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EXAMINING ARCHITECTURAL PROJECT APPLICATIONS WITH PHOTOGRAMMETRIC POINT CLOUD: IĞDIR UNIVERSITY MOSQUE

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Abstract

Original scientific paper

In accordance with the developments in today's technology, the use of unmanned aerial vehicles in architectural documentation and 3D modeling studies is becoming increasingly widespread. When the studies in the literature are examined, it is seen that they focus on the documentation and 3D modeling of historical buildings. In this study, unlike the research in the literature, the usability of UAV photogrammetry in architectural project implementation and monitoring is investigated. In line with this aim, 3D point clouds and 3D models were generated using UAV photos in the study. For the identified reference points, measurements obtained from architectural project drawings, measurements taken on-site using the measurement technique with a laser meter, and finally the comparison of the measurements corresponding to these reference points on the 3D model produced from UAV photos were conducted. Based on the obtained data, when the detailed measurements taken with a laser meter are compared with the detailed measurements taken from the 3D model obtained with UAV, the consistency level is observed to be an average of 98% and above. Thus, the accuracy of the measurements obtained using UAV photogrammetry has been proven. Additionally, it was observed that measurements taken with a laser meter from the same reference points on the architectural project were different. The reason for this is the modification of the forms of details in the implementation phase of the architectural project. In this regard, it is thought that obtaining precise measurements on photos taken with UAV photogrammetry will provide an important groundwork for future studies on architectural project implementation and monitoring.

Keywords: *Photogrammetry, UAV, point cloud, 3D model, building survey.*

MİMARİ PROJE UYGULAMALARININ FOTOGRAMETRİK NOKTA BULUTU İLE İNCELENMESİ: IĞDIR ÜNİVERSİTESİ CAMİİ ÖRNEĞİ

Özet

Orijinal bilimsel makale

Günümüz teknolojisindeki yaşanan gelişmelere bağlı olarak mimari belgeleme ve 3B modelleme çalışmalarında insansız hava araçlarının kullanımı gün geçtikçe yaygınlaşmaktadır. Literatürdeki çalışmalar incelendiğinde tarihi yapıların belgelenmesi ve 3B modellenmesi konuları üzerine yoğunlaşıldığı görülmektedir. Bu çalışmada literatürdeki araştırmalardan farklı olarak İHA fotogrametrisinin mimari proje uygulama ve takibinde kullanılabilirliği araştırılmıştır. Çalışmada bu amaç doğrultusunda İHA fotoğrafları kullanılarak 3B nokta bulutu ve 3B model üretilmiştir. Belirlenen referans noktalar için; Mimari proje çizimlerinden elde edilen veriler ile lazer metre kullanılarak yerinde ölçüm tekniği ile alınan ölçüler ve son olarak da İHA fotoğraflarından üretilen 3B model üzerindeki bu referans noktalarına karşılık gelen ölçülerin karşılaştırılması yapılmıştır. Elde edilen veriler doğrultusunda lazer metre ile alınan detay ölçümlerinin, İHA ile elde edilen 3B model üzerinden alınan detay ölçüleri ile kıyaslandığında tutarlılık derecesinin ortalama %98 ve üzerinde olduğu gözlemlenmiştir. Bu sayede İHA fotogrametrisi kullanılarak elde edilen ölçülerin hassasiyeti kanıtlanmıştır. Ayrıca lazer metre ile mimari proje üzerindeki aynı referans noktalarından alınan ölçülerin farklı olduğu tespit edilmiştir. Bunun nedeni ise mimari projedeki detayların uygulama aşamasında formlarının değiştirilmesidir. Bu doğrultuda İHA Fotogrametrisi ile çekilen fotoğraflar üzerinde yapılabilecek hassas ölçümlerin elde edilmesi gelecekte yapılacak mimari proje uygulama ve takibine yönelik çalışmalara önemli bir altlık oluşturulacağı düşünülmektedir.

Anahtar Kelimeler: *Fotogrametri, İHA, nokta bulutu, 3B model, röleve.*

1 Introduction

The efforts to achieve accurate and precise data in documentation and 3D modeling studies in architecture have led to the emergence of new methods and techniques. Due to advancements in today's technology, these methods and techniques continue to evolve, and their

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applications are becoming increasingly widespread. One of these modern techniques is Photogrammetry.

Photogrammetry, generally, refers to the scientific discipline of making precise measurements of the relative positions of points by utilizing data obtained from images and other information sources. This allows for accurate determination of properties such as distances, angles, areas, volumes, elevations, dimensions, and shapes of objects [1]. Furthermore, it is possible to create a three-dimensional (3D) model from detailed two-dimensional (2D) photographs of objects.

