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Investigation of accuracy of detailed verified by unmanned aerial vehicles with RTK system; The example of Ortakent-Bodrum Area

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Abstract

There has always been a sense of adoption of human beings and the knowledge to define their types, boundaries and areas, especially in terms of the immovables they own. It is known from past to present those measurements are difficult and require effort and time. However, with the developing technology, measuring systems have been renewed and new methods have emerged. With the new systems, project time and cost savings were achieved. Although the production of orthometric maps has accelerated thanks to the advances in remote sensing and photogrammetry, their accuracy compared to terrestrial measurements is questioned. In this study, it is aimed to investigate whether there are differences between the location information of the orthometric map produced by Unmanned Aerial Vehicles (UAV) and the location information of the data produced by Global Navigation Satellite Systems (GNSS), and to investigate the reasons for these differences, if any. The study area covers in Ortakent, Bodrum-Muğla. One of the most important features of the UAV used in the project is that it has a Real Time Kinematic GNSS system (RTK-GNSS). After measuring with UAV, the Digital Surface Model and orthophoto was produced. After the measurements made with the GNSS, triangulation was made and the undulations were subtracted and orthometric heights were obtained. Thus, the differences between the obtained values were determined by measuring with both the UAV and the GNSS system. These differences are very small like cm. It has been seen that the photogrammetric values created with Ground Control Points are more accurate than the photogrammetric values created without Ground Control Points.

1. Introduction

Photogrammetry is a science where spatial measurements and geometrically reliable products can be obtained through photographs. Through to the developing technology, the science of photogrammetry has been divided into different fields and started to be used in many fields [1].

The most important reason for the development of photogrammetry over time is that it accepts the principles of accuracy, flexibility and practicality, which are accepted as basic by the positive sciences [2-3].

Photogrammetry is a suitable tool for equipping information about human-made and natural objects such as terrain, vegetation, and urban features [4]. Photogrammetry and digital image-based processing techniques have an important role in making visualization technology practical and providing a low-cost workflow compared to traditional and geodetic surveys [5].

Unmanned Aerial Vehicles (UAV) technology emerges as a platform that provides innovations and develops in Photogrammetric map production [6]. Aerial image acquisition is carried out automatically or semi-automatically with remote control. Besides, UAVs provide great advantages in terms of low cost, speed, repeated measurements, convenience and accuracy [7]. UAVs include equipment such as camera, (multispectral infrared etc.), video, GNSS/INS (Inertial Navigation System).

High resolution Digital Surface Model and orthometric images created with UAVs are used to serve many areas [8]. UAVs can make high-resolution and 3D terrain measurements in areas that are life-threatening, sloping, and where people cannot normally access. UAVs with integrated systems such as the RTK system provide data with higher spatial accuracy.

Today, UAVs are used not only for map production, but also in applications such as agriculture, mining, determination of archaeological sites [9-10] and disaster management [11]. Especially in recent years, it has become one of the most preferred measurement methods in the field of engineering, because it provides practicality, speed, repeated measurement and high accuracy. UAV photogrammetry is a platform that has different sensors on it, can continuously provide the 3D coordinates of the platform, can also collect spatial data and optionally supports ground-controlled GNSS data. [12].

The aim of this study is to test the accuracy of the RTK integrated UAV according to the measurement data obtained from the ground control point measurement values and the measurement value differences without ground control point, and the measurement data obtained from the GNSS measurement, and to compare GNSS measurements and the final products produced from UAVs. In addition, it is aimed to present the advantages and disadvantages of UAVs in terms of cost, time and accuracy compared to conventional (classic) measurements.

2. Method

High resolution Digital Surface Model and orthometric images can be obtained with UAVs. Images obtained from UAVs can be easily processed by computers and software, and the final product can be reached in a short time [13].

