ISSN: 2687-8402

Open Access Journal of Archaeology and Anthropology

DOI: 10.33552/OAJAA.2023.04.000596

Iris Publishers

Research Article

UAVs in Cultural Heritage: The Case of Geraki Lakonia, Greece

Kompoti A*, Panagiotidis V V and Zacharias N

Laboratory of Archaeometry, University of the Peloponnese, Greece

***Corresponding author:** Aggeliki Kompoti, Laboratory of Archaeometry, Department of History, Archaeology and Cultural Resources Management Old Camp, University of the Peloponnese, 24133 Kalamata, Greece

Received Date: June 01, 2023

Published Date: July 19, 2023

Abstract

The archaeological site of Geraki, Lakonia is located on the south-western slopes of Mount Parnon in the SE Peloponnese, is comprised of the medieval castle and its settlement and has recently been restored by the Greek Ministry of Culture. Geraki was built during Frankish rule in the Peloponnese, in the middle of the 13th century. The castle's location was crucial for controlling the road communication between Mystras and Monemvasia. The aim of this study is the initial documentation of the current situation of the medieval settlement of Geraki applying innovative technology including unmanned aerial vehicles (UAVs). Following the developments in image capturing and processing, UAVs have become an alternative in cultural heritage domain and have successfully been used in different projects. Due to their ability to perform in high-risk situations (e.g. lack of accessibility, high slop remote areas and sites of high altitude) while the pilot maintains a safe distance UAVs can reach places where people cannot, making them a standard platform in the cultural heritage sector.

In this study, a UAV was used in order to visualize the archaeological site with surrounding buildings and structures through the capture of high-resolution aerial photographs. Following processing the photos with photogrammetry software, digital orthophotos and digital surface models are produced. The orthophoto in turn is used with GIS software for the identification of the specific location of the archaeological site's buildings. Separated layers in GIS were created in order to include information about the topography, the architecture, the characterization and categorization of buildings, creating thus an important historical and archaeological database.

Keywords: UAVs, Geraki Lakonia, orthophotos, visualization archaeological sites, GIS

Introduction

During the past decades, the field of archaeology has witnessed significant advancements in technology, revolutionizing the way we study and visualize ancient sites from Geographic Information Systems (GIS) to digital repositories. The last decade has introduced rapidly growing technological innovations including the use of Unmanned Aerial Vehicles (UAVs), resulting in the enhancement of the documentation and analysis of archaeological sites and monuments. In this context, the medieval city of Geraki in Lakonia, Greece, is the focus of a comprehensive study that employs such innovative tools to create a visual database of the archaeological site.

Geraki, situated on the south-western slopes of Mount Parnon in the southeastern Peloponnese, encompasses a medieval castle and its surrounding settlement [1]. The archaeological site, built during Frankish rule in the 13th century, held strategic importance as it controlled the crucial road communication between Mystras and Monemvasia [2]. Recognizing its significance, the Greek Ministry of Culture recently undertook restoration efforts in Geraki with impressive results. In 1262, when the Peloponnese was recaptured by the Byzantines, the castle came into their possession until the conquest of the Despotate of Morea by the Ottoman Turks in 1460.

During the first Venetian-Turkish War (1463-1479) it was occasionally occupied by the Venetians, as during the period of the second Venetian rule (1685-1715).

An important settlement, Paleogerako, developed on the hill during the late Byzantine period. From the findings so far, it appears that the area was used limitedly after the 15th century and a concentration of habitation was present in the area of modern Geraki from at least the beginning of the 18th century allowing the medieval ensemble to retain authentic elements of its initial phases, without subsequent interventions. The castle was abandoned relatively early, between the 15th or 16th century, in which most inhabitants moved to the site of present day Geraki [3,4].

The aim of the present study was to document the current state of the medieval settlement of Geraki using cutting-edge technology, including UAVs. In the field of cultural heritage, UAVs have emerged as a valuable tool for capturing and processing images, offering alternative means of data collection in various projects [5] Their ability to operate in challenging and high-risk environments, such as remote areas with difficult accessibility or steep slopes, has provided for additional reasons for UAVs to be considered integral means for documentation in the cultural heritage sector.

