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Research Article

ANALYSIS OF THE UTILITY OF THE UNMANNED AERIAL VEHICLE(UAV) IN VOLUME CALCULATION BY USING PHOTOGRAMMETRIC TECHNIQUES

Ulvi, A.

Selçuk University, Hadim Vocational School, Hadim/Konya
(aliulvi@selcuk.edu.tr);

ORCID 0000-0003-3005-8011

*Corresponding Author, Received: 23/12/2017, Accepted: 03/04/2018

ABSTRACT: Together with developments in software technology, various interpolation methods allow terrain surfaces to be better identified. The accuracy rate in volume calculations is directly proportional with representation in the best form. The non-metric cameras, which are assembled to unmanned aerial vehicles (UAVs), provide convenience in the photogrammetric measurements. Sensitive images are obtained with less cost by the use of unmanned aerial vehicles.

The purpose of this study was to take photos from the air with the help of UAVs and to make volume calculations by using photogrammetric techniques. At the end of the study, the photogrammetric method had been completed in a shorter period than with the traditional method. The values found as the result of both methods have been found to be compatible with each other in the ratio of 99.33% in terms of sensitivity.

Keywords: *UAV, UAV photogrammetry, volume calculation*

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1. INTRODUCTION

UAV technology represents feasible instrumentation for places or projects that would require periodic measurement of volume calculations, such as large construction sites, mines with excavations and fillings, or coal dumping areas. It is, of course, possible to make such volume calculations by classical geodetic methods; however, regarding time management, economics, and precision, deploying UAVs would be a more optimum solution. It is not possible to re-measure the previously measured spots in areas measured by classical methods at the same positions and at the necessary frequency, so triangulation of the previously constructed digital land models and the later-constructed digital land models would not be possible. Therefore precise volume calculations cannot be performed.

In general, the volume of earth to be excavated and filled needs to be calculated in the land-related works of engineering projects (roads, construction, mining, etc.).

Volume calculations are usually performed by using cross sections, prisms, surface-leveling measures, and contour maps (Yakar et al., 2009).

The most prominent techniques to prepare Digital Elevation Models are photogrammetric methods with

stereo data (Hohle, 2009;Kraus, 2007,Akar, 2017).

Generally, classical methods have been used in volume computing. The trapezoidal method (rectangular or triangular prisms), classical cross-sectioning (trapezoidal, Simpson, and average formula), and improved methods (Simpson-based, cubic spline, and cubic Hermite formula) have been presented in the literature (Yanalak, 2005). Efficient volume computation at high accuracy is an important question, both theoretically and practically (Soole and Poropat, 2000).

Also, in modern times, land surfaces are better defined by using various interpolation methods with the recent developments in software technologies. Also, accuracy in volume calculations is correlated with how well the land surface is represented. The best representation of land surface depends on the density and distribution of spots with known coordinates at the land surface and on the interpolation method applied. Undoubtedly, more spots with appropriate distribution would enable better representation of the land surface. However, more spots would mean more time and more cost. In some cases, producing spots geodetically can be risky and even impossible. Accordingly, land surfaces cannot be represented at the desired precision (Yılmaz and Yakar, 2007).

2. UNMANNED AERIAL VEHICLE (UAV) PHOTOGRAMMETRY

Imaging of terrestrial surfaces by cameras mounted on unmanned aerial vehicles (UAV) has presented certain advantages over geodetic measurement techniques. Very-high-resolution spatial and temporal images can be obtained by deploying unmanned aerial vehicles. Such high-resolution images can be used for various purposes (Yılmaz et al., 2013).

The use of UAVs has become a recently adopted method in acquiring needed spatial data. A UAV is a vehicle that can move, automatically or semi-automatically, within a flight plan or can be flown through remote control by a pilot on land or in another vehicle. UAV systems can be an alternative for piloted mapping systems, which pose low resolution and high cost constraints due to high-altitude flight necessities. UAV-based data gathering and mapping can provide the precision needed for works in many areas, such as agriculture, forestry, urban planning, and disaster management (Döner et al., 2014). UAV photogrammetry (Eisenbeiss, 2008c) defines a photogrammetric measurement platform that operates by remote control, semi-independently or fully independently, lacking a pilot seated in the vehicle. The platform is equipped with photogrammetric measurement systems, including a smaller mid-sized immobile video camera, thermal or infrared camera systems, and LIDAR systems. With a standard UAV, it is possible to monitor recording, location, and direction of the applied sensors in a local or general coordinate system.

