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# Production of digital maps by uncrewed aerial vehicle (UAV)

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**Abstract**

Unmanned aerial vehicles (UAVs) have recently been used to generate digital maps. UAVs are utilized in a variety of applications today and are among the most modern measurement systems. There is a direct correlation between the calculation of the geometric components of the horizontal and vertical lines of digital maps and their accuracy and precision. Consequently, the horizontal and vertical errors of the generated digital maps are a significant factor. This study used the data collected by the unmanned aerial vehicle to investigate the creation of digital maps. Due to the photogrammetric analysis of these images, a Digital Elevation Model and orthophoto of the study area were produced. In addition to the GCP used as a reference, the location accuracy of the orthophoto map created by determining the coordinates of the detail points in the field with the RTK GPS technique was measured, and an approximation cost comparison between the two techniques was conducted.

## 1. Introduction

Many mapping organizations worldwide use large-format aerial cameras to acquire large-format aerial photographs for topographic map production (Ulvi et al., 2019). However, some mapping organizations have begun using various brands' digital mapping cameras (Remondino et al., 2011). However, due to the high price of the digital mapping camera alone, few mapping organizations can afford to use it, despite its accurate and swift photogrammetric output. Producing a topographic map using conventional aerial photogrammetry is typically a time-consuming and expensive process, as it involves numerous steps, such as producing a flight map, acquiring an aerial photograph, establishing a ground control point, and a lengthy image processing procedure (Colomina et a., 2008). Additionally, this method is only appropriate for mapping vast areas. However, there are times when a small-area aerial photograph is required for mapping purposes. Large-format aerial cameras are not cost-effective for imaging small areas (Yılmaz & Yakar, 2006a; Polat et al., 2020). Photogrammetrists have begun acquiring aerial photographs with small-format cameras to circumvent this issue. Small-format cameras for cartography have been the subject of research with optimistic outcomes. With a compact format camera, photogrammetric outputs such as a digital map and orthophoto can be obtained successfully. More research has been conducted on using light platforms to acquire aerial photographs for cartography and other purposes (Siebert & Teizer, 2014). Small format cameras such as high-resolution digital cameras, video cameras, and other sensors combined with light platforms such as helicopters, gliders, balloons, etc., are commonly used by people worldwide to acquire digital aerial images/photographs. It is possible to remotely control the light platform manually or operate it autonomously (i.e., automatically) based on pre-programmed flight plans or more complex dynamic automation systems. Unmanned aerial vehicle (UAV) refers to the sensor, light platform, and procedure for piloting the system without a pilot. Using UAVs for surveying and other purposes in Malaysia is still relatively novel. UAVs have been effectively utilized for large-scale mapping to produce photogrammetric outputs such as digital maps, digital orthophotos, digital elevation models (DEM), and contour lines (Yakar & doğan, 2018; Alptekin and Yakar, 2021).

The Unmanned Aerial Vehicle (UAV) system is a flexible, low-cost photogrammetry and remote sensing system. Consequently, this system represents a new revolution in photogrammetry and an appropriate alternative to other mobile mapping systems (Alptekin & Yakar, 2020). UAVs are primarily employed for military purposes before being utilized for civilian applications. The military uses UAVs for reconnaissance missions,

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unmanned weapons, and other activities (Karataş et al., 2022). UAVs are more applicable to agricultural activities, such as paddy monitoring and sprinkling, for civil applications (Kuşak et al., 2021; Ünel et al., 2020). The fundamental principle of UAVs is photogrammetry at low altitudes. Like photogrammetry, the UAV camera is utilized for flight planning, mapping, and analysis.

## 2. Method

UAV is a small aircraft that flies autonomously guided by an on-board Global Positioning System (GPS), stabilized by an on-board 3-axis gyro sensor and magnetometer in the autopilot microprocessor, and whose telemetry is monitored at a Ground Control Station (GSC). The aircraft is radio-controlled from the Ground Control Station (GSC) and becomes autonomous at a fixed altitude (Yılmaz & Yakar, 2006). The antenna in the GSC will transmit a communication link to the UAV, and the UAV will transmit its location, altitude, and speed back to the GSC (Karataş et a., 2022a; b; c).

