary documentations and modeling aimed at conservation, enhancement and preservation of Cultural Heritage. This paper presents the comparison between the two methods of documentation, classic and digital. Research object is Sarlitza Pallas, a small, historical and noted hotel which is based from 1909 in a small village called Thermi in Mytilene, Greece.
A geometrical documentation has been done (elevations, floor plans, cross-sections), by using a conventional reflectorless total station. As regards the digital documentation and the 3D model of the hotel, have been produced by using a modern Multi-Station.
The result was the documentation of Sarlitza Pallas with two different methods and their comparison, in order to assess the overall time and accuracy of derivative product and the capability of Multi-Station autonomous use in similar studies of Cultural Heritage monuments.

Keywords:3D Visualization, Multi-Station, documentation, Cultural Heritage, Sarlitza Pallas, Dense Point Cloud, Orthophoto/Rectified Image

1 Introduction

Conservation and preservation of cultural heritage assets is nowadays a serious issue that concerns not only the scientific community but also the people around the world.

Current studies have shown that there is an approach concerning the architectural and geometric documentation, creating textured three-dimensional (3D) models or two-dimensional (2D) plans with high accuracy. (Delegou et al. 2019)

In addition, the historical buildings, in order to be properly highlighted and restored, have to be documented in three ways (Haddad and Akasheh 2005):

- The written documentation which includes the architectural description and all the results and reports of all investigations.
- The graphic documentation which is based on conventional surveying and includes plans, elevations and cross-sections (2D information).
- And the photographic documentation which uses photography, photogrammetry, and 3D laser scanner, so as to create 3D models or present textures and optical details.

During the years, different geometric methods of documentation have been utilized and implemented. Each of them has both advantages and disadvantages, concerning not only the use but also the required accuracy. On the other hand, over the last decade, due to the development of technology, Multi-Station is an innovation which combines features and provisions of the above methods.

In this paper, after the analysis of the existing geometric methodologies of documentation in buildings, a detailed presentation about Multi-Stations is made. Their capabilities will be explained and tested, and new possibilities can arise. In the end, there is also an implementation, of Sarlitza Pallas in Mytilene, Greece, using both known methods and Multi-Station technologies.

2 Geometric methods of documentation

″Geometric documentation is the action of acquiring, processing, presenting and recording the appropriate data for the determination of the position and the actual existing form, shape and size of an object in the three-dimensional space at a particular moment.″(Stylianidis and Georgopoulos 2017)

Four principal methods are used to compile metric data each of them is following described, so as to figure out its positive and negative aspects. By now, it’s well accepted that different methods are more accurate and describe the overall study better than one method. So selection and integration of the following survey techniques are used in order to preserve and conserve historical monuments.

2.1 The traditional manual method

The traditional manual method, is one the most ancient methodologies that used in monument documentation. It determines dimensions by measuring angles and distances using flexometers, plumb lines, poles, squares, measuring tapes, and manual laser distance meters.

Even if it is a low cost method (<3.000$), it needs trained people and a small area to be documented. Furthermore it is time-consuming and the accuracy in locating points is above ±5 cm. Also, the collected data are without spatial connection and the results are simple paper plans and not in digital format. (Arias et al. 2006)

2.2 The topography method

This method is also known as the geodetic methodology, and is one of the most famous methods in geometric documentation with a cost 3.000$ to 12.000$. It is based on calculating three-dimensional coordinates of specific points of an object in order to establish its geometry. (Arias et al. 2006)

The main equipment is a total station which is effective over a great range of scales and have an accuracy at around ±1mm. Polar coordinates' measurements (horizontal/vertical angle and slope distance) from fixed points provide horizontal and vertical information respectively.

Using a geodetic control network, georeferenced point regions are created, and after processing, the points are projected so as to be digital2D plans, elevations and cross-sections.

2.3 The photogrammetry method

Additionally, classical and close-range photogrammetry methods are also well-known in monument documentation at a cost of <3.000$ and >12.000$ respectively. The greatest advantage of them is that they are faster in measuring than the others, but the processing (office work) is more complicated.

Overlapping photographs, due to image matching, are aligned and a dense point cloud is created. In order to reproduce true position and scale, geodetic support is needed, by assigning coordinates to a set of points on the photographs of the object. (Bastonero et al 2014)

The final result can be 2D orthophotos and detailed 3D models with texture, which contains surface or other optical details. The accuracy, depends on the uncertainty of the geodetic points and the processing algorithms and it is between ±1mm to ±5cm. (Arias et al. 2006)

2.4 The scanning method

The last method using in monument documentation is the scanning, which is a combination between geodetic and photogrammetric method by an accuracy between ±1mm to some cm and cost higher than 12.000$.