Recently, several private companies have offered photogrammetric products produced by means of UAV-based imagery for certain applications; mainly these are DSMs and orthoimages. Furthermore, monitoring or change detection often plays a role—detection of new buildings and changes at forest areas, gravel pits, or waste sites have so far been identified as potential applications. Further and more specific applications can be found in the scientific literature (Eisenbeiss et al., 2005; Lambers et al., 2007; Reidelstuerz et al., 2007; Grenzdörffer et al., 2008; Eisenbeiss, 2009; Niethammer et al., 2009; Vogler et al., 2009; Sauerbier et al., 2011).

3. STUDY AREA

This application was carried out on the Alaaddin Keykubat Campus, Seljuk University. The dimensions of our application area were 20 m x 18 m x 3 m (L x W x H) (Figure 1).

Figure 1. General appearance of application area of volume calculation of the Alaaddin Keykubat Campus, Selcuk University

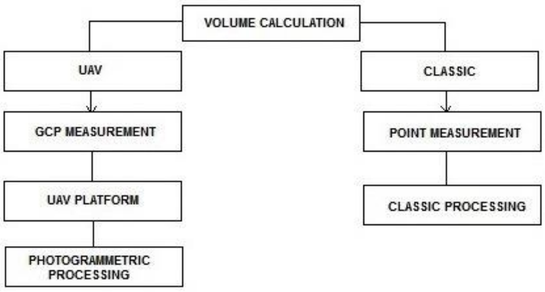


Figure 2. Flowchart of the applied methodology

The workflow of this application consists of preparation before study, field work, and office work.

3.1 Preparation before Study

The following were supplied for the study: UAV (Unmanned Air Vehicle) used in the application (Figure 2), camera (Figure 3), image transmission system (Figure 4), total station (Figure 5), and ground control markers (used in evaluating the photographs obtained from the UAV) (Figure 6).

Figure 2. Octocopter UAV

Figure 3. Canon PowerShot A810 Serisi Dijital Kamera

Figure 4. FatShark image transfer system(URL-1)

Figure 5. Topcon GPT – 3007 Reflectorless Total

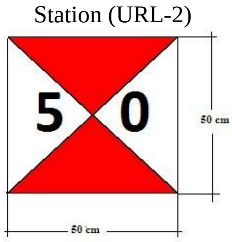


Figure 6. Close view of ground control point, used in the photographs taken from air

3.2 Field Work

First of all, our ground control points were homogeneously installed in the application area (Figure 7). For our application, eight ground control points were installed. Care was taken in installing the ground control points so that the distribution of the points was such that they completely covered the work area and that they could "see each other".

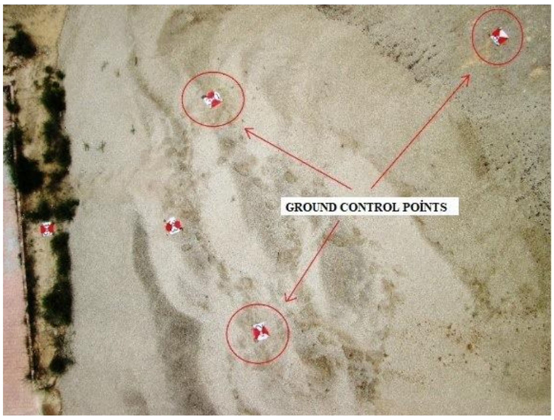


Figure 7. Ground control points used in the photographs taken from air

Coordinating the processing of ground control points was carried out by means of a Topcon GPT 8203A total station without a reflector. The coordinates of the ground control points were calculated by installing a closed polygonal route on the periphery of the application area. Besides this, 1415 detail points were measured with intervals of about 40 cm to calculate the volume via the classical method. The coordinates of ground control and detail points were evaluated in the local system.

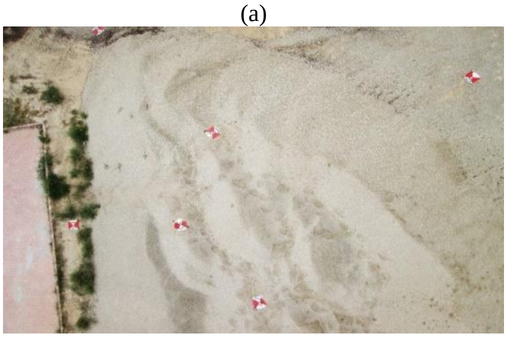
Figure 8. Coordinating and detail measurement process

After these processes, the stage of taking photos proceeded (Figure 9). The process of taking photos was integrated to the Octocopter UAV system, and the process was carried out by the Canon A810 digital camera (Figure 3). Thanks to the telemetric system that is present in the UAV, some information, such as flight altitude and horizontal and vertical velocity, were read, and, thanks to the GPS mode of the UAV, the process of taking photos was realized, on average, from 20 meters altitude.