UAVs fly between 100 and 300 meters above the earth and below the clouds (Colomina et al., 2008); Flying at the optimal altitude based on the earth's terrain is essential to avoid image distortion. Before flying, it is necessary to calculate the correct altitude.

The flight duration is dependent on the energy source used. Generally, oil has a much longer flight duration than batteries, though this depends on the aircraft's payload capacity (Yılmaz & Yakar, 2006). Hand-launched lightweight or micro UAVs typically have maximal payloads between 1 and 2 kilograms. A flight's duration and coverage area will vary based on the power source. The aircraft make two or three flights to conserve battery power to cover a large area (Yılmaz & Yakar, 2006b; Kanun et al., 2021a).

Geomatic applications like unmanned photogrammetry measure and map the earth's surface. The UAV (Unmanned Aerial Vehicle) has recently been adopted as a weapon by the military. The armed forces use the idea of photogrammetry to pinpoint the exact location of the adversary (Kanun et al., 2021b). UAVs have undergone a revolution in the hands of civilians for usage in fields including agriculture, surveillance, and more. Combining close-range photogrammetry, mosaicking aerial pictures, and terrestrial photogrammetry, UAV photogrammetry is the latest measuring method in photogrammetric applications (Karataş et al., 2022).

This is novel terminology for photogrammetry (Ulvi et al., 2019). Photogrammetry image processing techniques used in UAV photogrammetry include rectification, orthorectification, aerial triangulation, etc. UAV photogrammetry also details the various types of UAV platforms that can capture aerial imagery, including micro UAVs, standard UAVs, low-altitude UAVs, high-altitude UAVs, and so on (Yakar et al., 2015).

Global Positioning (GPS) technology achieves a more exact flight stabilization and navigation result. It is the same method used in photogrammetry. Camera calibration is a part of the package. However, most UAVs only employ small cameras. Lens distortion and focal length parameters may be corrected using the camera's settings. UAV pictures may be mosaicked and orthorectified using the same principle as aerial triangulation. However, many ground control points (GCPs) are required for this.

**Table 1.** The UAVs' classification depends on their size, endurance, range, and flying altitude

| Category name | lass [kg] | Range [km] | Flight Altitude [m] | Endurance e [hours] |
|---|---|---|---|---|
| Micro | < 5 | < 10 | 250 | 1 |
| Mini | <25/30/150 | < 10 | 150/250/300 | < 2 |
| Close Range | 25–150 | 10 — 30 | 3000 | 2 — 4 |
| Medium Range | 50–250 | 30 — 70 | 3000 | 3 — 6 |
| High Alt. Long Endurance | >250 | >70 | >3000 | >6 |

The UAV is capable of autonomous flight and operates in a wide range of missions and emergencies that can be controlled from a ground base station or by remote control. The UAV comprises the airframe, flight computer, payload, mission/load controller, base station, and communication infrastructure. UAVs with less than 5 kg mass are known as micro UAVs. Figure 1 shows an example of a micro fixed-wing UAV and a rotary UAV system used in the study.

**Figure 1.** UAV used in the study (Anafi Parrot)

## 3. Results

After capturing UAV images, a consistent and easy-to-follow methodology in Agisoft Metashape Pro was used to modify the data. An orthorectified picture mosaic was made after creating a point cloud from the photographs using Agisoft's structure-from-motion (SfM) computation technique. Compared to the photogrammetric approach, SfM can determine camera locations and orientation parameters with or without ground control points [30]. For each picture, the scale-invariant feature transform (SIFT) technique is first used by the SfM algorithm to gather and identify local features. A comprehensive evaluation of the SfM approach is unnecessary for this investigation; for a more in-depth discussion, the interested reader is referred to the works mentioned above [15], [40], [38], [23]. More information on the functionality of these Agisoft stages may be found in [25,27]. There are three primary phases to the processing: (1) picture alignment, (2) point cloud and mesh creation, and (3) DSM and orthophoto generation. In this research, two different types of wholly automated software were employed. Adding photos, marking features, and defining input parameters such as project datum and projection, GCPs and CheckPs, and final resolutions are all required of the user. After the cameras are correctly aligned, point clouds, DEMs, and orthomosaics may be generated.