A Terrestrial Laser Scanner, using polar measurements, creates dense point clouds of the monument. These clouds need cleaning, alignment and georeference so as to be correct in scale and size, and finally a 3D model without texture is created.

Although method's accuracy is high, it has time-consuming processing, and may have difficulties on some material surfaces.(Bastonero et al 2014)

3 Presentation of Multi-Station Technique

In many cases, Multi-Station (MS) tends to be the best alternative solution of Total Stations' (TS) measurements, thanks to the very high acquisition rate of points and the possibilities of deeper processing at the software level. Due to faster and more accurate sensor technology, MS is proven to be a reliable solution for high accuracy for 3D surveying and documentation of natural and technical infrastructure.

The up-to-date Multi-Station (SX10 of Trimble), is a geodetic instrument combining high accuracy 3D scanning and Image Assisted Total Stations (IATS) functionalities. SX10 released in October 2016, as a part of a wider instrument category of Multi-Stations that are multiplex and innovative multi-sensor systems (Lachat et al. 2017).

Most Multi-Stations have three cameras: one wide and two with smaller optical frames, called: overview, primary and telescope, depending on the manufacturer (Fig. 1). The first two are located parallel to the EDM axis with an offset. The third is placed in the measurement axis and is used for enlargement. All of them depict the reality on the screen of the controller-tablet, while it does not have a real/virtual telescope or screen. Furthermore, it creates panoramic images, and by choosing a region, MS captures several overlapping pictures in the horizontal and vertical direction (Lachat et al. 2017).

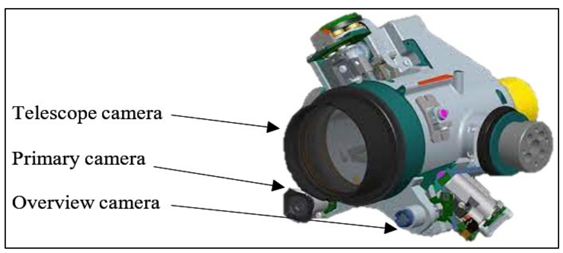

Fig. 1. Inside view and cameras of a Multi-Station (https://surveying.org.au/)

It is planned to be an innovative instrument merging the capabilities of TS with these of a Laser Scanner (LS). With this MS instrument, it is possible to get a dense point cloud of a scene in a very short time. Also, there is the opportunity to get a dense point cloud in full-dome mode. About the point cloud density there are four options: coarse (±10mm), standard (±5mm), fine (±2mm), and superfine (±1mm). A remarkable advantage is the capability of a real-time visualization of data in the field.

After the acquisition of the measurements, Trimble Business Center (TBC) contains all the post-process functions needed in order to analyze, inspect, correct, improve and produce the final digital documents.

According to previous studies, in building facades and road bridges, when using Trimble SX10, the longer the distance of the object is, the lower is the density of the point cloud. (Lachat et al. 2017)About the georeference methods (direct and indirect methodologies) higher 3D standard deviations are presented in direct method, in areas where the density of the point cloud is lower and incidence angles are big, causing bigger noise. As a result the direct georeferencing method is very convenient but it is not always the best solution for the creation of a high accuracy model.(Lachat et al. 2017)

There is not a single method that constitutes the perfect solution and a combination of methods seems to be the best idea. Therefore, the question posed is what will be more effective, cost-reducing, and time-saving when using different methods independently or a combination of them (Scherer 2002).

Multi-Station can be considered as a hybrid solution. Except for the capabilities mentioned before as a Laser Scanner, also belongs in the category of Total Stations. Some important advantages are the capability of object documentation with images, the capturing of georeferenced point clouds and panoramas or the originality which is based on the absence of a telescope (Lachat et al. 2017).

It has the ability of acquisition very high point density and large spatial coverage, with high measurement accuracy, in a short time. Moreover, a MS enables 3D visualization of an object or scene which allows users to interact with it from different angles and directions (Slob et al. 2004). The quality of independent points, in a point cloud, is not yet well understood because of its impact on the simple steps of post-processing procedure, such as the point cloud registration and segmentation.

Scanned point quality is affected by four significant factors: instrument mechanism, atmospheric conditions, object surface properties, and scan geometry. Therefore, it is very important to mention that the local geometry depends on the distance between object and scanner and also on the incidence angle (Soudarissanane et al. 2009).