Figure 9. Process of taking air photographs with the UAV

In the application, through the camera carried in the UAV, 85 photos were taken, and 24 of those photos were used in the process of photogrammetric assessment.

(a)



(b)

Figure 10. Two examples of photos taken by means of UAV for photogrammetric assessment

After these processes were completed by means of the data obtained, they were passed on to office work.

3.3 Office Work (Data Processing)

In this stage, the coordinates of the ground control points obtained from the field were initially displayed in the Netcad software by means of the total station device.

The coordinates of the ground control points were arranged in the format supported by Photomodeler software and recorded as ".txt".

Further, among photographs taken with the UAV, those to be used in the assessment of the photos in the "text" format were transferred to Photomodeler software, and the internal directing parameters of camera (its calibration values) were entered (Figure 11).

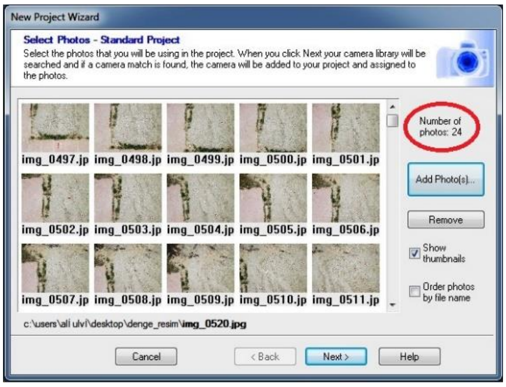


Figure 11. Transfer of photographs obtained from UAV to the Photomodeler software

After the photographs were transferred, by means of the "Smart Points Project" module in the Photomodeler software, the photographs were automatically directed and balanced to each other. As a result of that process, 24 photographs of the application area obtained from the UAV were balanced.

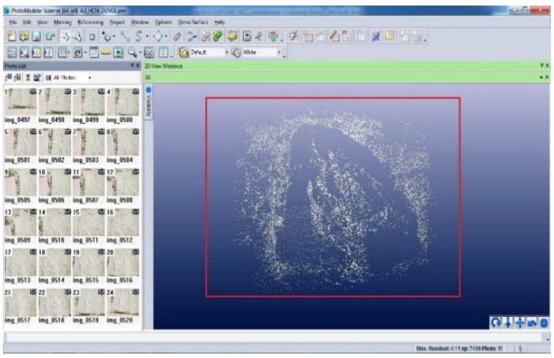


Figure 12. Automatically identified reference points on the photographs in Photomodeler software

After those processes, ground control points that were present on the different photographs in the Photomodeler software were matched by removing points (Figure 13).

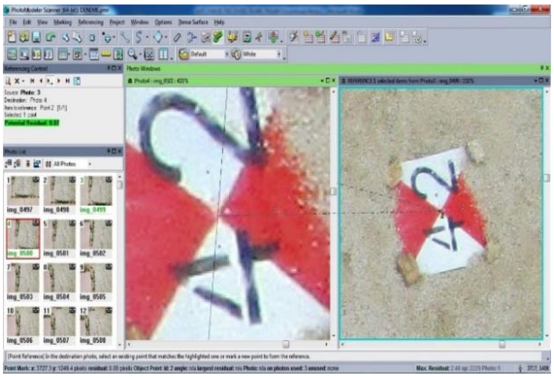


Figure 13. Matching ground control points from the different photographs in Photomodeler software

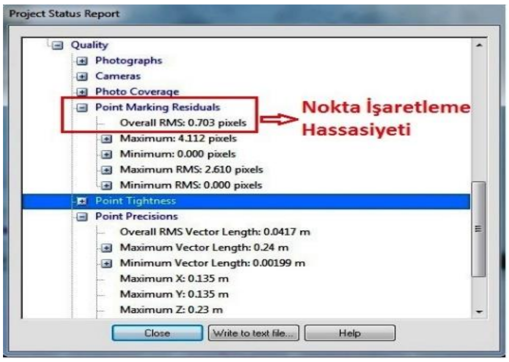


Figure 14. Balancing report in Photomodeler software

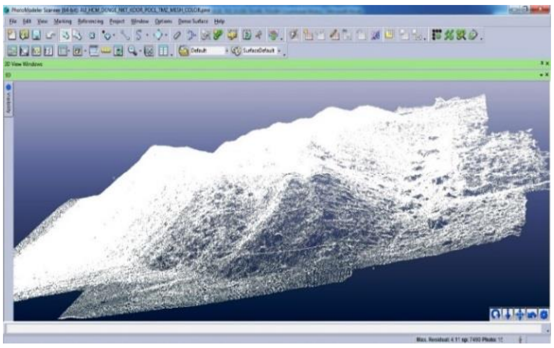


Figure 15. Point cloud of sand pile

After those processes had been completed, a triangle model was obtained from the point cloud that was present on the area and whose volume would be calculated. A solid model and a SAM were also produced from this model (Figures 17–18). Contour lines were passed through the triangle at 20-cm intervals, and a contour map was produced (Figure 19).

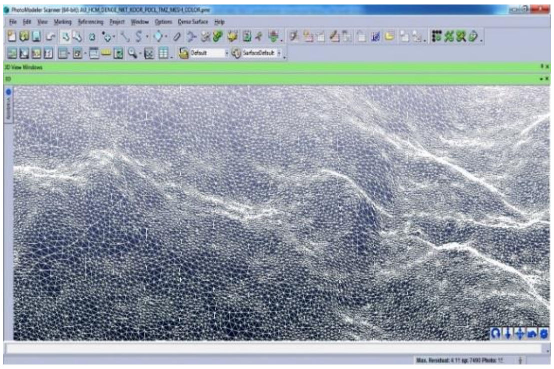


Figure 16. Triangle model formed by point cloud

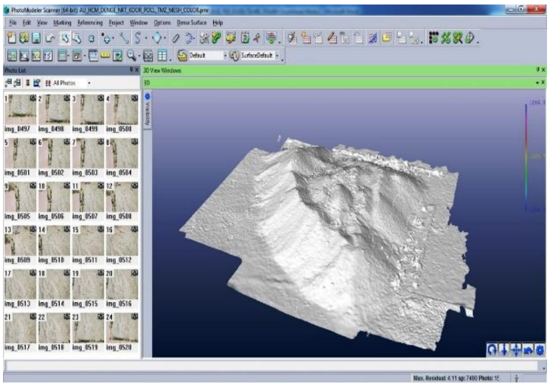


Figure 17. Solid model

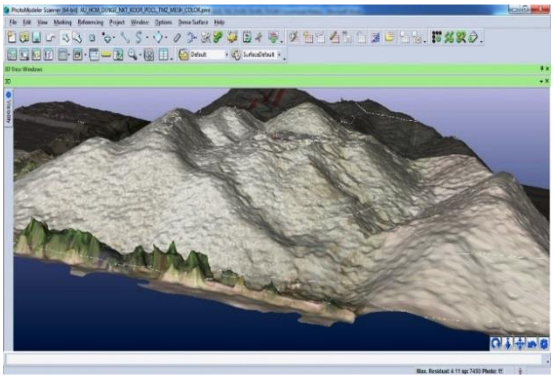


Figure 18. Texture-covered state of solid model (SAM)

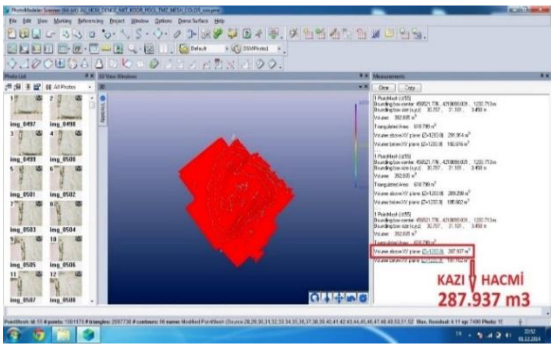


Figure 19. Result of volume calculation in Photomodeler software

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After calculation of volume made by means of the UAV by using photogrammetric techniques through Netcad software, volume was calculated by the classical method. For that calculation, 1415 detail points, measured in the field, were used, and base code was calculated as 1213 m (Figures 21–22).

To enable a more valid comparison, control points used in the volume calculation made by means of the UAV and photogrammetric techniques were used in the calculation of volume by the classical method.

Because of that, the differences that may have been formed between the border whose volume would be calculated by the classical method and the border whose volume would be calculated by photogrammetric techniques were impeded.

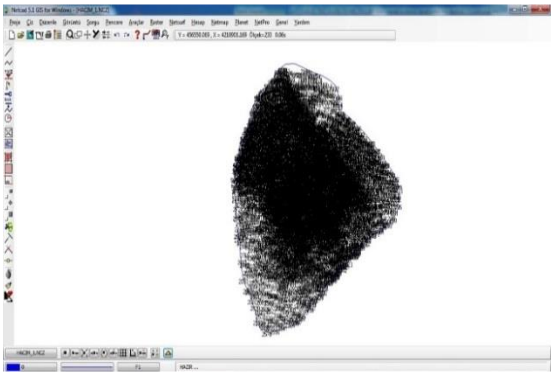

Figure 22. Displaying the detail points in Netcad software

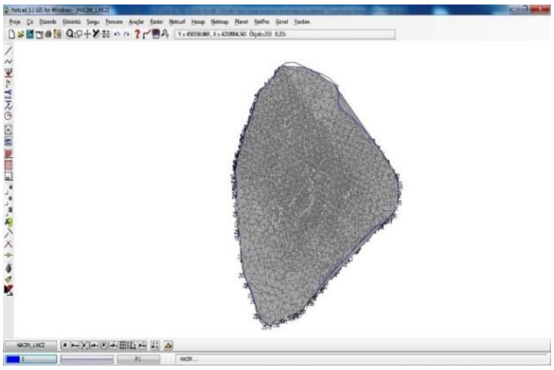

Figure 21. Triangle model formed in Netcad software

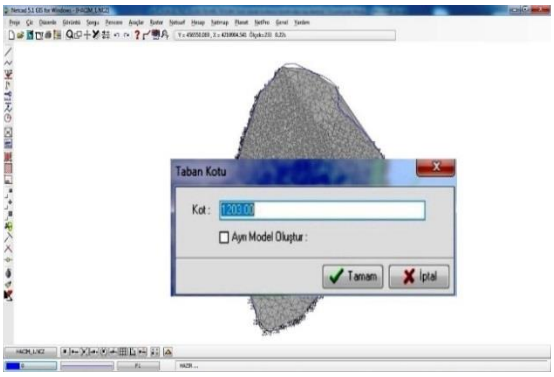

Figure 22. Identification of base code in Netcad software

After those processes,, a volume calculation was made by passing a common line through the triangle mode formed in the Netcad software for one time in each 25 cm (Figure 23).

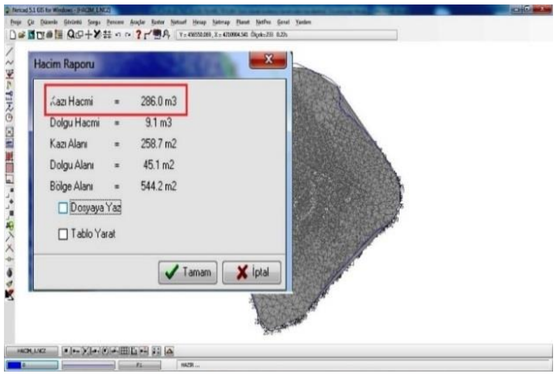

Figure 23. Result of unit calculations in Netcad software

4. RESULTS

Two different methods, photogrammetric and classic calculation, have been compared in the volume calculation. The comparison considered both duration and precision. The duration of total work of photogrammetric volume calculation was 60 minutes on a 360-m^2 area, while it was 220 minutes for the classical volume calculation (Table 1).

Table 1. Comparison of photogrammetric and classic volume calculation techniques

		TIME (Minutes)	
UAV STUDY	CLASSIC STUDY	UAV	CLASSIC
GCP Measurement	Point Measurement	10	180
Take photo with UAV	-	10	-
Photogrammetric Processing	Classic Processing	35	35
Volume Calculation	Volume Calculation	5	5
	TOTAL	60	220

Volume calculation by UAV was completed in one fourth the time required for the classical calculation, enabling time savings and thus financial savings. The values of volume calculation produced by using photogrammetric techniques were compared with the classical method and UAV (Table 2).

In comparing these values, the volume calculation determined by the classical method was accepted as the exact value.

Table 2. Results of accuracy research of the volume calculation, made by means of UAV by using photogrammetric techniques

VALUES				
PARAMETERS	CLASSIC (m^3)	UAV PHOTOGRAMMETRY (m^3)	DIFFERENCES (m^3)	ACCURACY RATE %
SOLID VOLUME (m^3)	286	287.94	-1.94	99.33
REFERENCE Code (m)	1203	1203	0	-------

In the light of these data, the volume calculation made by means of the UAV, using photogrammetric techniques, compared to the volume calculation made by the classical methods, were calculated with a difference of 1.94 m3 (table 1).Accuracy analysis shows that the volume calculation made by means of the UAV using photogrammetric techniques were in 99.33% agreement with the volume calculation made by means of the classical method, and it was seen that sufficient accuracy was provided. Also, when the advantages it provided in terms of the concepts of cost and time are considered, it is a clear reality that volume calculation by the classical method will be replaced by UAV and photogrammetric techniques. Besides those results, it should not be ignored that SAM was obtained in addition to volume calculation. Because of that, data can be used more realistically and accurately. SAM, produced in Photomodeler software, can be printed in various formats from the software.

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