UAV photos were processed in Agisoft Metashape Pro using a standardized, user-friendly workflow. You may learn more about the features of these Agisoft stages. The model was georeferenced using the coordinates of nine differential GPS control points installed at the site. The accumulation of smaller, more precise models in important areas allows Agisoft to estimate a horizontal spatial error of 8.23 cm for the overall model, which is within an acceptable range. The processed and georeferenced model yielded a high-resolution (2.5 cm) orthophotograph and a digital elevation model (DEM; see Figure 2). Due to the moderate vegetative cover at the site, the DEM that includes the plant heights and architecture at the site is inappropriate for mapping and spatial analysis. As a result, developing a DTM was required. As discussed in earlier articles, several ways exist to construct a DTM from datasets. However, the majority of them need a certain level of technical expertise. Agisoft Metashape's products are simple in design and operation, but they differ widely in the degree to which they automate common tasks.

Nine differential GPS control points were set up on-site, and their coordinates were used to georeference the model. Agisoft estimated a horizontal spatial inaccuracy of 8.23 cm for the whole model, which is within an acceptable range given the collection of smaller, more exact models in strategic locations. A high-resolution (2.5 cm) orthophotograph and a digital elevation model (DEM) were both produced from the processed and georeferenced model (Figure 2). With a DEM including the vegetation heights and architecture at the site, this dataset is unsuitable for mapping and spatial analysis due to the site's moderate vegetative cover. Therefore, making a DTM was essential. There are a variety of approaches to creating a DTM using datasets, as detailed in previous articles, albeit most of them need a fair amount of technical competence. However, Agisoft Metashape's offerings are generally straightforward but vary widely regarding how much automation is included and how well it works.

