The contribution of modern geodetic methods in the creation of geometric diagrams/plans for the management of historic centers. The Old & New Fortress of Corfu

G. Pantazis[1]*, V. Zafiris[1], N. Kanellopoulos[1], S. Ioannidou[1], G. Garoufos[1] and A. Iliodromitis[2]
[1] Laboratory of Geodesy, School of Rural and Surveying Engineering, National Technical University of Athens, Greece
[2] Department of Surveying and Geoinformatics Engineering, University of West Attica, Athens, Greece

*Corresponding author: E-mail: gpanta@central.ntua.gr, Tel +30 6986891003

Abstract
In recent years, the development of technology and the need for more accurate and detailed diagrams and plans, has led to the use of combined methods originating from different engineering specialties. In order to provide full geometric description of the land and the surroundings of the earth's surface, a measurements' system that utilizes both terrestrial and aircraft modules, is nowadays necessary. The rapid development of unmanned aerial vehicles (UAV or remotely piloted systems), but also the evolution of geodetic instruments can in one hand offer a combination of geometric and qualitative characteristics, and in the other hand guarantee the complete description of the research area with the best possible geometric and illustration results.
The key factor, to the creation of a correct geometric diagram/plan is the combination of these methods, especially when it comes to areas of great historical importance. Such areas are often studied in order to highlight their historical significance and to strengthen their modern evolutionary course. So, apart from the geometric factors, old and new characteristics referring to the building conditions, purposes and facts of these centers should be implemented to the study and ought to be properly integrated into the final deliverables.
In this paper, after describing, in detail, the terrestrial and aerial measuring methods, the ideal conditions for their combination for a correct geometric result will be presented. Their implementation took place in the Old and New Fortress of Corfu, Greece, in order to create initial backgrounds for the management of the historic center, which was created and developed between them. In addition, a comparative evaluation of new combined methods with older ones, which had been applied in the area, is carried out, in order to identify possible significant differences throughout the years.
Finally, conclusions and suggestions emerge regarding the evolution of precision and detail (geometric and qualitative) offered by the new combination technologies, thus opening new avenues for the future.
Keywords: historical center; terrestrial methods; aerial methods; Fortress of Corfu.

1. INTRODUCTION

Nowadays, more and more people are curious about the preservation of cultural heritage, and especially historic centers or buildings. In order to manage those centers, and create masterplans for future management, it is important to have accurate and detailed diagrams and plans with both geometric and qualitative characteristics. The qualitative and quantitative characteristics are combined in order to produce deliverables, which are scientifically acceptable and capable of being utilized at later stages of the study by other engineering specialties.
The geometric documentations, as it called, may be defined as [1]:

Proceedings of the International Conference on Changing Cities V:
Spatial, Design, Landscape, Heritage & Socio-economic Dimensions
Corfu Island, Greece ● 20-25 June 2022
ISSN:
ISBN:

- the acquiring, processing, presenting and recording the necessary data for the determination of the position and the actual form, shape and size of a monument or area in present time and
- the recording of the present form of the monument as it has been shaped in time in order to recognize its past and manage its future.

Additionally, it comprises the historical documentation, the architectural and archaeological documentation, the bibliographic documentation etc. [1]. Depending on the acquisition, the accuracy or the final products, there are different methods originating from different engineering specialties. Due to the rapid development of unmanned aerial vehicles (UAV) and also the evolution of geodetic instruments, photogrammetry (aerial) and geodesy (geodesy) are the most well-known methodologies. Each of them has both advantages and disadvantages, concerning not only the equipment, but also their implementation.

In this paper, after the analysis of the terrestrial and aerial measuring methods, a combination of them is presented. Their capabilities will be explained and tested, and new possibilities can arise. An implementation took place in the Old and New Fortress of Corfu, Greece, so as to create initial backgrounds for the management of the historic center which unfolds between them. In addition, a comparative evaluation of new and old methodologies was made, in order to identify significant differences throughout the years.