The photogrammetry method makes a significant contribution by providing texture data, which includes surface features, in addition to the fundamental three-dimensional data of objects. These texture data are combined with the geometric properties of three-dimensional objects to align with metric features. Since these textures are obtained from the objects' own photographs, more realistic models are produced. This ensures that objects appear in a detailed and realistic manner, similar to their appearance in the real World [2]. Additionally, the photogrammetric method;

- Obtaining the desired format of the product depending on the use of technological equipment,
- Significantly reducing processing time compared to conventional methods,
- Providing superiority in accuracy of evaluation compared to other approaches,
- Having data in digital format,
- Gaining advantages over traditional methods, such as the ability to be linked to the country coordinate system, for various reasons [3].

The advantages of photogrammetric technique over classical methods highlight it among other methods and contribute to its widespread use. This technique, whose usage is increasingly expanding, is divided into terrestrial and aerial photogrammetry based on the location of the photographing point

Terrestrial Photogrammetry refers to a technique carried out with photographs taken from fixed points on the Earth's surface, while Aerial Photogrammetry is defined as a technique where photographs are taken from the air to cover extensive areas that cannot be reached by terrestrial shooting techniques. [4]. Initially based on images taken from the ground, photogrammetry later expanded its field of view by moving the capture point to the air, becoming a significant method for creating plans and maps [5].

Aerial photogrammetry, despite undergoing different stages of development over time, is currently most commonly performed using Unmanned Aerial Vehicles (UAV). UAV photogrammetry is a method carried out using UAV or drones. Cameras on the UAV platform enable unmanned aerial vehicles to autonomously or manually perform the task of capturing photographs from a specific altitude. This has significantly reduced time and workload without the need for a large working team, allowing for the rapid attainment of the most accurate results. UAV photogrammetry is extensively used in architectural studies, as in many engineering fields.

In the field of architecture, UAV photogrammetry is a technology used for detailed measurement and digital 3D modeling of architectural structures. Photogrammetry is commonly employed in architecture, not only for modeling historical buildings but also effectively for post-construction measurement and analysis of modern structures. This method allows for the documentation and analysis of architectural projects to be carried out more quickly compared to traditional methods.

Both terrestrial photogrammetry and aerial photogrammetry have been widely used in recent years in the field of architecture for the preparation of survey projects and documentation of historical structures. In the literature, there are numerous studies documenting cultural heritage and creating 3D models using photogrammetric techniques (Erdoğan [6]; Asri and Çorumluoğlu [7]; Asri and Çorumluoğlu [8]; Maraş et al. [9]; Marangoz and Özen [10]; Şasi [11]; Polat et al. [12]; Zeybek and Kaya [13]; Erdoğan et al. [14]; Şenol and Orman [15]; Döş and Yiğit [16]; Kabadayı and Erdoğan [17]; Karataş [18]; Yıldırım Demir and Yaman [19]; Susam [20]). In these studies, applications have been carried out for ruins, mosques, small mosques, museums, churches, tombs, fountains, bridges, city walls, pulpits, mansions, and historical settlements. In addition to these, archaeological artifacts such as historical sculptures and tombstones have also been 3D modeled and documented.

In the literature, research generally focuses on documenting and 3D modeling historical heritage. In contrast, this study investigates the usability of UAV photogrammetry in the implementation and monitoring of architectural projects. In pursuit of this goal, 3D point clouds and models were generated using UAV photos. For the identified reference points, measurements obtained from architectural project drawings, measurements taken on-site using a laser meter, and finally, a comparison of the measurements of these reference points on the 3D model produced from UAV photos were conducted. This allowed for an analysis of the accuracy and precision of the measurements obtained through UAV photogrammetry. In this regard, achieving precise measurements on UAV photogrammetry images is believed to provide a significant foundation for future studies focusing on the implementation and monitoring of architectural projects.

2 Material and Method

2.1 The Case Study

The study involved the application on a mosque located at Iğdır University Şehit Bülent Yurtseven Campus (Figure 1). The mosque, with a capacity of 3000 people and a construction area of 1600 m2, includes 2 minarets with a height of 50 m each, one large dome with a height of 26 m, and 5 small domes. The construction of this mosque, characterized by a highly modern and aesthetic architectural concept, began in 2014 and was completed in 2017.

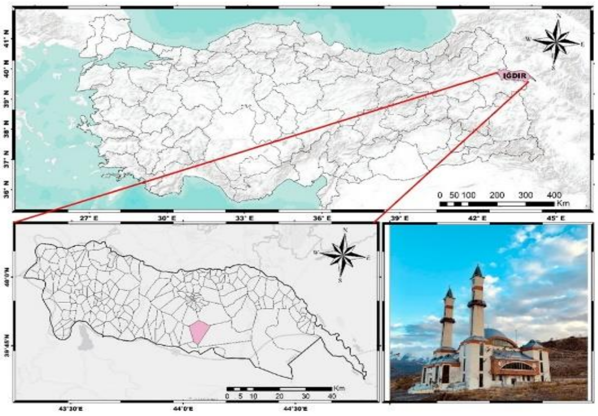

Figure 1. Working area (39.0811423,44.0080929).