According to the above literature, MS can be an optimal solution considered the fact of the implementation framework. Additionally, automatic post-processing often is realized during the capture, e.g. removing points according to a criterion that may also affect the quality of the overall point cloud (Soudarissanane et al. 2009). MS's process is much correlated with the reference point network and as a consequence, a lot of attention must be given to the implementation methodology. It is a high-cost new generation instrument but can be an added value factor in surveying studies or jobs.

4 Implementation

Multi-Station SX10 of Trimble has been used for the digital documentation of a small, historical and famous hotel, which is called Sarlitza Pallas, and it is located at Thermi in Mytilene, Greece (Fig. 2). The research study refers to the creation of the hotel's digital model, vertical plans and facades, in order to be compared with those using classic methods. In this section, data acquisition and processing for generating the final products are analyzed.

4.1 Data Acquisition

In order to do the scans for the digital documentation of Sarlitza Pallas, nine points with known coordinates (from a geodetic network) had been used. Each station measured both the previous and next station for its orientation. The reference system used was arbitrary and it was founded by assigning local coordinates to the first point. Scanning procedure of the object took place with a standard point density (±5mm).

The described implementation was done for the acquisition of necessary data using MS SX10. It is clear from the measurement procedure that the MS has many capabilities either like a Total Station or Laser Scanner.

Fig. 2. Front and back view of Sarlitza Pallas at Thermi in Mytilene, Greece.

4.2 Data Processing

This section describes the process to create the orthophotos of facades of Sarlitza Pallas, which are essentially the final product of this study. Data processing has been done with TBC.

Loading the point cloud to a computer, an initial check for gross errors took place through a general inspection of the point cloud to assess the quality of its completeness. Another check took place to confirm basic surveying information (by checking the angles and distances report) for the station points.

The process continues with cleaning of the point cloud from noise and vegetation. All the data that were out of the polygon, defined by the scanner stations, were cleaned up automatically. On the other hand vegetation is done manually and it is time-consuming, and not simple. During the study of Sarlitza Pallas, big quantities of vegetation had to be discarded. After this procedure, a general inspection of the point cloud is done especially on the building corners which was hidden by vegetation. (Fig. 3)

Fig. 3. Before and after the cleaning of vegetation

The next step refers to the georeferencing of the station points. After these procedures a recomputing of the project is necessary. With this functionality, possible error flags appear in the project. These errors have to be corrected so as to complete the georeference procedure with the proper results. (Fig. 4)

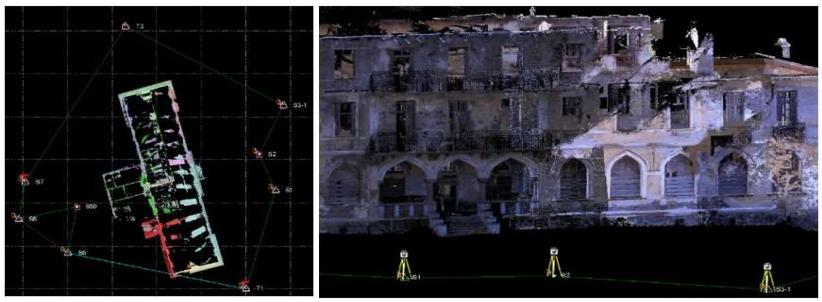

Fig. 4. Error flags in georeferencing and final georeferenced point cloud in 3D

Then, it is necessary to do a geometric check as well as errors may appear in the surveying (e.g. wrong distances between the point stations). Their correction can be done with the definition of a threshold. The georeference procedure ends after the manual correction of these errors and a general inspection.

Subsequently, the coordinates of specific points on the hotel's facades calculated from the MS scanning procedure, were checked and also compared with the coordinates of corresponding points in the classical surveying method. Moreover, some significant distances were measured, like the general dimensions of the building, dimensions of specific windows, etc.

A very important part of the process is the definition of planes to which the final products will be referred to. After the definition, the following procedure is the creation of orthophotos that is particularly the final product of this study. (Fig. 5) Through an option in TBC software, a cut was done with the definition of a vertical plane from two points of the point cloud. Then, the selection of the pixel size is done carefully to follow the corresponding point density from the acquisition (standard: ±5 mm). Pixel size selection procedure is trial and error. It is essential that the pixel size must be the same in all the orthophotos of building facades to be uniform.

