**XXVIII INTERNATIONAL SYMPOSIUM ON
MODERN TECHNOLOGIES, EDUCATION AND PROFESSIONAL PRACTICE
IN GEODESY AND RELATED FIELDS**

Sofia, 08 - 09 November 2018

3D MODELLING OF HISTORICAL REMAINS USING UNMANNED AERIAL VEHICLE, A CASE STUDY: GALLIPOLI PENINSULA

**Mehmet Ali Yucel, Deniz Sanliyuksel Yucel,
Cahit Caglar Yalciner, Derya Yilmaz (TR)**

ABSTRACT

The Gallipoli Peninsula was the scene of a great battle occurred on both land and sea during the First World War. Almost the whole peninsula carries the traces of this war and consists of a lot of historical remains survived until today. In recent years, unmanned aerial vehicles (UAVs), which are described as remotely controlled aircrafts, have been extensively used in engineering and geology studies for surface observation purposes. UAVs are air vehicles that can be controlled remotely and carry cameras and communication devices. In this study, 20 megapixel resolution aerial photographs with visible band were obtained using Phantom4 Pro UAV, in order to examine and detect historical remains of the war in Gallipoli Peninsula Historical National Park. The UAV images were modelled using the structure from motion algorithm in Agisoft PhotoScan Professional software, and a 1 cm resolution orthomosaic image, 3D point cloud and 3D digital terrain model of the research area were created. The cemetery areas were detected using these images and land surveys. Future work will focus on determining historical remains in the underground using thermal imaging UAV and ground-penetrating radar.

Key words: Gallipoli Peninsula, historical remains, UAV, 3D modelling.

1. INTRODUCTION

Gallipoli Peninsula Historical National Park is known for the First World War cemeteries and memorials for the Turkish and foreign soldiers killed during the Canakkale marine and land battles in 1915. There are sunken ships, trenches, castles, towers, memorials, cemeteries and hundreds of remnants of the war. In total, there are graves and memorials for around 250,000 Turkish soldiers, and 250,000 from Australia, New Zealand, England and France (URL1). Gallipoli Peninsula Historical National Park, established in 1973 and included in the UN List of National Parks and Protected Areas, covers almost 33,000 hectares at the southern end of the Gallipoli Peninsula on the European side of the Dardanelles, NW Turkey (Figure 1).

The use of remote sensing data has been appreciated in archaeological investigations for almost a century. During this period the type of remote sensing data has changed due to technological developments (Nikolakopoulos et al., 2017). The platforms carrying sensors changed from balloons to planes and from satellites to unmanned aerial vehicles. Remote sensing with UAVs has the potential to provide imagery at an unprecedented spatial and temporal resolution (Oleire-Oltmanns et al., 2012). UAV systems for collecting images are low cost, have fast speed, high manoeuvrability, and high safety and they are already a reliable replacement for satellites and manned vehicles. Moreover, they have overcome the disadvantages of aerial imagery of low flexibility and high cost (Siebert and Teizer, 2014). They can be used as baseline data for orthophoto and digital elevation model generation, as well as for map production (Yucel and Turan, 2016; Dubbini et al., 2017). This study deals with archaeological work and presents 3D modelling of historical remains during a UAV survey in Gallipoli Peninsula Historical National Park.

Figure 1. Location map of the study area.

2. MATERIALS AND METHODS

In this study, the DJI Phantom4 Pro UAV system was used to take aerial photographs using a DJI digital camera capable of obtaining data at 20 megapixels in the visible band (Figure 2). Using a GPS-supported UAV system, flight plan and photographs are geographically referenced. Ground control points (GCPs) are used to increase the coordinate accuracy of the orthomosaic in the merging process. GCPs were 50 cm x 15 cm in size consisting of a rectangular plate. GCPs placed on the ground before UAV flights were measured using the CHC X91 geodetic GPS providing high precision GCP coordinates.

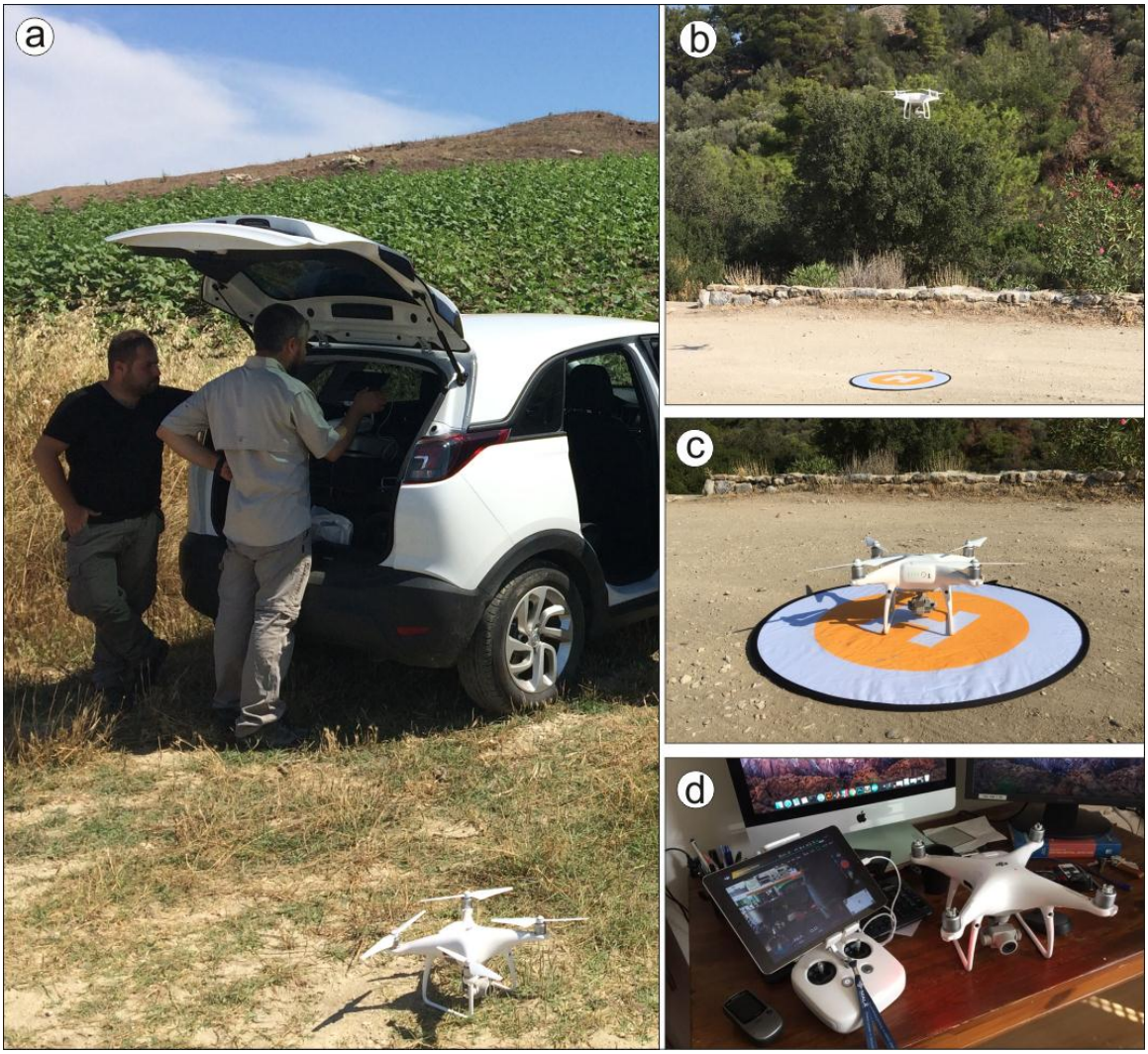

Figure 2. a and b: UAV survey of study area; c and d: DJI Phanton4 Pro UAV.

Flight plans for UAV flights are created using a mobile phone connected to the UAV system with the Pix4D mobile application (Figure 3). Merging and three-dimensional modelling of the UAV images was performed in Agisoft PhotoScan Professional software. The high resolution orthomosaic image, 3D digital terrain model (DTM) and 3D point cloud of the study area are obtained after image processing. Agisoft PhotoScan Professional software provides three-dimensional data from two-dimensional images using the Structure from Motion (SfM) algorithm. The SfM technique is a method developed by Lowe (2004), which creates a 3D point cloud. In this method, geographically referenced images are produced with the GCP coordinates and the camera GPS positions. A 3D dense cloud is created by applying a depth filtering to the 3D point cloud (Furukawa, 2009; Sanliyuksel Yucel and Yucel, 2017). Digital elevation model (DEM), orthomosaic and DTM were created by applying the nearest neighbour interpolation method to the 3D dense point cloud.

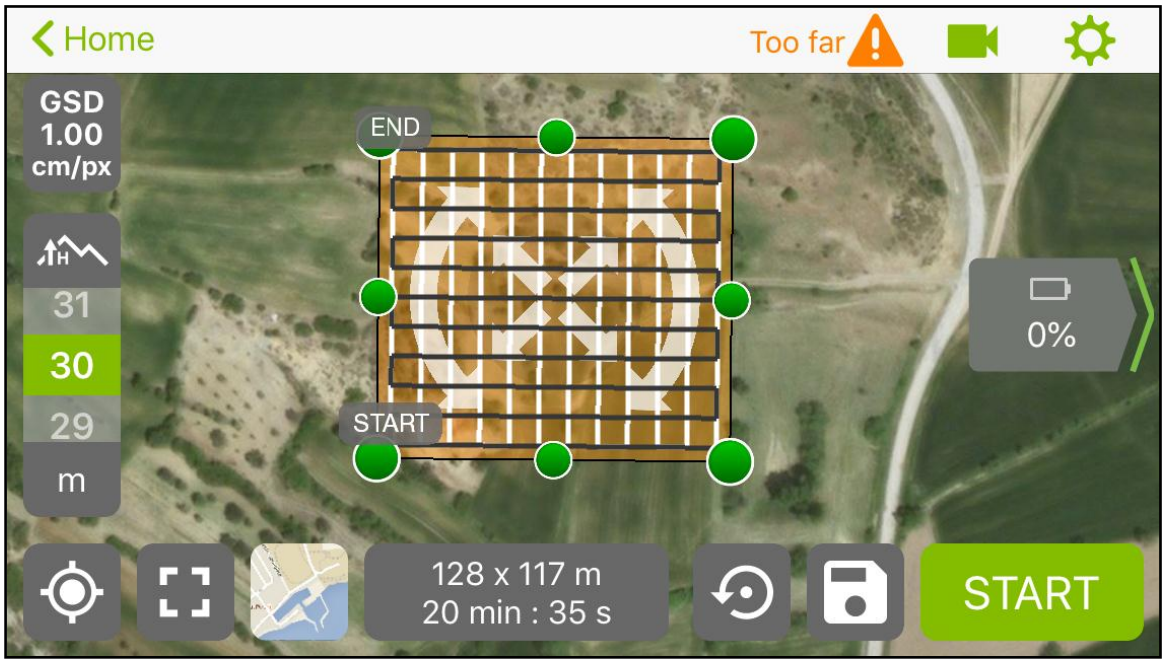

Figure 3. Flight plan on Pix4D mobile application.

3. RESULTS AND CONCLUSION

In this study, Besyol Village Kucukanafartalar Site, located in Gallipoli Peninsula Historical Site, was modelled three dimensionally as DLM and DTM using images captured by a UAV system. The flight plan was prepared with Pix4D mobile application. In the flight plan, the image acquisition in the field was performed with 20-minute flights at 30 m height. The flight plan was implemented using the "double grid" feature in north-south and east-west directions, providing the most proper images for three-dimensional modelling. This method provides objects to be captured in two different directions perpendicular to each other. 234 UAV images taken in the study area on June 22, 2018 were processed with Agisoft PhotoScan Professional software. The result of this process generated a 3D point cloud consisting of 1.6 million points, a 3D digital terrain model consisting of 245 thousand faces and high resolution orthomosaic image data (Figure 4). Using a digitization process on the orthomosaic image with a spatial resolution of 1 cm, the existing cemetery area was calculated as 800 m^2 and the possible burial site as 1100 m^2. Then the high resolution orthomosaic image was integrated into the Google Earth program (Figure 5). UAV technology, which provides low cost, fast and high resolution geographical data production, has been used in the Gallipoli Peninsula Historical Site. It was determined that the topographical structure of the study area and the terrain structure can be visualized in a very realistic manner. Future work will focus on determining historical remains in the underground using thermal imaging UAV and ground-penetrating radar.

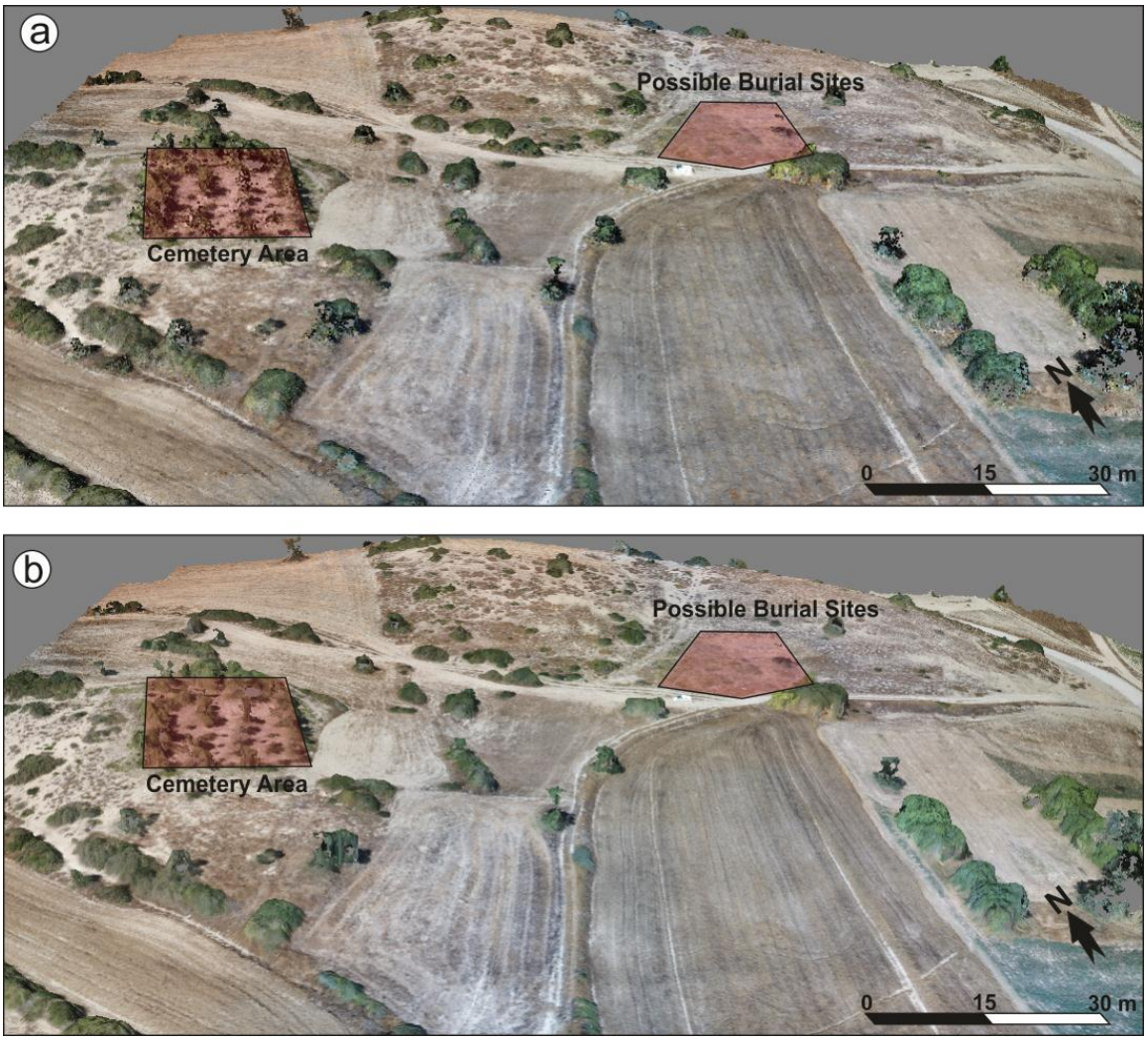

Figure 4. Agisoft PhotoScan results: a. 3D point cloud data of study area; b. 3D digital land model of study area.

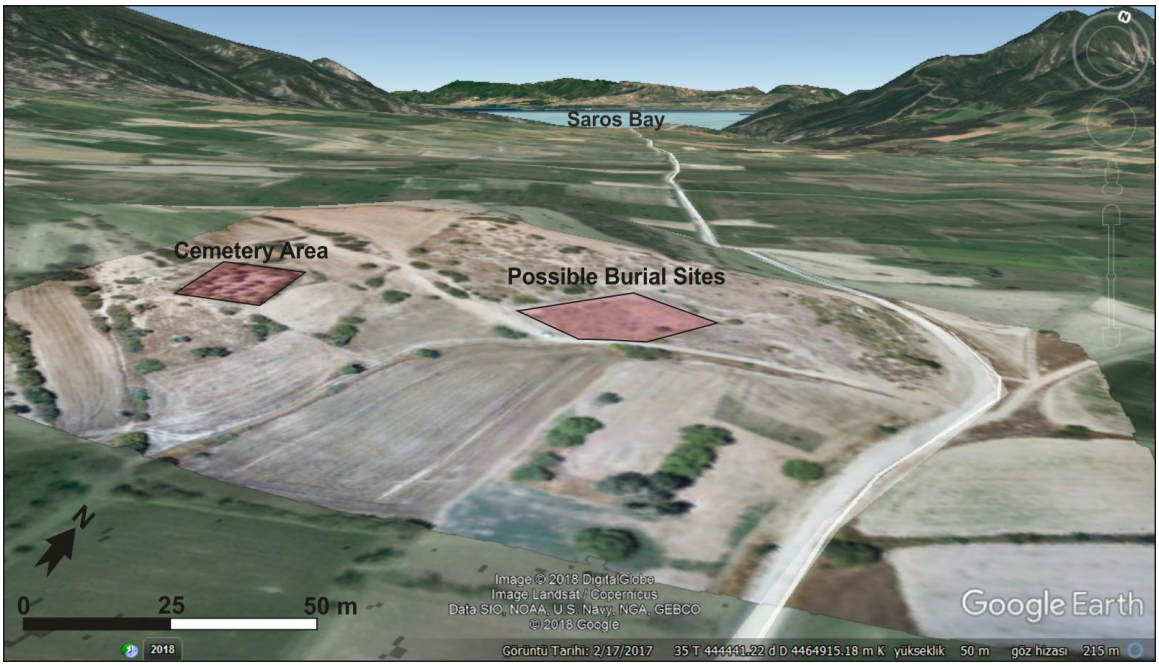

Figure 5. Google Earth integration of high resolution orthomosaic.

ACKNOWLEDGMENTS

This research is funded by the Canakkale Onsekiz Mart University, Scientific Research Project Number: FBA-2018-2500. The authors would like to thank Canakkale Onsekiz Mart University Scientific Research Projects Coordination Unit.

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Authors:

Assoc. Prof. Mehmet Ali Yucel
Canakkale Onsekiz Mart University,
Faculty of Engineering,
Department of Geomatics Engineering,
17100, Canakkale, Turkey
Tel: + 90 286 218 00 18 / 2344
Fax: +90 286 218 05 41
E-mail: aliyucel@comu.edu.tr

Assist. Prof. Deniz Sanliyuksel Yucel
Canakkale Onsekiz Mart University,
Faculty of Engineering,
Department of Mining Engineering,
17100, Canakkale, Turkey
Tel: + 90 286 218 00 18 / 1472
Fax: +90 286 218 05 41
E-mail: denizsyuksel@comu.edu.tr

Assoc. Prof. Cahit Caglar Yalciner
Canakkale Onsekiz Mart University,
Can Vocational Collage,
Department of Mining Technology,
17400, Can, Canakkale, Turkey
Tel: + 90 286 416 77 05 / 119
Fax: +90 286 416 37 33
E-mail: yalciner@comu.edu.tr

Assist. Prof. Derya Yilmaz
Ankara University,
Faculty of Languages History & Geography,
Department of Archeology,
06100, Sihhiye, Ankara, Turkey
Tel: + 90 312 310 32 80 / 1177
Fax: +90 312 309 36 73
E-mail: d.yilmaz@ankara.edu.tr