To visualize the archaeological site of Geraki, a UAV was employed to capture high-resolution aerial photographs. These photographs were subsequently processed using photogrammetry software, enabling the creation of digital orthophotos and digital surface models. The orthophoto, combined with GIS software, facilitated the identification of specific locations within the archaeological site, including the buildings and structures. In GIS, separate layers were generated to incorporate information related to the topography, architecture, and characterization of these buildings, thereby forming a crucial historical and archaeological database.

UAV photogrammetry provides numerous benefits in contrast to conventional land surveying. It enables cost and time savings by capturing high-resolution images in hard-to-reach or risky locations, which would otherwise be inaccessible. This paper centers on digitally documenting the present state of the medieval settlement of Geraki, utilizing cutting-edge technology like unmanned aerial vehicles (UAVs). Additionally, it aims to establish a valuable geodatabase for efficiently managing various types of information [6].

Materials and Methods

The study area is located in Laconia, southeastern Peloponnese, Greece (Figure 1). The total area that includes the castle and the settlement on the western side of the northern hill of Palaiokastro has an area of 20.151 square meters, according to the UAV photogrammetry conducted. The elevation range is about 55 m, varying from 510 to 565 m above mean sea level (MSL). The study area has low and bushy vegetation, except for the Acropolis area where there are some trees 4–5 meters high.

Figure 1: Location of the study area.

Given the expansive and topographically diverse nature of the Archaeological site of Geraki, it was apparent that capturing comprehensive data in a single flight would not be feasible. Consequently, a strategic decision was made to conduct two separate flights, each targeting a specific area of interest. The first flight focused on the Acropolis area, while the second flight was dedicated to the Settlement area, as depicted in Figure 2. This approach allowed for efficient coverage and ensured that the relative altitude of the UAV could be accurately adjusted to accommodate the varying terrain within each surveyed region.

Figure 2: Map of Geraki and its survey segmentation-two regions.

The 3D survey Pilot application was utilized in this study to plan the UAV flights and acquire photos for the study (Figure 3). Each flight plan was prepared with an 80% front and side overlap using a single grid flight. The 3Dsurvey Pilot application enables the pilot to set up all necessary parameters prior to flight, including flight altitude, overlapping, etc., [7]. Although the UAV is equipped with internal GPS for navigation, Ground Control Points (GCPs) were used to achieve more precise georeferencing.

Figure 3: 3DSurvey Pilot application.

Another element crucial to planning a flight was Ground Control Points (GCPs). GCPs are points/targets on the ground with known coordinates required in UAV photogrammetry to ensure data accuracy and quality control. Photogrammetric checkerboard targets (with dimensions of 20 cm x 20 cm and 10 cm x 10 cm) were placed (Figure 4).

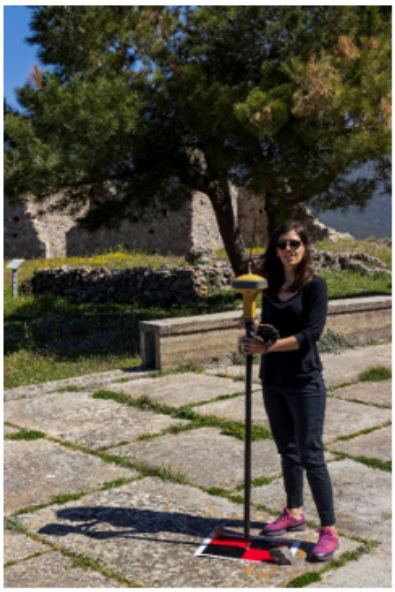

Figure 4: Ground Control Points (GCPs) & 3D coordinate measurements using GPS (RTK mode).

A total of 20 GCPs were placed in the field on the basis of the size and shape of the archaeological area to be surveyed. More specifically, the location of the GCPs ensure good visibility so that they can be identified in photographs, while at the same time covering the study area and its elevation differences (Figure 5).

Figure 5: Ground control points (GCPs) used for the survey.

Previous to image acquisition, three-dimensional (3D) coordinates of each GCP were measured with a GPS Top Con GR5 geodetic station working in Real Time Kinematic (RTK) method ensuring accurate measurements. For RTK measurements, these dual-frequency geodetic instruments have a manufacturer's stated accuracy specification of ±10 mm + 1.0 ppm horizontal RMS and ±15 mm + 1.0 ppm vertical RMS [8]. All data collected in the Greek Geodetic Reference System 1987 (GGRS87). (Meouche et al., 2016).