Evaluation of high-resolution images obtained by UAV is a very difficult and time-consuming task by perform using classical photogrammetric approach software. For this purpose, computer vision techniques for processing datasets have been widely used in the evaluation of UAV images [14]. In addition to the high speed and accuracy provided by computer vision technologies, the minimal operator contribution they bring, the manual processes based on the visual activities of the operator, required for determining the common areas, which are the main and difficult stages, and creating the stereo model, are semi-automatic or automated [15].

Today, commercial software developed has its own algorithms for performing the internal routing and external routing stages. Thus, UAV images are directed geometrically with great success [16].

A small area was determined in Bodrum for the measurements to be made with UAV and GNSS, and assessments have been performed in this area.

2.1. Study Area

This study was carried out on an area of approximately 68000 m^2 in Muğla Province, Bodrum District, Ortakent Neighborhood. (Figure 1). A sloping area was preferred for the study area.

(a)

(b)

Figure 1a. Google Earth Satellite Image of Study Area, **Figure 1b.** Orthophoto Image

2.2. Application

First, leveling was done to reach the orthometric heights in the study area and the orthometric heights of the points were obtained.

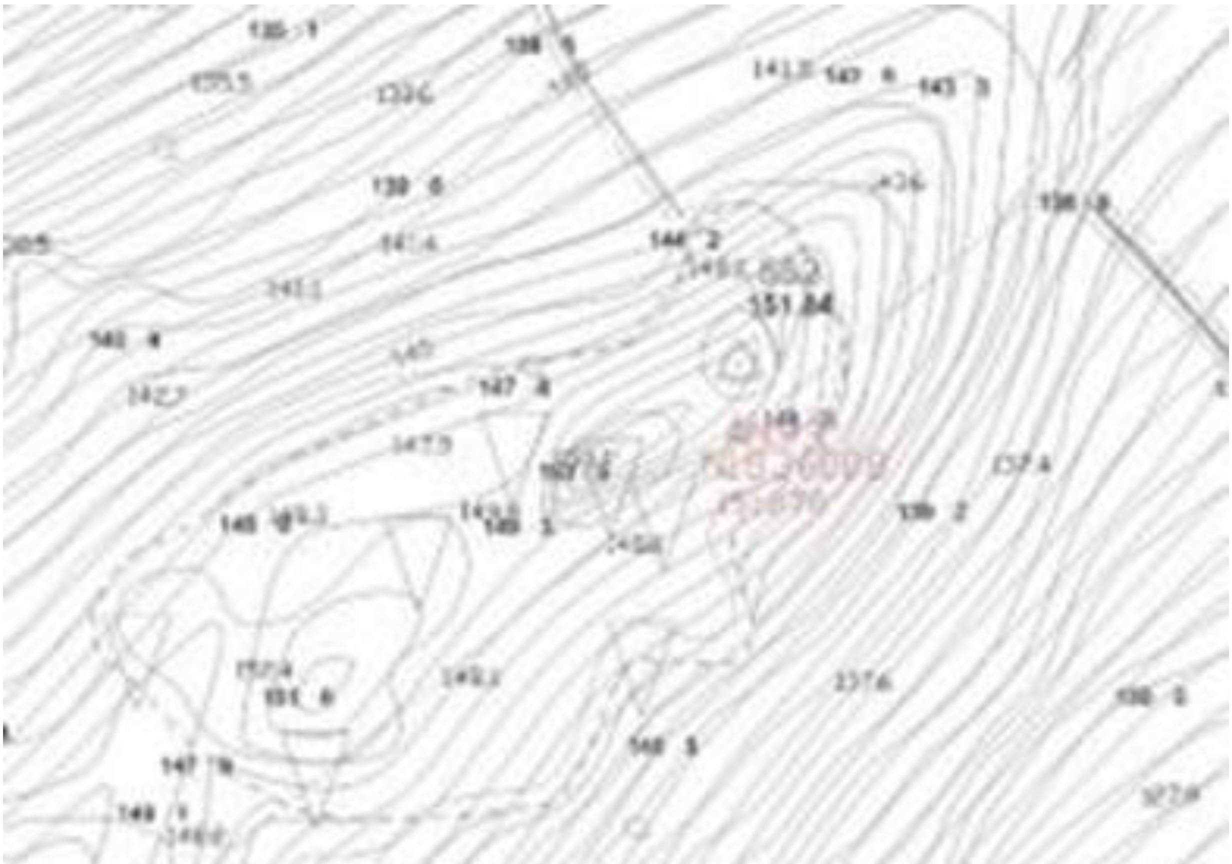

Figure 2. Triangulation on a base map