2. TERRESTRIAL METHOD

The terrestrial method consists of the majority of classical geodetic measurements. Geodetic surveying is one of the oldest methodologies in documentation, and contribute to a geometrically correct result. Topographic surveying is used to create topographic 2D plans or maps of an area [2]. Depending on the accuracy and the size or geometry of the study area, the appropriate measuring method is chosen. The GNSS survey method can be used in an outdoor survey with clear horizon, but total station and its accessories can provide higher accuracy, which is necessary in documentation [3]. (Figure 1)

Figure 1. GPS (left) and Total station (right) [4]

The initial task is to establish a geodetic network in the study area. All the measurements must be in the same coordinate reference system, so as orientation, scale or relation problems be solved automatically [3]. Total stations use the polar method, which is based on measuring the horizontal and vertical angles and slope distances from the standpoint of the station to the points of interest [3].

Proceedings of the International Conference on Changing Cities V:
Spatial, Design, Landscape, Heritage & Socio-economic Dimensions
Corfu Island, Greece ● 20-25 June 2022
ISSN:
ISBN:

After calculations, the result is a set of points with coordinates x, y and elevation, with accuracy at around ±1mm. A base map of the area is usually created, based on horizontal coordinates, and also a DEM of the surface using the third dimension [5].

3. AERIAL METHOD

The aerial method uses UAV or remotely piloted systems (Figure 2), by utilizing the basic principles of photogrammetry. This method brings new opportunities both in the documentation of Earth's surface and also in historical monuments. They are almost independent from the ground control station, and can capture images at predetermined positions [5].

Figure 2. Different types of UAVs [6]

In order to have an accurate result, photos must be overlapping in a high percent, and due to image matching and alignment, a dense point cloud of the area is created. To reproduce true position and scale, geo-reference is needed [7].This can be done either directly using known exterior orientations of photographs or by providing appropriate coordinates to points that are recognizable in the photographs [8].
In this method, 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 known points and the processing algorithms and it is between ±1mm to ±5cm [9].

4. COMBINED METHOD

The combined method results from the optimal combination of terrestrial and aerial methodology. It is worth noting that the participation rate of each of these methodologies in the final method depends solely on the characteristics of the study and the final deliverables. For example, in cases where illustrative deliverables are acceptable, the aerial methodology is preferred, while in cases where high geometric accuracy is required, the terrestrial method is preferred.
As already mentioned, both methods are based on the use of ground points, whom position can be determined with great accuracy. If the use of both methodologies is planned in advance, common points can be used that serve both methodologies. In this way, the measurements' curriculum is optimized and improved as well as their systematic control.

Proceedings of the International Conference on Changing Cities V:
Spatial, Design, Landscape, Heritage & Socio-economic Dimensions
Corfu Island, Greece ● 20-25 June 2022
ISSN:
ISBN:

The fact that the two methodologies ought to be used with the common goal of always allowing a solution to emerge should not be overlooked. For example, choosing only the terrestrial methodology would create gaps in the description of the roof of tall buildings, where the aerial methodology could help. Respectively, the only use of the aerial methodology would create anomalies in areas where shadows or overlaps of objects are presented, where the terrestrial methodology could easily solve.

5. CASE STUDY

The case study refers to the historic center (Old Town) of the Corfu Island, located at the northwest end of Greece. The limits of the historic center are currently described by the location of two fortresses (Figure 3). The layout of the historic center indicates preliminary signs of various connections between the two major fortresses (old and new). The Old fortress lies along the east side on the sea, while on the west side and completely on land lies the new one. During the past, the two fortresses of Corfu were linked by large walls, so that the inhabitants could live safe inside. The walls were destroyed and nowadays there are only two of the four gates of the town [10].

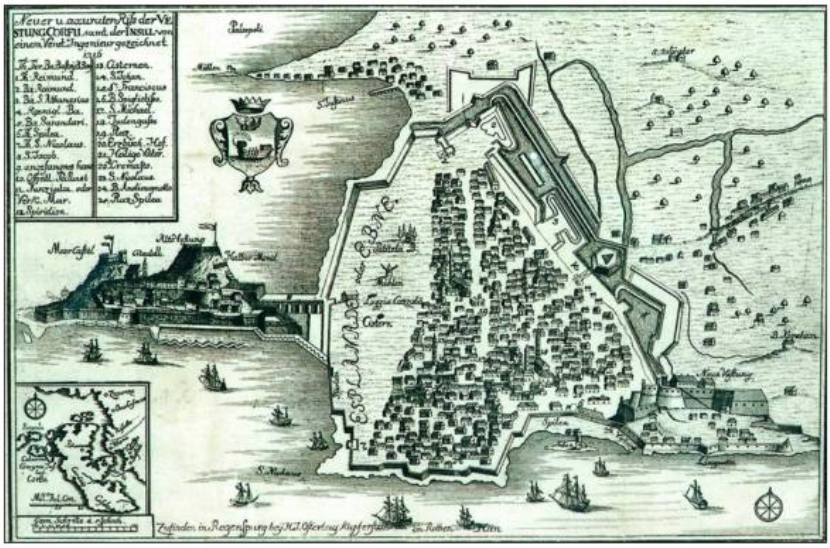

Figure 3. Old town and fortresses in 1716 [11]