2.2 Obtaining Data (Field Study)

The data acquisition process in the study consists of three stages. First, the length measurements of the sections to be compared were taken from the architectural implementation project shown in Figure 2. In the second stage, corresponding to the lengths obtained in the first stage, measurements of the existing state of the structure were taken using a laser meter, as depicted in Figure 3. In the final stage, photos of the mosque were captured using the DJI Phantom 4 RTK Unmanned Aerial Vehicle (UAV) (Figure 4), through a versatile (multi-oriented) flight performed at a height of 60 m. The technical specifications of the UAV used in the photo shoot are provided in Table 1.

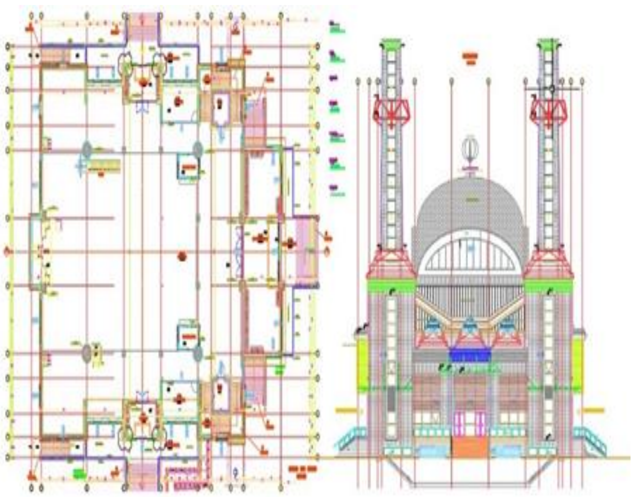

Figure 2. Architectural application project.

Figure 3. Kl pro laser meter.

Figure 4. Djı phantom 4 rtk drone.

Table 1. Technical specifications of the unmanned aerial vehicle.

DRONE BODY	
Takeoff Weight	1391 gr
Cross Length	350 mm
Maximum Operating Altitude	19685 ft
Maximum Ascension Speed	6 m / s (automatic flight); 5 m / s (manual control)
Maximum Descent Speed	3 m/s
Maximum Speed	31 mph (50 kph) (P-mode)
Maximum Flight Time	Approximately 30 min
Operating temperature range	32 °C
Operating frequency	2.400 GHz- 2.483 GHz (Europe, Japan, Korea) 5.725 GHz- 5.850 GHz (United States, China)
Accuracy Range	RTK is active and working properly: Vertical: ±0.1 horizontal: ±0.1 m RTK off Vertical: ±0.1 m (vision positioning); ±0.5m (GNSS positioning) Horizontal: ±0.3m (Vision positioning); ±1.5 m (GNSS positioning)
CAMERA	
Sensor	FOV 84°; 8.8mm / 24mm (35mm format equivalent: 24mm);
Lens	FOV 84°; 8.8mm / 24mm (35mm format equivalent: 24mm); f/2.8- f/11, autofocus, 1 m
Image Size Maximum	4864×3648(4:3);
photo format	JPEG
BATTERY	
Capacity	5870 mAh
Voltage	15.2 V
Weight	**468**

2.3 Processing of Data (Office Work)

After the fieldwork was completed, 496 photos taken with the UAV were input into the demo version of the DJI Terra software (Figure 5), and point cloud, Digital Surface Model (DSM), and 3D model results for the mosque were obtained. Subsequently, reference measurements from the architectural implementation project were displayed on the model. Later, measurements taken with a laser meter from the same reference points were processed onto the model.

Figure 5. Photography shooting points.

3 Findings

The photos taken with the UAV were processed in DJI Terra software, resulting in a point cloud (Figure 6), DSM (Figure 7), and 3D model (Figure 8). Measurements taken from the reference points on the generated 3D model were compared with measurements taken with a laser meter and the length measurements from the architectural implementation project (Figures 9-11). All three measurement values are presented in Table 2. In this table, values measured with the laser meter are considered as the exact measurement values. Additionally, in Table 2, L1 represents the difference between the exact measurement and the length in the architectural project, while L2 represents the difference between the exact measurement and the length of the same detail on the 3D model.

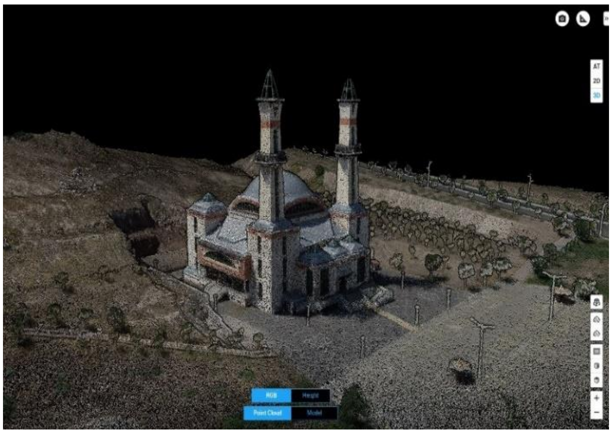

Figure 6. Point cloud view.

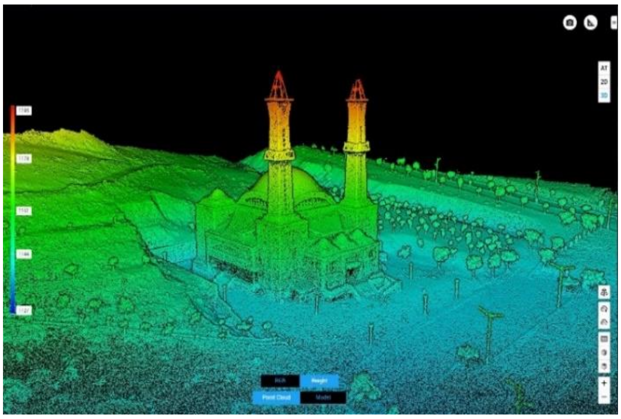

Figure 7. Dsm view.

Figure 8. 3D model view.

Figure 9. North front reference points.

Figure 10. South front reference points.

Figure 11. West front reference points.

Table 2. Comparison of reference point measurements.

Facade/Detail		MEASUREMENT VALUES			GAP	
		Lazer Metre (m)	Architectural Project (m)	3D Model (m)	L_1 (m)	L_2 (m)
Front Facede	A-1	5.83	5.88	5.86	0.05	0.03
	A-2	3.06	4.63	3.03	**1.57**	0.03
	B-1	6.90	5.89	6.80	1.01	**0.10**
	B-2	5.72	5.45	5.78	0.27	0.06
	C-1	5.82	5.96	5.82	0.14	0.00
	C-2	3.08	4.63	3.09	1.55	0.01
Back Elavation	D-1	3.96	***	3.92	-	0.04
	D-2	1.31	1.45	1.27	0.14	0.04
	E-1	10.10	9.97	10.05	0.13	0.05
	E-2	6.93	7.09	6.92	0.16	0.01
	E-3	1.84	1.56	1.87	0.28	0.03
Side (Right) Elavation	F-1	5.87	5.89	5.89	0.02	0.02
	F-2	2.39	3.20	2.40	0.81	0.01
	F-3	6.70	6.61	6.67	0.09	0.03
	G-1	16.72	16.72	16.74	0.00	0.02
	G-2	7.65	7.71	7.64	0.06	0.01

***Due to the differences in form between the architectural project and the implementation, measurement values could not be taken.

In Table 2, detailed measurements for 16 points on three different facades of the mosque located at Iğdır University Suveren Campus are provided. When examining the differences in detailed measurements taken with a laser meter on the 3D model, it is observed that the maximum difference is ±10 cm. In detail C-1, the measurements taken with a laser meter on the 3D model were found to match exactly. Based on the obtained data, the consistency degree of detailed measurements taken with a laser meter compared to detailed measurements taken from the 3D model obtained with UAV is observed to be an average of 98% and above. Additionally, it was found that measurements taken with a laser meter from the same reference points on the architectural project were sometimes different. Especially when detail A-2 is examined, a length difference of 1.57 m is observed. The reason for such significant differences is the construction of details in the architectural project at different dimensions during the implementation phase. Furthermore, the measurement value for detail D-1 could not be obtained as it was not consistent with the architectural Project.

4 Results

The regularly captured images with UAV photogrammetry during the construction stages of architectural projects can be used to monitor and supervise the construction progress, assess potential issues early, and ensure compliance with the project. Photogrammetry has become a significant tool in the field of architecture, offering advantages such as providing precise measurements, supporting detailed modeling, and aiding conservation efforts.

This technique provides the opportunity to obtain faster, more effective, and more detailed information compared to traditional measurement and documentation methods. In this study, various detail measurements were taken on three different facades of the mosque located at Iğdır University Suveren Campus. Evaluation of these measurements indicates that UAV photogrammetry provides information about the adherence of the construction process and post-construction to the architectural projects, as well as the accuracy of the constructed forms. Particularly, the precise detection of differences between architectural projects and the actual construction during the construction process demonstrates the effective use of UAV in such scenarios.

Declaration

Ethics committee approval is not required.

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