Then, plankote of the study area was made with CORS_RTK. Bodrum CORS Network was used for measurements made with GNSS. SOUTH NRS technology was used with 5 reference stations in Ortakent, Turgutreis, Göl-Türkbükü, Mumcular and Yaliciftlik Districts. Through by South NRS, VRS correction and physical correction are made and sensitive data is obtained with measurements. In the plankote process, all the details were taken in the land measurement. Triangulation was made in Netcad program and contour lines were created.

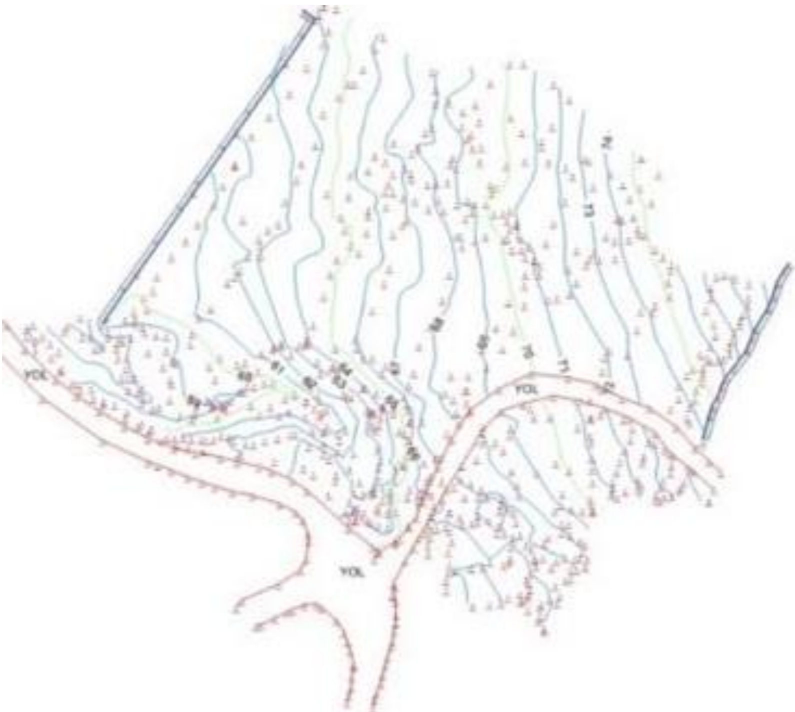

Figure 3. Plankote of the application area

Figure 4. Bodrum CORS Network [17]

After these processes, 4 Ground Control Points were established in the area where the flight will be made. Ground Control Points are of great importance in terms of providing a more accurate and sensitive balancing of routing parameters with the GNSS/IMU receiver, which is the integrated system of the UAV. Ground Control Points are homogeneously distributed and painted with red to be visible. It is also established in places that can be distinguished according to the terrain conditions.

Figure 5. Presentation of ground control points in the working area through the software program

South Galaxy G1 Plus (IMU) GNSS set was used for the measurement of Ground Control Points in the study (Figure 3). GNSS has IMU technology that does not require calibration and is not affected by magnetic field. Its positioning in the Real-Time Kinematic Network has an accuracy of ±8 mm+0.5 ppm horizontally and ±15 mm+0.5 ppm vertically. There is SurvX program as software. For the measurement of 4 Ground Control Points, six one-minute epoch measurements were made at each point with GNSS. And these measurements were averaged. These measurements were obtained from Bodrum CORS Network.