Images were acquired in autonomous mode according to the flight plan we created for each area through the 3Dsurvey Pilot application. It is also important to mention that the first flight (to the Acropolis area) took place at a flight altitude of 50m and lasted about 3 minutes, while the second one lasted 5:30 minutes at 90 m. The different flying heights were planned not only according to the characteristics and the size of the surveyed areas but also in our case in order to keep the same Ground Sampling Distance (GSD) at 1.22cm/px. Ground Sample Distance plays an important role to build detailed and accurate maps [9].

Thus, a total of 284 images with a resolution of 5472 X 3648 pixels and 20 GPCs were acquired in order to cover the archaeological area of Geraki with the Mavic 2 Pro. All technological equipment used in this research (UAV DJI Mavic 2 Pro and GPS Top Con GR5) belongs to the Laboratory of Archaeometry of the University of Peloponnese.

Data Processing

All acquired images were transferred from the UAV to a computer and processed using the photogrammetry software Agisoft Metashape v1.8.5 following photogrammetric workflow, based on Structure from Motion (SfM). Agisoft Metashape is a photogrammetric software used in the production of georeference point clouds, digital surface models (DSM), 3D models and orthophoto maps from images taken with UAV [10].

The images are imported into the software, the first step of processing includes resolving the camera internal position and external orientation for each photo known as image (camera) alignment resulting a sparse 3D point cloud (Figure 6).

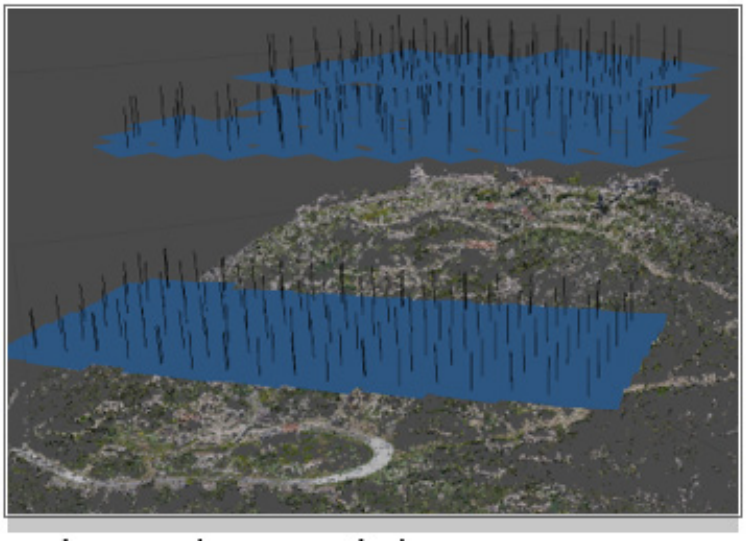

Figure 6: Camera positions, alignment and sparse point cloud.

The point cloud and 3D model are georeferenced to a real-world coordinate system by using ground control points (GCPs) that were measured using the Top Con GNSS GPS. 20 GCPs' coordinates are directly imported as a csv file into the workspace. The coordinates are automatically added to the model as markers by the software. To ensure that the markers are placed correctly above the visible GCPs in each image, the position of the markers must be adjusted separately in each image. Better georeferencing outcomes are guaranteed by this process than by using the UAV's GPS alone. A dense point cloud of the study area is produced after optimization. A detailed three-dimensional model of the area being studied is produced by the dense point cloud (Figure 7) [11]. A dense point cloud produces the study area's digital surface model (DSM) from which in turn the high resolution orthophoto image of 23272 x 22532 size were obtained from 284 aerial images was produced. (Figure 8).

Figure 7: 3D dense cloud.

Figure 8: Study area's Orthophoto.

Geodatabase

A Geographic Information Systems (GIS) is a system used to collect, retrieve, manage, analyze, and map all types of data. GIS is an important contribution to the field of archaeological information in recent years as there is not only the possibility of storing and managing a large amount of information, visualizing this data but also helping to make decisions. Consequently, GIS in an archaeological site is a very useful tool, which provides many possibilities for users to draw correct conclusions. For all these reasons, a geodatabase using GIS software was created in order to manage all types of data in a high-resolution map [12].

The generated orthophoto described above is used as a georeferenced basemap for the development of geodatabase including representative data of Geraki. The orthophoto was imported to ArcGIS Pro 3.1.0. in order to recognize significant elements of the current landscape. Separate layers were created in GIS in order to include information about the topography, the architecture, the characterization and categorization of buildings, creating thus an important historical and archaeological database. In Figure 10 we can see the separated layers used for every object and entity such as roads, walls, churches, buildings, cisterns found on the maps.

Each building is depicted on the map with a location and its code. By clicking on the position, a window is activated providing a code number for the building, its characterization and categorization as a structure as well as its location in the settlement (Figure 9). The registered attributes in the geodatadase regard published research data from the available literature which has been collected and recorded for each item creating a digital map of the medieval castle and its settlement (Figure 10).

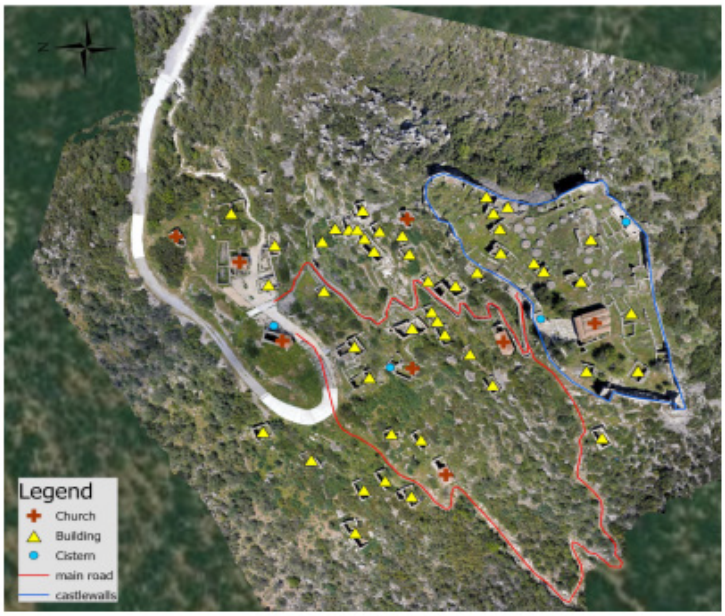

Figure 9: Spatial data of building 38.

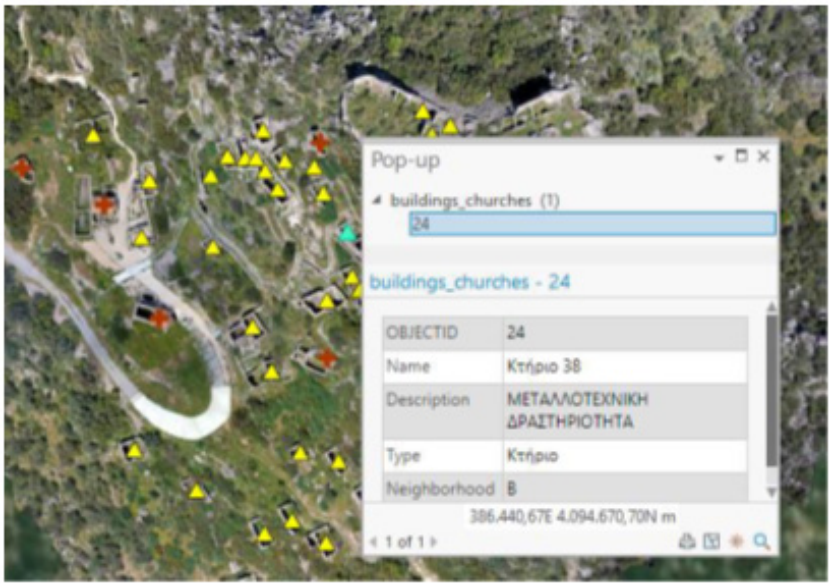

Figure 10: The map of Geraki.

Conclusion

This survey represents the initial phase of a comprehensive study focused on the medieval city of Geraki, showcasing the potential for visualizing spatial information in archaeology. By combining structural data with additional information such as building types, characterization, and location within the settlement, this research lays the foundation for the development of a dynamic map with multiple layers of information pertaining to the documentation of the archaeological site. The utilization of GIS as a tool for organizing diverse types of data has proven invaluable for historians and archaeologists alike. Through the visualization of these data and the identification of their interconnections, experts are able to derive more efficient, expedient, and secure conclusions regarding the characterization of archaeological sites and artifacts.

The future objective is to expand upon the existing database by incorporating additional sources and enriching it with 2D and 3D information. This will contribute to the creation of a more dynamic map, providing a comprehensive overview of the medieval city of Geraki. The ongoing research aims to ensure the database's flexibility, allowing for regular updates and modifications as new findings

emerge. By leveraging advanced technologies and expanding the available bibliography, this project seeks to create a robust resource that will continue to enhance our understanding and appreciation of Geraki's archaeological heritage.

Overall, the combination of GIS, UAVs, and databases presents a powerful solution for visualizing and analyzing archaeological data. The study of Geraki serves as a prime example of the potential of these technologies, offering researchers the ability to organize and interpret diverse datasets with greater ease and efficiency. Through the continued development of a dynamic map and the integration of multidimensional information, this research contributes to the preservation and exploration of Geraki's rich historical past.

Acknowledgements

This project was implemented within the scope of the "Exceptional Laboratory Practices in Cultural Heritage: Upgrading Infrastructure and Extending Research Perspectives of the Laboratory of Archaeometry", a co-financed by Greece and the European Union project under the auspices of the program "Competitiveness, Entrepreneurship and Innovation" NSRF 2014-2020.

Conflict of interest

No conflict of interest.

References

1. Ministry of Culture and Sports, Ephorate of Antiquities of Lakonia (2015) Organization, Improvement of Visitor Accessibility and Conservation of Monuments on the Archaeological Site of Geraki, Sparti, Greece.
2. Christodoulou R, Simatou A (1991) Observations in the medieval settlement of Geraki. Deltion of the Christian Archaelogical Society. Deltion XAE (1989-1990), Period D, Athens, pp. 67-88.
3. Ministry of Culture and Sports, Ephorate of Antiquities of Lakonia, Organisation, Improvement, of Visitor Accessibility and Conservation of Monuments on the Archaeological Site of Geraki.
4. Ministry of Culture and Sports, Archaeological site of Geraki castle.
5. Korumaz A, Korumaz M, Tucci G, Borona V, Niemeier W, et al., (2012) UAV systems for documentation of cultural heritage. In: ICONARCH I-International Congress of Architecture-Innovative Approaches in Architecture and Planning, Konya, Turkey 978-975-448-206-5: 419-430.
6. Bhatsada Abhisit, Wangyao, Komsilp (2022) The Optimum Number and Placement Pattern of Ground Control Points for Mapping In Risk Areas: A Case Study Of Landfill Mapping. Fresenius Environmental Bulletin 31: 7888-7901.
7. Panagiotidis V V, Zacharias N (2022) Digital Mystras: An approach towards understanding the use of an archaeological space. 2nd International Conference on Global Issues of Environment & Culture, Scientific Culture 8(3): 85-99.
8. Martínez Carricondo P, Agüera Vega F, Carvajal Ramírez F, Mesas-Carrascosa F X, García Ferrer A, et al., (2018) Assessment of UAV-photogrammetric mapping accuracy based on variation of ground control points. International Journal of Applied Earth Observation and Geoinformation 72: 1-10.
9. Panagiotidis V V, Zacharias N (2022) Digitizing Mystras: The Palace Complex. In: Moropoulou, A, Georgopoulos A, Doulamis A, Ioannides M, Ronchi A (Eds.), Trandisciplinary Multispectral Modelling and Cooperation for the Preservation of Cultural Heritage. TMM_CH 2021. Communications in Computer and Information Science 1574.
10. Zacharias N, Malaperdas G, Panagiotidis V, Kouri M (2022) Cultural Heritage and New Technologies, Papazisis, p. 151-155.
11. Mafredas T, Malaperdas G (2021) Archaeological Databases and GIS: Working with Databases. European Journal of Information Technologies and Computer Science, p. 1-6.