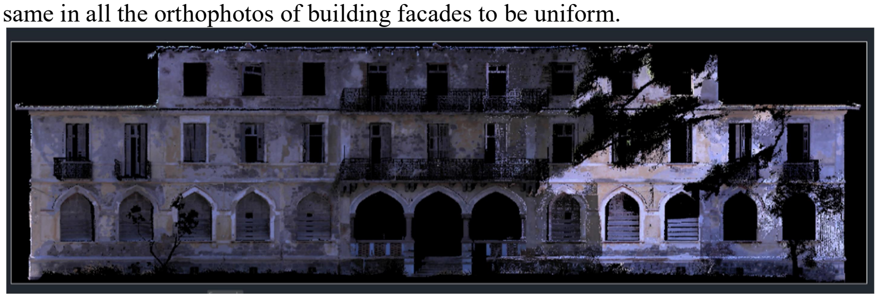

Fig. 5. Orthophoto of the front view of Sarlitza Pallas

After the creation of the orthophotos for each different façade, the point cloud and the photos are exported from the TBC software. These products are then inserted in AutoCAD to rectify their geometry and to carry out specific geometric checks. In the same layer are also facade points of the classical geodetic method. This is a reliable way to do a complete check on the final products. (Fig. 6)

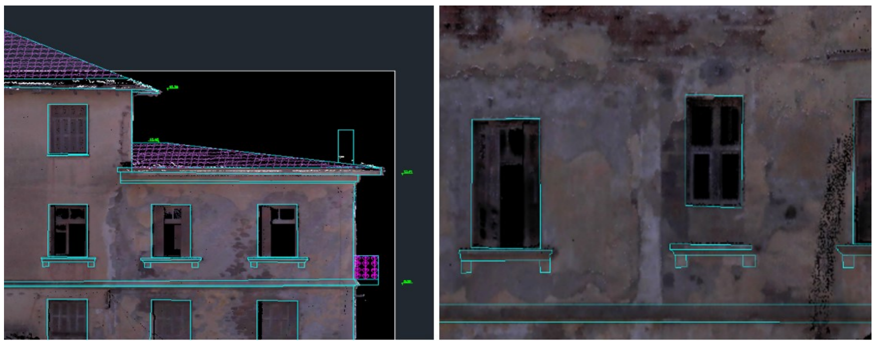

Fig. 6. Orthophotos and classical geodetic method in AutoCAD

5 Discussion and Conclusions

Nowadays, when technology is growing rapidly, more and more companies are creating hybrid measurement instruments that are able to combine different methodologies in only one station. Multi-Stations combine the Geodetic and Image Assisted total stations with the 3D laser scanners, in order to create 2D and 3D models of an object.

On the other hand, digital documentation is necessary in conservation and preservation of cultural heritage, and combines many methodologies for the final decision.

When using a Multi-Station in digital documentation of historical buildings, an immediate modern solution is offered. It is possible to check the scans from the tablet to identify any problems before starting data processing. Even if the measurements are faster than other classical methods, the processing is time-consuming and not simple, especially at point cloud cleaning.

According to the final products, the MS and its methodology mentioned above, offers both vector and raster (textured) details of the building. It may be plans, 3D models or orthophotos. If it is used under special conditions, the same accuracy, with the well-known methods, will be obtained.

Regarding the coordinates' differences, obtained from the MS and the classic methods, they fluctuate from ≤±1cm to ±10cm. A representation of the residuals calculated between the values of coordinates' obtained from each method, is made at figure 7. Various points from one of the facades have been picked in order to examine the overall accuracy and proper implementation of the documentation.

Specifically, with cyan hue are represented the points which residuals don't exceed ±5cm, with green hue the ones that fluctuate from ±6cm to ±10cm and with the orange color the points, whose coordinates differ between the two methods by ±10-15cm.

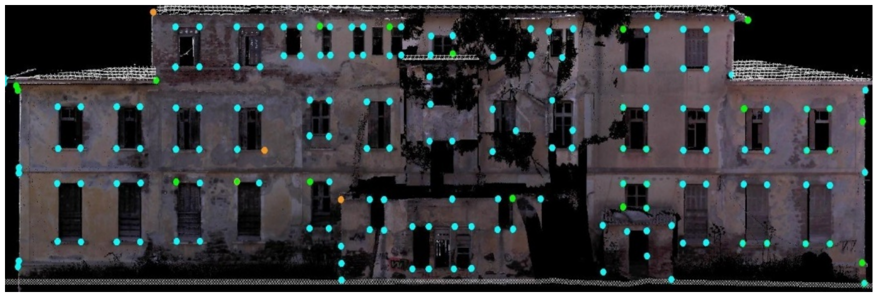

Fig. 7. Residuals between the points obtained from MS and classic methods

A total number of 170 check points were used for the differences evaluation. From this dataset only three points (Fig. 8) refer to the ≥±10cm boundary and 95% of the remaining points refer to minimum differences.

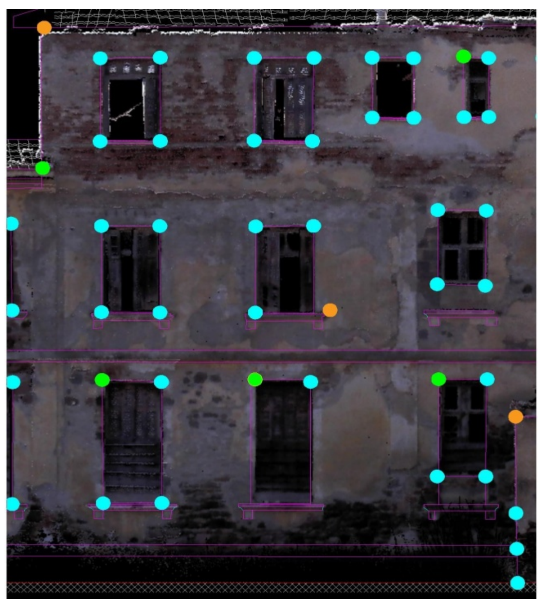

Fig. 8. Check points with higher residual values (orange color)

Finally, according to the advantages or disadvantages, Multi-Stations can be used as a new multi-sensor system, depending on the expectations required by the project. It can meet the needs of common topographic tasks and enlarges the users' choice for a smart, hybrid surveying instrument.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations:

EDM: Electronic Distance Measurement
GCP: Ground Control Points
IATS: Image Assisted Total Station
MS: Multi-Station
TBC: Trimble Business Center
TS: Total Station

References

1. Arias, P., Ordóñez, C., Lorenzo, H., Herraez, J.: Methods for documenting historical agro-industrial buildings: a comparative study and a simple photogrammetric method. Journal of Cultural Heritage 7(4), 350-354 (2006).
2. Bastonero, P., Donadio, E., Chiabrando, F. Spanò, A.: Fusion of 3D models derived from TLS and image-based techniques for CH enhanced documentation. ISPRS Ann. Photogramm. Remote Sens. Spat. Inf. Sci, 2(5), 73-80 (2014)
3. Delegou, E.T., Mourgi, G., Tsilimantou, E., Ioannidis, C., Moropoulou, A.: A multidisciplinary approach for historic buildings diagnosis: the case study of the Kaisariani monastery. Heritage 2(2), 1211-1232 (2019)
4. Haddad, N., Akasheh, T.: Documentation of archaeological sites and monuments: ancient theatres in Jerash. In: Conservation of Cultural Heritage in the Arab Region, pp. 64-71. ICCROM – International Centre for the Study of the Preservation and Restoration of Cultural Property (2005).
5. Stylianidis, E., Georgopoulos, A.: Digital surveying in cultural heritage: the image-based recording and documentation approaches. In: Ippolito, A., Cigola, M. (eds.)Handbook of research on emerging technologies for digital preservation and information modeling. pp. 119-149. IGI Global (2017).
6. Lachat, E., Landes, T.,Grussenmeyer, P.: Investigation of a combined surveying and scanning device: the trimble SX10 scanning total station. Sensors 17(4), 730 (2017).
7. Landes, T.,Lachat, E., Grussenmeyer, P.: First experiences with the Trimble SX10 Scanning Total Station for building facade survey. The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, 42, 405 (2017).
8. Slob, S., Hack, R.: 3D terrestrial laser scanning as a new field measurement and monitoring technique. In: Hack, R., Azzam, R., Charlier, R. (eds.)Engineering geology for infrastructure planning in Europe, pp. 179-189. Springer, Heidelberg(2004).
9. Soudarissanane, S., Lindenbergh, R., Menenti, M., Teunissen, P.: Scanning geometry: Influencing factor on the quality of terrestrial laser scanning points. ISPRS journal of photogrammetry and remote sensing, 66(4), 389-399(2011).
10. Scherer, M.: Advantages of the Integration of Image Processing and Direct Coordinate Measurement for Architectural Surveying-Development of the System TOTAL–JS 28. Integration of Technics and Corrections to Achieve Accurate Engeneering Survey. In: FIG XXII International Congress. Washington, D.C. USA (2002).