As regards the size comparison of the two fortresses, the Old is mainly bigger and consists of several altitude levels. The old fortress houses many buildings inside and is fully accessible to most of its area. This fortress was constructed by the Venetians in the 15th century on the site of a former Byzantine castle. To make it more secure, they made an artificial moat and thus they separated the fortress from the mainland. It was connected to the land by a movable, wooden bridge. In 1819, the British replaced this bridge with the present stable pathway, which is 60 m long and stands 15 m above the moat. Nowadays the old fortress holds a special pole of attraction for tourists as well as for important artistic and cultural events of the island.

The New fortress was built by the Venetians and is strategically located in close proximity to the Old Harbour of the town. It took a rather long time to be built (1576 and 1645) and played a pivotal role as far as protecting the town of Corfu and its residents were concerned. The entire fortress is an intricate network of compartments and galleries. The two main gates of the fortress seem to have somehow withstood the ravages of time and are still very well preserved. The first

Proceedings of the International Conference on Changing Cities V:
Spatial, Design, Landscape, Heritage & Socio-economic Dimensions
Corfu Island, Greece ● 20-25 June 2022
ISSN:
ISBN:

gate faces to the Old Harbor's square while the other faces down south. A section of the fortress was demolished by the then British colonial rulers as per the agreement of 1864 that united Corfu with the rest of Greece [12].

The ensemble of the fortifications and the Old Town of Corfu is located in a strategic location at the entrance to the Adriatic Sea. Historically, its roots go back to the 8th century BC and to the Byzantine period. From the 15th century, Corfu was under Venetian rule for some four centuries, then passing to French, British and Greek governments. Corfu was a well thought of example of fortification engineering, and it proved its worth through practical warfare. Corfu has its specific identity, which is reflected in the design of its system of fortification and in its neo-classical building stock. As such, it can be placed alongside other major Mediterranean fortified port cities.

The overall case study refers to the promotion and management of the Old Town of Corfu. In order to achieve this, it was deemed necessary to clarify the physical and technical boundaries of the city. The initial step was to identify historically the reasons and ways that shaped these boundaries. As mentioned above, the two fortresses played a major role. Therefore, in order to carry out the management study of the historic center, the complete geometric measurement of both fortresses must precede.

In this case, a separate measurement of the characteristics of each of the castles was performed and deliverables were produced that can be used to extract information concerning both vector and illustrative derivatives. The method used was described in Chapter 4.

For the Old fortress, a geodetic network of six points was created and measured using GNSS methodology, where ±1cm accuracy was obtained. Additionally, 40 more points, measured using classical geodetic methods, were used to capture all the necessary details. On the other hand, for the New fortress, the geodetic network had two and ten points, respectively, and same accuracy.

An amount of 4700 points of detail (3700 in Old and 1000 in New fortress) were measured using total station, while the georeferencing of aerial data utilized 33 ground control points (GCPs), (18 in Old and 15 in New fortress). As a result, geometrically correct backgrounds were created for both castles (Figure 4-7) which include accurate information on exact location and altitude, and also 3D elevation models and a several orthophotos and photo-mosaics were produced in order to describe in the best way possible the current state of the fortresses.