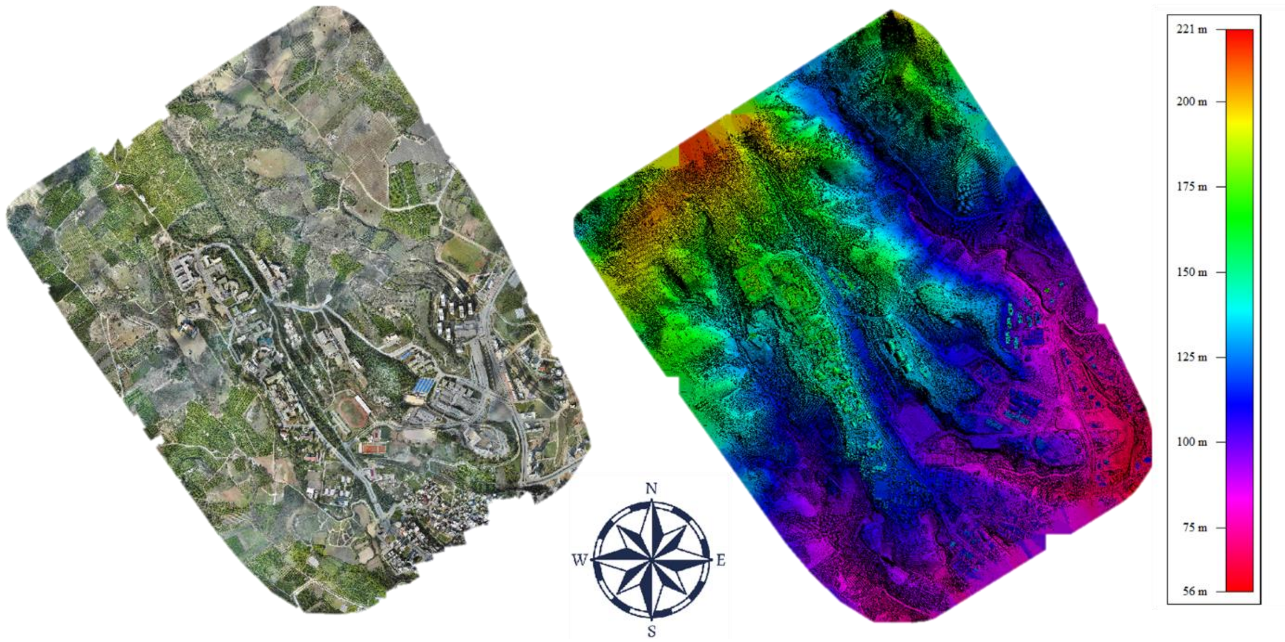


**Figure 2.** Orthomosaic (left) and DEM (right)

## 4. Conclusion

In this investigation, small-format digital camera data was processed using digital photogrammetric software. Digital orthophoto and digital maps were generated using digital photogrammetric software. The 3D stereoscopic model was quickly built with digital photogrammetric software. This study found that the most effective method for digital UAV mapping was using GPS from a fixed location with a 10-minute observation. This information demonstrates that the UAV when flying at 152m, achieved a precision of 1 m. A UAV is an invaluable tool when making a 3D model of a place, especially one with steep terrain. It was found that a UAV flying at 152m could successfully create the DEM and orthophoto, with the orthophoto having a planimetric accuracy of 2.5 cm. This study demonstrates that UAV systems can quickly and precisely capture DEM and provide high-quality mapping results. This study's methodology is applicable and valuable for high-resolution mapping of a compact area on a limited budget.

## References

Alptekin, A., & Yakar, M. (2020). Determination of pond volume using an unmanned aerial vehicle. Mersin Photogrammetry Journal, 2(2), 59-63.

Alptekin, A., & Yakar, M. (2021). 3D model of Üçayak Ruins obtained from point clouds. Mersin Photogrammetry Journal, 3(2), 37-40.

Colomina, I., Blázquez, M., Molina, P., Parés, M. E. & Wis, M. (2008). Towards a New Paradigm for HighResolution Low-Cost Photogrammetry and Remote Sensing. IAPRS&SIS, 1201-1206.

Kanun, E., Alptekin, A., & Yakar, M. (2021a). Cultural heritage modelling using UAV photogrammetric methods: a Kanlıdivane archeological site case study. Advanced UAV, 1(1), 24-33.

Kanun, E., Metin, A., & Yakar, M. (2021b). Yersel Lazer Tarama Tekniği Kullanarak Ağzıkara Han'ın 3 Boyutlu Nokta Bulutunun Elde Edilmesi. Türkiye Lidar Dergisi, 3(2), 58-64.

Karataş, L., Alptekin, A., & Yakar, M. (2022a). Creating Architectural Surveys of Traditional Buildings with the Help of Terrestrial Laser Scanning Method (TLS) and Orthophotos: Historical Diyarbakır Sur Mansion. Advanced LiDAR, 2(2), 54-63.

Karataş, L., Alptekin, A., Kanun, E., & Yakar, M. (2022b). Tarihi kârgir yapılarda taş malzeme bozulmalarının İHA fotogrametrisi kullanarak tespiti ve belgelenmesi: Mersin Kanlıdivane ören yeri vaka çalışması. İçel Dergisi, 2(2), 41-49.

Karataş, L., Alptekin, A., Karabacak, A., & Yakar, M. (2022c). Detection and documentation of stone material deterioration in historical masonry buildings using UAV photogrammetry: A case study of Mersin Sarisih Inn. Mersin Photogrammetry Journal, 4(2), 53-61.

Korumaz, A. G., Dülgerler, O. N., & Yakar, M. (2012). Digital techniques in cultural heritage documentation. Selçuk University Journal of Engineering, Science and Technology.

Kusak, L., Unel, F. B., Alptekin, A., Celik, M. O., & Yakar, M. (2021). Apriori association rule and K-means clustering algorithms for interpretation of pre-event landslide areas and landslide inventory mapping. Open Geosciences, 13(1), 1226-1244.

Polat, N., Önal, M., Ernst, F. B., Şenol, H. İ., Memduhoğlu, A., Mutlu, S., Mutlu, S. İ., Budan, M. A., Turgut, M. & Kara, H. (2020). Harran Ören Yeri Arkeolojik Kazı Alanınındın Çıkarılan Bazı Küçük Arkeolojik Buluntuların Fotogrametrik Olarak 3B Modellenmesi. Türkiye Fotogrametri Dergisi, 2 (2), 55-59.

