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The effect of the number and distribution of ground control points (GCP) on map production

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Orthophoto
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Abstract

Thanks to recent advances in data collection technologies from Unmanned Aerial Vehicles (UAVs), very large data sets covering important surfaces with centimeter-scale resolution can be rapidly collected, resulting in the opportunity to analyze areas digitally. With the presence of a regular monitoring program carried out over a wide area, UAVs provide significant advantages in the cost of data collection. Many studies in the literature have focused on finding an effective and sustainable research strategy to limit costs and study times. Unmanned aerial vehicle (UAV) photogrammetry has recently emerged as a popular solution to obtain certain products required in linear projects such as orthoimages or digital surface models. The main reason for this is the ability to provide these topographic products quickly and economically. It is important to know how many ground control points (GCPs) are required to guarantee a certain degree of accuracy and how to distribute them across the work area. The purpose of this study is to determine the number of GCPs for a work area and how to distribute them to provide higher accuracy.

1. Introduction

Unmanned Aerial Vehicle (UAV)-based photogrammetry is becoming a valuable data source for topographic mapping, volume calculations, terrain mapping and creating 3D models. However, using UAVs for any purpose requires basic knowledge of various flight settings. The number and distribution of Ground Control Points (GCPs) are the most important, so the number of GCPs should be used economically. Ground control points (GCPs) are often used to georeference the 3D point cloud created in the photogrammetric process. These control points may be permanent ground features or reference targets scattered on the ground before flight; these need to be examined to obtain their precise coordinates and ensure they can be clearly identified in the raw images. Although it is strongly recommended to increase the number of GCPs to increase the accuracy of photogrammetric products, at least three GCPs are required to perform the georeferencing process (Villi and Yakar, 2022; Kaya et al. 2023). The effect of the GCP number on DSM and the orthoimage accuracies obtained by UAV photogrammetry were examined. Photogrammetric products such as orthoimages and DSM can be obtained from a georeferenced dense point cloud. There are several factors that affect the accuracy of these UAV photogrammetry products, such as the number and distribution of GCPs, flight altitude, examined surface morphology, camera calibration methodology, image overlap, and inclusion of oblique images (Kaya et al. 2021; Şasi and Yakar, 2018).

Considering that the use of GCP directly affects the accuracy of photogrammetric products, many researchers have conducted various studies over the years to evaluate the accuracy of the products obtained from UAV images by changing the number of GCPs. Agüera-Vega, Carvajal-Ramírez and Martínez-Carricondo (Agüera-Vega,2016) investigated the effect of flight altitude, terrain morphology and GCP number on digital surface model (DSM) and orthophoto accuracy. Ruzgiene et al. (Ruzgine et al., 2015) determined the quality of DSMs created using UAV photogrammetry techniques and the impact of GCP number on accuracy. Sanz-Sanz-Ablanedo et al. (Ablanedo et al.,2018) conducted a study on the frequency and accuracy of GCPs in an area of 1200 hectares. Rangel, Gonçalves and Pérez tested the accuracy of DSM and orthophoto maps in their study (Rangel et al., 2018; Yılmaz et al. 2000; Yakar et al. 2015).

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2. Study Area

Mersin University Çiftlükköy campus area was determined as the study area. This area is approximately 700 ha.

Figure 1. General view of the work area

3. Material and Method

Matrice 300 RTK device was used in the study. The general view of this device and the technical specifications of its camera are given in Figure 2 and Table 1.

Figure 2. Matrice 300 RTK rotary wing UAV (URL-1)

Table 1. Zenmuse P1 camera technic specifications

Product Name	ZENMUSE P1
Dimensions	198×166×129 mm
Absolute Accuracy	Horizontal: 3 cm, Vertical: 5 cm *
Sensor size	35.9×24 mm (Full frame)
Effective Pixels	45MP
Pixel size	4.4 µm
Aperture Range	f/2.8-f/16

* Using Mapping Mission at a GSD of 3 cm and flight speed of 15 m/s, with an 75% front overlap rate and a 55% side overlap rate.

The study was carried out in two stages: field work and office work. Field work; Following the establishment and coordination of Ground Control Points (GCP) and Control Points (CHP), the flights were completed with the UAV, and the office work was completed by evaluating the raw data obtained from the field in photogrammetric software and creating an orthophoto map of the area. GCPs were measured in real-time kinematic (RTK) mode before the flight, using virtual reference stations from the permanent global navigation satellite system (GNSS) (Figure 3).

20 GCPs and 30 control points (CP) were used in the study (Figure 4). Photogrammetric evaluation of the images was done in Agisoft Metashape software.

In the study, UAV images were obtained from an altitude of 428 m. A total of 878 pictures were taken.

Camera locations in the working area are shown in Figure 5.

Figure 3. Topcon hiper SR GNSS alıcısı

Figure 4. General view of GCP

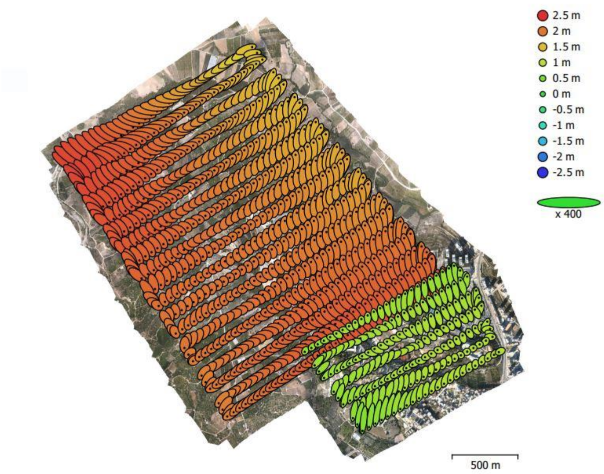

Figure 5. Camera locations and error estimates

The resulting digital elevation model can be seen in Figure 6.

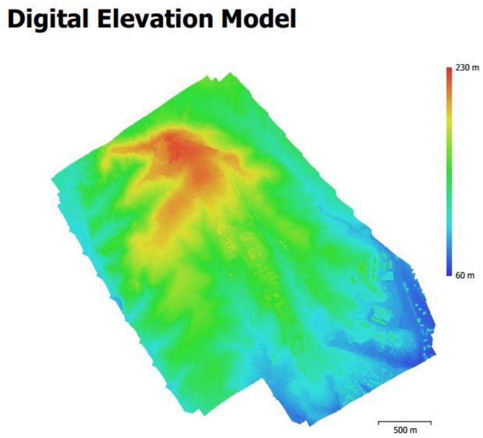

Figure 6. Reconstructed digital elevation model

As a result of the study, the orthophoto map seen in Figure 7 was obtained.

Figure 7. Orthophoto map for study area

4. Results

As a result of the analysis, the locations of GCPs are very important in order to maximize the accuracy obtained in photogrammetric projects. It was envisaged that GCPs should be placed at the edge of the work area to achieve optimum planimetric accuracy. However, this configuration does not mean that it will optimize the results in altimetry. This means that GCPs should be placed in a layered distribution within the study area. This means that as the density of GCPs increases, accuracy will increase until the results are improved. When the GCP reaches a certain number, both planimetric and altimetric accuracy will become stable.

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