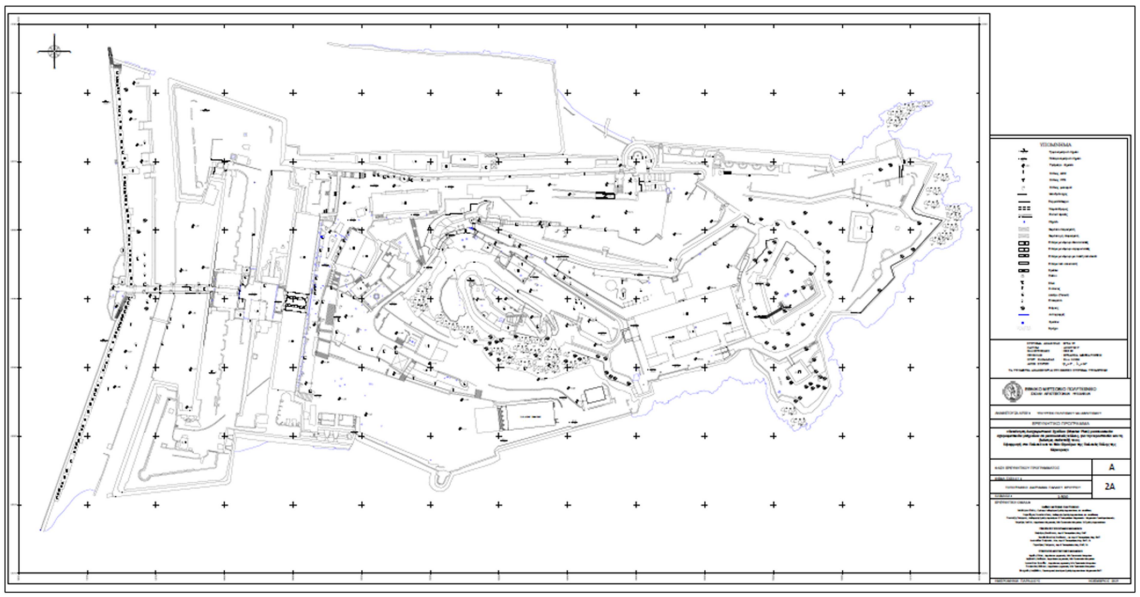

Figure 4. Vector background of Old fortress

Proceedings of the International Conference on Changing Cities V:
Spatial, Design, Landscape, Heritage & Socio-economic Dimensions
Corfu Island, Greece ● 20-25 June 2022
ISSN:
ISBN:

Figure 5. Illustrative Background-Orthophoto of Old fortress

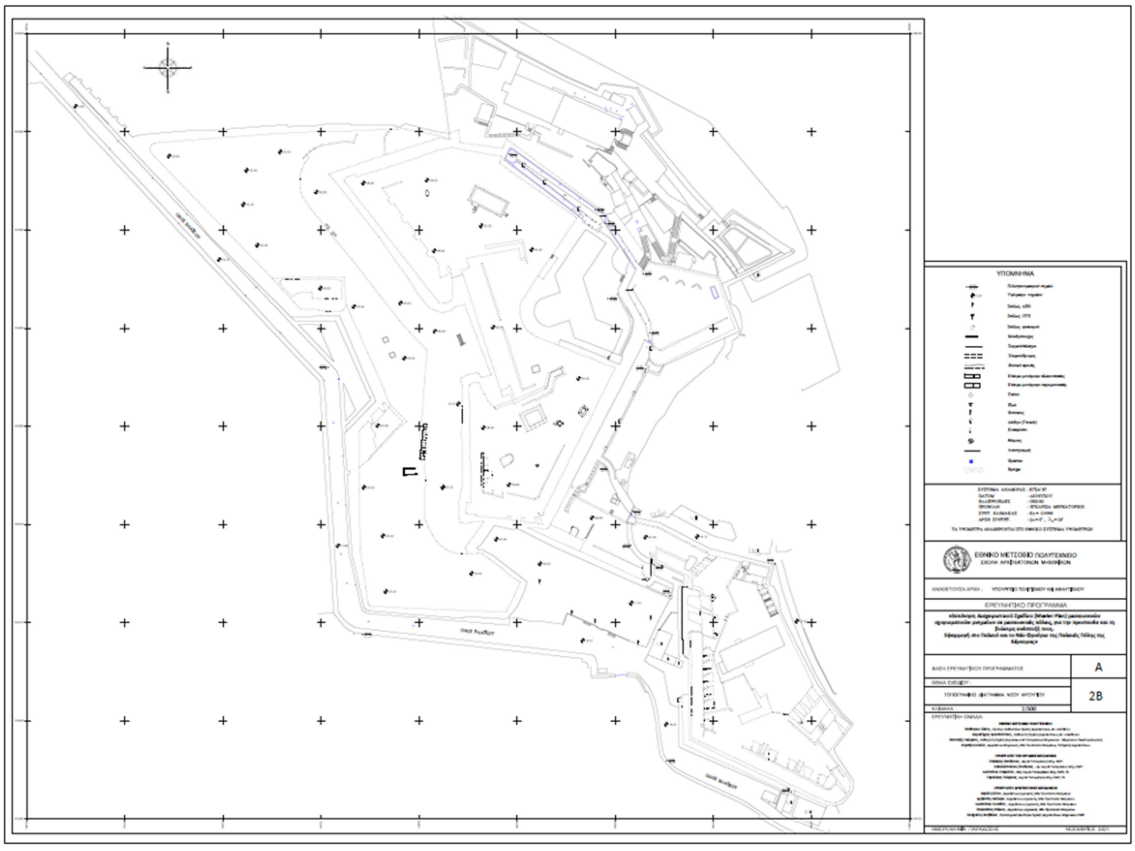

Figure 6. Vector background of New fortress

Proceedings of the International Conference on Changing Cities V:
Spatial, Design, Landscape, Heritage & Socio-economic Dimensions
Corfu Island, Greece ● 20-25 June 2022
ISSN:
ISBN:

Figure 7. Illustrative Background-Orthophoto of New fortress

The steep and inaccessible boundaries of the fortresses emerged using orthophotos and overlapping objects or areas with great detail using terrestrial measurements. For example small details of the back side of the English Hospital inside the Old fortress (Figure 8), or the underground arcades in the New fortress (Figure 9), that are not recognizable in orthophotos.

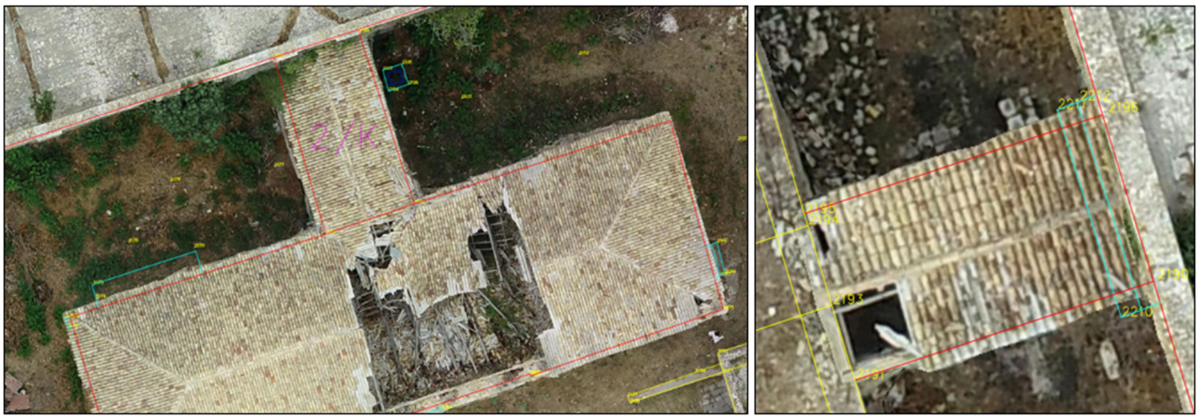

Figure 8. Details of the Old fortress that added using terrestrial measurements

Proceedings of the International Conference on Changing Cities V:
Spatial, Design, Landscape, Heritage & Socio-economic Dimensions
Corfu Island, Greece ● 20-25 June 2022
ISSN:
ISBN:

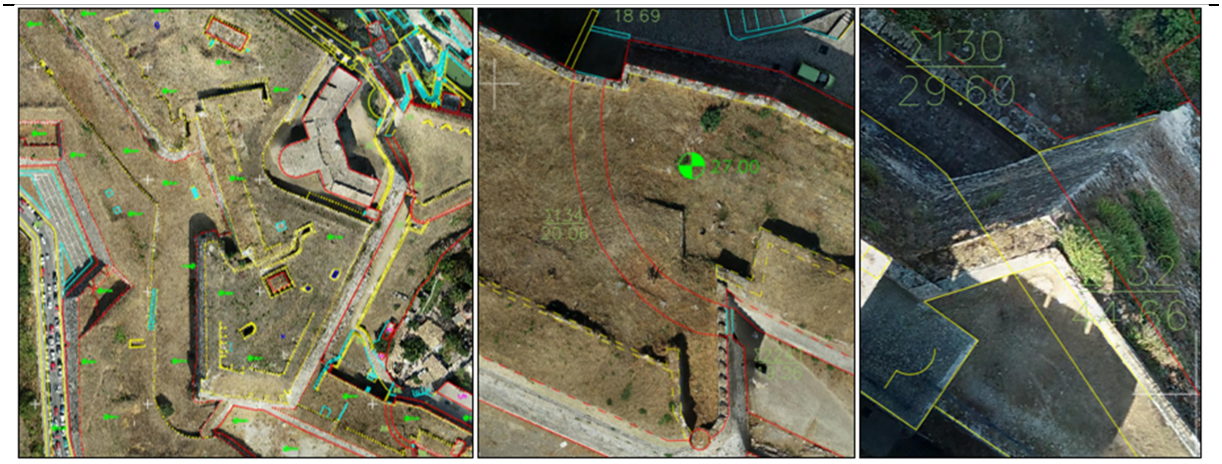

Figure 9. Geodetic measurements for the underground paths in New fortress

6. COMPARATIVE EVALUATION

The process of creating backgrounds for a specific area also includes the comparison of the current mapping situation with corresponding previous studies. In this work, this process plays an important role because in addition to the geometric differences that may occur between the measurement moments, qualitative data can emerge about the history and methods used in previous times. The results of this process are very important as they can indicate trends of improvement or deterioration of the structural and overall geometric conditions.

The comparison stages include, initially, direct visual inspection to highlight statistically significant differences between backgrounds generated at different times. Once significant differences have been identified, a comprehensive litigation recognition and quantification procedure should be implemented. The procedure requires the modern and old backgrounds to be transformed into the same coordinate system in order to highlight the differences between them. After the transformation of the old backgrounds, the comparison is fairly simple (site to site comparison) and many indexes can be produced and utilized to describe the changes through time.

The most recent documentation of the fortresses is from Ministry of Culture and Sports. The plans were produced in 2000, using aerial photographs. After the system transformation, a comparison between the plan and the new backgrounds, was made (Figure 10).

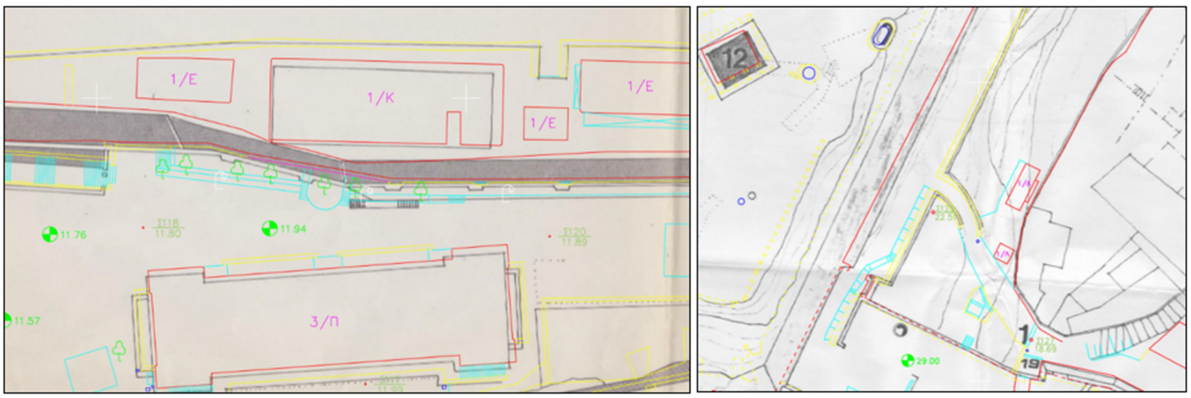

Figure 10. Comparison in old (left) and new (right) fortress

Proceedings of the International Conference on Changing Cities V:
Spatial, Design, Landscape, Heritage & Socio-economic Dimensions
Corfu Island, Greece ● 20-25 June 2022
ISSN:
ISBN:

The differences in the old fortress are up to 1m and in the new one up to 1.5m. There are additions concerning the coffee shop or the music school in the old one and the tourist cashier in the new one.

7. CONCLUSIONS AND SUGGESTIONS

The study of integrated management of historic centers is a modern occupation which is carried out in collaboration with many different types of engineers. Also the geometric documentation by using multisource data is a topic that has occupied a large part of the scientific community in recent years. In order to investigate and make any change, however, a complete picture of the current situation must be created. This process involves creating backgrounds for areas that sometimes exceed the size of the main study area. In order to carry out the process in the most accurate and beneficial way, the appropriate combination of modern supplied methodologies and measuring instruments should be used.