Figure 6. DJI South Galaxy G1 Plus (IMU)

After measuring the Ground Control Points, a flight plan was made for the flight area. For orthophoto production, flights were carried out with DJI Phantom 4 RTK, which has both automatic and semi-automatic features (Figure 8).

Figure 7. Flight Area

Figure 8. DJI Phantom 4 RTK

DJI Phantom 4 RTK consists of integrated camera system with 1/20'' sensor, 5472×3648 maximum image size, ISO 100-6400 (manual), 24mm equivalent focal length, aerial optimized f/2.8 wide-angle lens.

DJI Phantom 4 RTK weighs approximately 1.4 kg and has a maximum flight time of 30 minutes. In addition, Positioning Accuracy in Multi-Frequency Multi-System High Precision RTK GNSS is: Vertical 1.5 cm +1 ppm, (RMS); Horizontal is 1 cm + 1 ppm (RMS).

The fact that the DJI Phantom 4 RTK has the RTK feature is important for position correction. It provides position correction by receiving data from satellites and fixed base station.

The flight with the UAV was carried out in Ortakent-Bodrum in July, when the temperature was 32 °C. Flight planning was carried out with 70% horizontal overlap and 80% vertical overlap. It was flied from a height of 80 meters and 242 photographs were taken.

The formation flow of images created by using computer and software programs is shown in Figure 9.

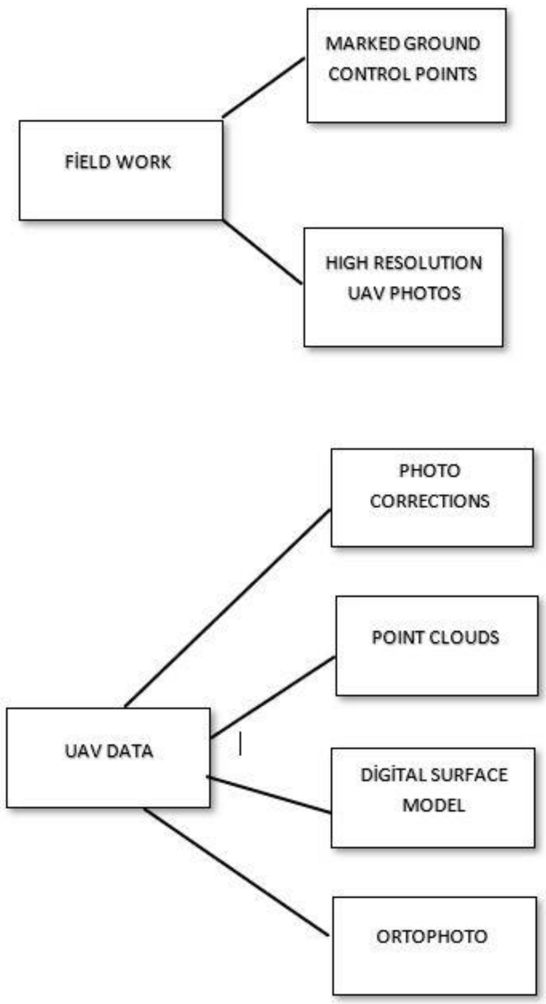

Figure 9. Study Workflow Display

The images obtained from the UAV were evaluated with Pix4D software. From these images, first point cloud, condensed point cloud, then Digital Surface Model and Orthophoto were created. The Digital Surface Model is a mathematical surface on which the position and height information of the surface are created by including the objects on the surface (building, tree, power line, etc.).

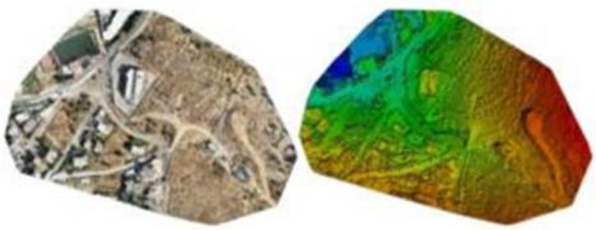

Figure 10. Orthophoto and digital surface model of the study area

Ground control points are marked by entering coordinates in Pix4D program. The matching process has started on the marked photos. With Automatic Aerial Triangulation and Bundle Block Adjustment (block balancing with images), the Pix4D program automatically optimizes and calibrates the camera, also corrects atmospheric and systematic errors. In the program, the Structure from Motion (SFM) method is used when creating a 3D model from photographs.

SfM method is used to create 3D models with photogrammetric method. SfM has been translated into Turkish as Motion Based Structural Detection. SfM photogrammetry technique has emerged as a cost-effective and practical modeling tool that has become increasingly popular in recent years in parallel with the development of computer hardware and software capabilities. (Westoby vd., 2012). SFM photogrammetry is a revolutionary, low-cost and user-advantaged photogrammetric technique that has been used in recent years, enabling wide-scale work on high-resolution datasets. The SfM technique, in biological image perception, corresponds to the perception of humans (and other living things) of the 3-dimensional environment around them from two-dimensional moving images formed in the retina layer in the eye. Based on photogrammetric measurement processes, SfM provides three-dimensional modeling of objects based on matching objects in a series of photographs taken at different locations with a certain overlap ratio [18-20].

3. Results

GCP coordinates obtained from classical CORS measurements, point coordinates formed by including GCP points in the Pix4D program after UAV measurement and coordinates formed as a result of UAV measurement without GCP are shown in Table 1.

Table 1. GCP coordinates obtained from CORS, photogrammetric valuation with GCP and without GCP

	CORS			Photogrammetric Valuation			Photogrammetric Valuation withot GCP		
P.N	X(m)	Y(m)	H(m)	X(m)	Y(m)	H(m)	X(m)	Y(m)	H(m)
GCP_1	4102350.380	531705.810	59.098	4102350.383	531705.814	59.128	4102350.376	531705.816	59.218
GCP_2	4102373.940	531717.616	63.280	4102373.928	531717.618	63.321	4102373.910	531717.618	63.380
GCP_3	4102370.771	531761.753	70.774	4102370.783	531761.743	70.807	4102370.756	531761.742	71.574
GCP_4	4102317.212	531739.518	65.495	4102317.216	531739.497	65.529	4102317.216	531739.492	66.425

The values obtained by using the GCP in the UAV measurement with the RTK integrated system and the values obtained without the GCP in the UAV measurement, the root mean square errors and position errors calculated from these values are shown in Table 2.

Table 2. Error Values Obtained with GCP and without GCP

Error amounts of coordinates with GCP			Error amounts of coordinates without GCP			
di Differences (cm)						
dx	dy	dh	dx	dy	dh	dx
0.3	0.4	3.0	-0.4	0.6	12.0	-0.4
-1.2	0.2	4.1	-3	0.2	10.0	-3
1.2	-1.0	3.3	-1.5	-1.1	8.0	-1.5
0.4	2.1	3.4	0.4	-2.6	9.3	0.4

Table 3. Root Mean Square and Position Errors as a Result of Photogrammetric Valuation (cm)

With GCP				Without GCP			
RMSEx	RMSEY	RMSEH	Mxy	RMSEx	RMSEY	RMSEH	Mxy
1.02	1.37	4.01	1.71	1.96	1.67	11.47	2.57

The coordinates of the SGK wall measured from the CORS Network in Plankote, the coordinates reached by the UAV measurement with the GCP, the coordinates obtained by the UAV measurement without the GCP, and the calculation of these values and the square mean and position errors are shown in Table 3.

Table 4. Coordinates of SGK Wall Measurement

	CORS			With GCP			Without GCP		
P.N	X (m)	Y (m)	H (m)	X (m)	Y (m)	H (m)	X (m)	Y (m)	H (m)
1	4102362.496	531691.116	58.502	4102362.515	531691.049	58.520	4102362.536	531691.033	58.602
2	4102363.870	531691.869	60.124	4102363.868	531691.872	60.168	4102363.875	531691.865	60.199
3	4102370.846	531696.789	60.239	4102370.849	531696.783	60.298	4102370.851	531696.781	60.304
4	4102384.430	531706.266	60.395	4102384.428	531706.268	60.450	4102384.433	531706.273	60.525
5	4102394.459	531713.365	62.019	4102394.465	531713.355	62.038	4102394.469	531713.351	62.109
6	4102406.182	531721.709	63.419	4102406.194	531721.672	63.809	4102406.212	531721.644	63.539
7	4102413.354	531726.542	63.638	4102413.347	531726.537	63.680	4102413.345	531726.529	63.718

Table 5. Root Mean Square and Position Errors as a Result of Photogrammetric Valuation (cm)

With GCP				Without GCP			
RMSEx	RMSEY	RMSEH	Mxy	RMSEx	RMSEY	RMSEH	Mxy
1.01	2.47	4.55	2.67	2.14	4.40	10.47	4.89

Figure 11. SGK Building and Wall Measurement

The wall length of the SGK Building was obtained from Cors Network, UAV measurement with GCP and UAV measurement without GCP. The results are shown in Table 6.

Table 6. The Wall Length of the SGK Building

Method of Measurement	Lenght (m)
Coordinates Obtained From CORS	62.00
Coordinates Obtained as a Result of Photogrammetric Valuation	61.98
Coordinates Obtained as a Result of Photogrammetric Valuation Without GCP	61.97

4. Discussion

This study reveals that UAV photogrammetry is an ideal system for orthophoto. Photogrammetric method is getting fast results and more office work in comparison with classical surveying methods. In the study, it was determined that GCP markings should be shown more clearly. If GCPs increase and distribute more homogeneously, the accuracy will be higher.

UAV flights were carried out in Bodrum's summer heat, at noon During flights at high temperatures, the engine is overworked so that the drone can hover. As the battery life decreases, the flight time decreases and the efficiency of the UAV decreases.

The data obtained from the study, which was carried out by selecting a small area, shows us that UAV photogrammetry will improve with even more widespread use.

5. Conclusion

In this study, the accuracy of photogrammetric measurement with UAV was investigated. Orthophoto data and CORS measurements were compared. In the study, it was observed that the error values were a few cm. When the result values in the tables are examined, it is seen that the x, y and H error values obtained as a result of the measurements made with GCP points are less than the measurements made without GCP. When the result values are examined, photogrammetric measurements made with GCP contain less errors than photogrammetric measurements without GCP. Position errors (Mxy) are below 5 cm even in measurements without GCP, which is an indication of the advantage of UAVs with RTK systems. In all measurements, the error values of the orthometric height component were higher. However, it is seen that the orthometric height component gives much more accurate results in the measurements made with GCP. In addition, as a result of the wall measurement of the SGK Building, it was seen that there was a difference of 2 cm in the measurement made with GCP and 3 cm in the measurement made without GCP with the length of the wall. In this study, the measurements made with the UAV with the RTK integrated system require less effort, time and cost, and the measurements must be made of control points, etc. and should be supported by ground surveying method. Thus, it is seen that more accurate results are obtained. Although the study was carried out by selecting a small area, it can be thought that UAV systems will develop and become more widespread in the future with errors in the cm unit and the desired accuracy can be achieved without the need for GCP.

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Author contributions

Hazal Altuntabak: Conceptualization, Methodology, Software, Writing-Original draft preparation, **Ercenk Ata:** Data curation, Validation. Visualization, Investigation, Writing-Reviewing and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

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