Pulat, F., Yakar, M., & Ulvi, A. (2022). Comparison of photogrammetric software using the terrestrial photogrammetric method: The case of Hüsrev Paşa Mosque. Intercontinental Geoinformation Days, 4, 192-195.

Remondino, F., Barazzetti, L., Nex, F., Scaioni, M. & Sarazzi, D. (2011). UAV Photogrammetry for Mapping and 3D Modeling Current Status and Future Perspectives. ISPRS ICWG I/V UAV-g Conference, Zurich, Switzerland.

Şasi, A., & Yakar, M. (2017). Photogrammetric modelling of sakahane masjid using an unmanned aerial vehicle. Turkish Journal of Engineering, 1(2), 82-87.

Siebert, S.& Teizer, J. (2014). Mobile 3D Mapping for Surveying Earthwork Projects Using an Unmanned

Ulvi, A., Varol, F., & Yiğit, A. Y. (2019). 3D modeling of cultural heritage: the example of Muyi Mubarek Mosque in Uzbekistan (Hz. Osman's Mushafi). International Congress on Cultural Heritage and Tourism (ICCHT), 115-123, Bishkek, Kyrgzstan.

Ulvi, A., Yiğit, A. Y. & Yakar, M. (2019). Modeling of Historical Fountains by Using Close-Range Photogrammetric Techniques. Mersin Photogrammetry Journal, 1(1), 1-6.

Unal, M., Yakar, M., & Yildiz, F. (2004, July). Discontinuity surface roughness measurement techniques and the evaluation of digital photogrammetric method. In Proceedings of the 20th international congress for photogrammetry and remote sensing, ISPRS (Vol. 1103, p. 1108).

Ünel, F. B., Kuşak, L., Çelik, M., Alptekin, A., & Yakar, M. (2020). Kıyı çizgisinin belirlenerek mülkiyet durumunun incelenmesi. Türkiye Arazi Yönetimi Dergisi, 2(1), 33-40.

Yakar, M. & Dogan, Y. (2018). 3D Reconstruction of Residential Areas with SfM Photogrammetry. In Conference of the Arabian Journal of Geosciences, 73-75.

Yakar, M., & Doğan, Y. (2017). Uzuncaburç Antik Kentinin İHA Kullanılarak Eğik Fotogrametri Yöntemiyle Üç Boyutlu Modellenmesi. 16. Türkiye Harita Bilimsel ve Teknik Kurultayı. TMMOB Harita ve Kadastro Mühendisleri Odası, Ankara.

Yakar, M., Orhan, O., Ulvi, A., Yiğit, A. Y., & Yüzer, M. M. (2015). Sahip Ata Külliyesi Rölöve Örneği. TMMOB Harita ve Kadastro Mühendisleri Odası, 10.

Yakar, M., Toprak, A. S., Ulvi, A., & Uysal, M. (2015). Konya Beyşehir Bezariye Haninin (Bedesten) İHA ile fotogrametrik teknik kullanilarak üç boyutlu modellenmesi. Türkiye Harita Bilimsel ve Teknik Kurultayı, 25, 28.

Yakar, M., Ulvi, A., Yiğit, A. Y., & Alptekin, A. (2022). Discontinuity set extraction from 3D point clouds obtained by UAV Photogrammetry in a rockfall site. Survey Review, 1-13.

Yakar, M., Yılmaz, H. M., & Mutluoglu, O. (2014). Performance of photogrammetric and terrestrial laser scanning methods in volume computing of excavation and filling areas. Arabian Journal for Science and Engineering, 39, 387-394. https://doi.org/10.1007/s13369-013-0853-1

Yilmaz, H. M., & Yakar, M. (2006a). Lidar (Light Detection And Ranging) Tarama Sistemi. Yapı Teknolojileri Elektronik Dergisi, 2(2), 23-33.

Yilmaz, H. M., & Yakar, M. (2006b). Yersel lazer tarama Teknolojisi. Yapı teknolojileri Elektronik dergisi, 2(2), 43-48.