In this paper a complete case study of the combination of different terrestrial and aerial methodologies is described. The scope of the paper is to illustrate the basic advantages and possibilities of each of the different methods in order to conclude about the proper use of them.

Using aerial methods, such as UAVs, a detailed 3D model or orthophotos of the area can produced. The steep and high walls that are inaccessible or the qualitative characteristics such as the stages or the type of the road materials can be recognized. On the other hand, the terrestrial methodologies can measure the underway paths or areas with high vegetation that are not recognizable by photos. The combination of the methods provides high accuracy (±2-3cm) and both geometrical and qualitative information.

According to the comparative evaluation, through the years, the state has taken care to improve the public spaces of the historic center and to highlight its fortresses. Tourist facilities and options within the forts have increased, while efforts are being made to increase traffic within them. In that way, their history can be revealed and recognized by tourists or residents.

References

1. Ioannidis, C., Georgopoulos, A. 2007. 'Innovative techniques for the acquisition and processing of multisource data for the geometric documentation of monuments', International Journal of Architectural Computing, 5(2), pp.179-197, DOI: 10.1260/1478-0771.5.2.180.
2. Pozdysheva, O. N., Taldykina, V. V. 2020. 'Geodesy and modern technologies',in IOP Conference Series: Materials, Science and Engineering, Vol. 775(1), DOI:10.1088/1757-899X/775/1/012145.
3. Guney, C., Celik, R. N., Thys-Şenocak, L., Ozsavasci, A. 2003. 'The utility of geodetic survey techniques and equipments in architectural heritage documentation–An assessment of recent approaches in turkey: The documentation project of the Ottoman fortresses of Seddulbahir and Kumkale',in CIPA 2003, International Symposium Conference Proceedings, Antalya, Turkey, pp. 122-38.
4. https://www.indiamart.com/proddetail/ (accessed February 24, 2022).
5. Kršák, B., Blišťan, P., Pauliková, A., Puškárová, P., Kovanič, Ľ. M., Palková, J., Zelizňaková, V. 2016. 'Use of low-cost UAV photogrammetry to analyze the accuracy of a digital elevation model in a case study', Measurement 91: 276-287, DOI:10.1016/j.measurement.2016.05.028.
6. Xiang, T. Z., Xia, G. S., Zhang, L. 2018. 'Mini-UAV-based Remote Sensing: Techniques, Applications and Prospectives', arXiv preprint arXiv: 1812.07770.

ISSN:
ISBN:

7. Garoufos, G., Ioannidou, S., Kanellopoulos, N., Pantazis, G. 2021. 'Documentation of cultural heritage monuments, by introducing new surveying technologies-implementation in Sarlitza Pallas, in Thermi Mytilene', in proceedings of the 2nd International Conference TMM-CHTransdisciplinary Multispectral Modelling and Cooperation for the Preservation of Cultural Heritage Recapturing the World in Crisis through Culture, 13-15 December 2021, Athens, Greece (under publication).
8. Sanz-Ablanedo, E., Chandler, J. H., Rodríguez-Pérez, J. R., Ordóñez, C. 2018. 'Accuracy of unmanned aerial vehicle (UAV) and SfM photogrammetry survey as a function of the number and location of ground control points used', Remote Sensing, 10(10), 1606, DOI: 10.3390/rs10101606.
9. Arias, P., Ordóñez, C., Lorenzo, H., Herraez, J. 2006. 'Methods for documenting historical agro-industrial buildings: a comparative study and a simple photogrammetric method', Journal of Cultural Heritage, 7(4), pp 350-354, DOI: 10.1016/j.culher.2006.09.002.
10. Fürst, F. 2001. (eds), *Corfu*, Hunter Publishing, Inc. ISBN: 3-88618-735-7.
11. https://www.corfuhistory.eu/?p=401 (accessed February 26, 2022)
12. Papadamou, C. 2018. 'A Secret War: Espionage in Venetian Corfu during the Construction of the San Marco Fortress', In A Military History of the Mediterranean Sea, pp 347-370, Brill, DOI: 10.1163/9789004362048_018

ISSN:
ISBN: