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EVALUATION OF UAV-BASED DEM FOR VOLUME CALCULATION

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ABSTRACT

In the latest decades, Unmanned Aerial Vehicles (UAVs) have witnessed rapid growth and it plays a vital role in different fields of engineering and architecture. This technique can also be applied in land surveying as a device in order to measure the 3D ground coordinates and Earth work. The main aim of this paper is to evaluate the accuracy of volume that obtained by using Digital Elevation Model (DEM) derived from UAVs images.

In this research, three different flights were performed with DJI phantom 4 pro (25m, 50m, and 100m) with 80% forward and side overlaps at Duhok Dam. Several Ground control points (GCPs) were installed and evenly distributed throughout the study area and their coordinates were determined using GPS-RTK technique for geo-referencing. The data images captured with UAV were processed using Agisoft photoscan Professional software. GPS survey was carried out using Leica viva GS10 base, and GS15 rover for the same place. The volumes acquired by the UAV images including all three flight heights were compared to the volume obtained with GPS survey techniques which considered as a base for comparison. The results showed that the volume calculated with UAV images encountered to the base were compatible with each other with (99. 86%,99. 76% and 99. 74%) for altitudes (25,50, and 100) respectively.

***KEYWORD**:* UAV images, accuracy assessment of DEM, volume commutation, GCP, GPS-RTK.
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1. INTRODUCTION

The rapid development of Unmanned Aerial Vehicles (UAVs) contributed in various disciplines of engineering and architecture. They are also used as a device to measure 3D ground coordinates and compute earthworks which can be applied in land surveying. With the help of photogrammetry fundamental rules, UAV system is used to study the Earth's surface. Aerial surveys are becoming more and more popular as a result of high spatial resolution of the images captured from UAV's. UAVs seem to be more efficient than ground surveys with advantage of time and flexibility compared to the traditional surveying such as total station in the small areas of study, and they have lower cost than conventional photogrammetric flights using expensive metric digital cameras mounted on the board or LiDAR sensors (Zietara, 2017) Images captured from (UAVs) are used for generating Digital Surface Models (DSMs) and orthophoto (Saskia , Ruedi , & Daniel, 2017).

A Digital Elevation Model (DEM) is an important product that represents topography of the ground surface or defines the Z values of ground surfaces digitally with different accuracies for variety of application fields (Polat & Uysal, 2018). Also there are other two most widely used terms in the literature: digital surface model (DSM) and digital terrain model (DTM). The terms DEM, DTM, and DSM are generally used to denote to diverse types of continuous and three-dimensional (3D) geospatial data. A DEM is represented as a three-dimensional (3D) raster image that shows the elevations of ground above the mean sea level by its pixel values. A DSM is defined as a raster image that represents the elevations of ground above the mean sea level by its pixel values including all features such as hills, trees, buildings, etc., present on it, whereas a DTM is a raster image that represents the elevations of ground above the mean sea level (MSL)or above vertical datum by its pixel values as shown in figure (1) (Ravi, 2018) (Ajayi , Salubi, Angbas , & Odigure, 2017).

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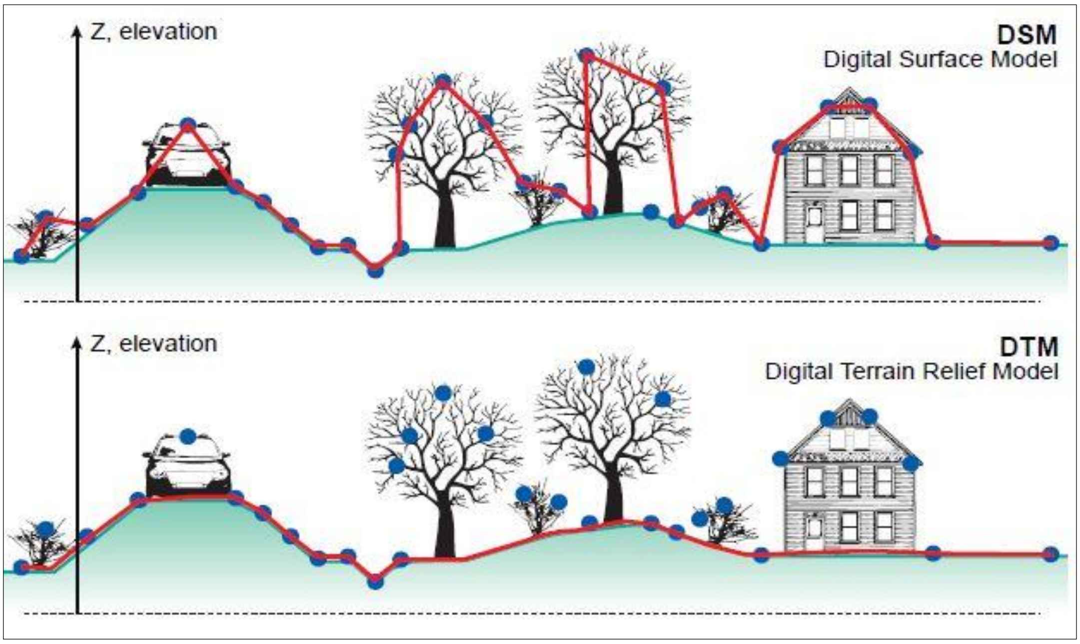

Fig. (1):- Difference between DSM and DTM (BEGASHAW, 2018).

In recent years, UAVs have also been used for volume calculation for different purposes such as excavation and filling of mines, huge construction sites, the places where coal dumped and recycling area. In addition, activities of road construction are treated as one of the most economic operations, since the cost of earthwork has commonly the major portion among these activities (Akgul, Yurtseven, Gulci, & Akay, 2017). Undoubtedly, it is also possible to calculate volumes by using conventional geodetic methods including Theodolite, total station and GPS, but by taking the time saving, accessibility and cost efficiency into account, UAV is considered the ideal solution(Ulvi, 2018).

The major concern that is related to the accuracy of DEM should be taken into consideration and the main thing to take into account is whether the DSM produced from accuracy of aerial surveys implemented by UAV is sufficiently accurate to be used in volume computation.

Over recent years, many investigations have been done to evaluate the quality of products generated from data collected by drones. For instance, (Ulvi, 2018), analyzed the utility of unmanned aerial vehicle in volume calculation, while (Akgul et al., 2017) conducted a research on the assessment of DEMs derived from both UAV and Global Navigation Satellite System (GNSS) for earthwork computations. Furthermore, (Tucci, Gebbia, Conti, Fiorini, & Lubello, 2019) used UAV system for monitoring and computing stockpile volumes of bulk materials etc., therefore the accuracy of DEM is an important subject to be studied in volume calculation. The main aim of this paper is to evaluate the accuracy of volume that obtained by using Digital Elevation Model (DEM) derived from UAVs images at different flight heights.

2. RELATED WORK

Numerous most recent researches and investigations have written and published on the accuracy volume calculation derived from UAVs using variety procedures and software.

(Wang, Al-Shabbani, Sturgill, Kirk, & Dadi, 2017), estimated earthwork volume of a stockpile and trench through the use of conventional GPS survey and unmanned aerial system (UAS). The flight was performed with help of dual-controlled DJI Inspire 1 drone with 75% forward overlap and 60% side overlap. The captured images were processed with Pix4Dmapper software, and comparison was made between volumes obtained by both methods. The result of their study showed that the error in volume for stockpile and trench

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in comparison with GPS survey were found about ±206.94 ft3 (7%) and ±3311.4563 ft3 (0.9%) respectively.

(Ulvi, 2018), analyzed the utility of unmanned aerial vehicle in volume calculation. The volume calculation was made by both photogrammetric technique and conventional survey methods. Ground Control Points (GCPs) were installed for geo-referencing and evenly distributed throughout their area of study, in addition to 1415 points were measured with spaces of 40 cm to calculate the volume by using Topcon GPT 8203A total station reflector-less. The process of taking photographs was carried out using Octocopter UAV at 20 m high. The captured images were processed with Photomodeler software. Finally, the volume comparison was made by both mentioned methods, and the results showed that, volume acquired by photogrammetric technique agreed with the volume got by classical method by 99.33%.

(Akgul et al., 2017), conducted a research on the assessment of DEMs derived from both UAV and GNSS for earthwork volume. (Trimble UX5) drone was used in the process of study area mapping with 80% longitudinal and traversal coverage at flying height 200 m. All image data were processed by means of Agisoft Photoscan Professional software in order to produce point cloud and orthomosaic data. GNSS-based DEM was generated by measuring 5478 points with the help of Network Real Time Kinematic (NRTK), GNSS receiver and Pentax SMT-888 depending on NRTKs. Turkey Continuously Operating Reference Stations (CORS). At the end, the result showed that the volume of excavation and embankment obtained by both techniques were very close to each other.

(Cryderman, Mah, & Shufletoski, 2014), evaluated the accuracy of earthwork computation of UAV photogrammetry against GNSS on a stockpile. In photogrammetric technique, in-house UAV was used to be flown multiple times over the study area with average height of 118 m and 75% frontal and side overlap. The acquired image data were processed by means of Agisoft PhotoScan Professional (version 1.0.4). In the other method, Trimble R8s receiver was used to measure 11 ground control points GCPs for geo-referencing and 220 detail points using GNSS-RTK technique. Finally, the volume comparison was made, and the results showed an agreement between both methods within 3 755 m^3 (0.7%) of the total volume or 5 cm thickness over the entire surface area of pile.

(Siebert & Teizer, 2014), assessed the performance of UAV system for earthwork calculation and compared to the conventional survey techniques. The process of mapping the study area was performed using quadrocopter UAV at height of 50 m above the ground with 70% and 40% forward and side overlap respectively. The obtained images were processed and point clouds generated by utilizing Agisoft Photoscan Professional. In classical survey GNSS receiver and SAPOS (German DGNSS Reference Station System) was used for measuring 8 ground control points GCPs for geo-referencing and hundred single points using traditional RTK- GPS technique. The volumes of three earth piles were compared by both methods, and the results agreed with each other within 59 m3(8%) for Pile 1, 93 m3(9%) for Pile 2, and 14 m3(16%) for Pile 3.

(Tucci et al., 2019), UAV system was used for monitoring and computing stockpile volumes of bulk materials. The ground control points GCPs for geo-referencing were obtained from the 3D point model which was generated with terrestrial laser scanning. The laser scan data were processed with Leica Cyclone software. In UAV survey, DJI Phatom4Pro multirotor quadcopter was used for the process of image capturing with two flights. The flight altitude was 75 m above the ground with 85% longitudinal and 70% traversal coverage where the positions of the cameras were vertically situated for the first one and the other obliquely situated at a (30˚) angle. All captured images were processed with the software Agisoft Photoscan. The vertical position was considered as a base reference and the volume of several stockpiles were computed with both ArcGIS and Agisoft Photoscan. The results indicated that the volumes were well-matched with each other in a ratio of 99%.

(Ahmad, Dutsenwai, Periola, & Falowo, 2017), analyzed volume computation of a water tank using low-cost close range photogrammetry. Phantom 3 Professional UAV was utilized to take images for making 3D model of the water tank at low altitude of 20 m from the ground surface. The UAV-based data were processed by Agisoft Photoscan software. Their study, focus on the influence of the number of images and ground control points GCPs were tested to select the optimum number of images and GCPs to get the actual volume of the water tank. The 3D coordinates of the GCPs were acquired from the traversing technique. The results showed that using four GCPs and 95 images can get the water tank volume within 5% error of the actual volume, as well as it was also demonstrated that the use of 4 GCPs and (115 to 220) images were needed to get the actual volume of the water tank.

(Chunsen & Qiyuan, 2018), computed the volume of coal pile using UAV images and compared to the results obtained by conventional RTK survey. DJI M600 six-rotor drone was used to take images of the study area with 60% Heading overlap and 50% Lateral overlap. The acquired photos were processed based on the SfM-PMVS. Finally, the volumes of pile coal obtained by both methods were compared to each other, and it found that, the UAV-based volume was 30374.1 m3, and the volume calculated using classical method was 30446.3 m3. The two volumes calculated agreed with each other within 72 m3 or 0.238 % error of the total volume.

(Samad, Nekmat, & Rg, 2018), evaluated the DTM model generated by using UAV sensors in earthwork calculation at quarry area. The UAV flight carried out using fixed-wing eBee UAV at altitude of 325m from the ground surface with 75 % frontal and lateral overlap. The collected image data were processed with Agisoft Photoscan software. The volume comparison analysis was made between UAV with and without GCPs depending on their contour interval. The six GCPs were established by GPS using RTK technique. Contours ranging from 1m to 10 m interval generated relying on the data from Origin Surveying Services Company. In conclusion, the results demonstrated that the suitability of UAV-based DTM for volume computation at quarry area.

(Julge, Ellmann, & Köök, 2019) used unmanned aerial vehicle for monitoring earthwork of road construction. The authors investigate the effect of different heights and the numbers of Ground Control Points were analyzed. Thirteen ground control points GCPs were signaled and equally distributed over the study area using GNSS-RTK technic. Receiver of GPS/ GLONASS Trimble R8 and Virtual Reference Station (VRS) service provided via data-link by a commercial CORS network were used to measure 196 detail points with distance between them not exceed 15m. These points were depended on GNSS and digital elevation model was generated.

On the other hand, Octocopter (8 rotors) UAV was used in the process of taking images at flight heights of 60m and 100m. After processing the collected data, dense point clouds, orthophoto mosaics and surface models were generated. The two obtained surface model were compared and results analyzed. Finally, the results showed that the difference between volumes acquired by both methods did not exceed 1%.

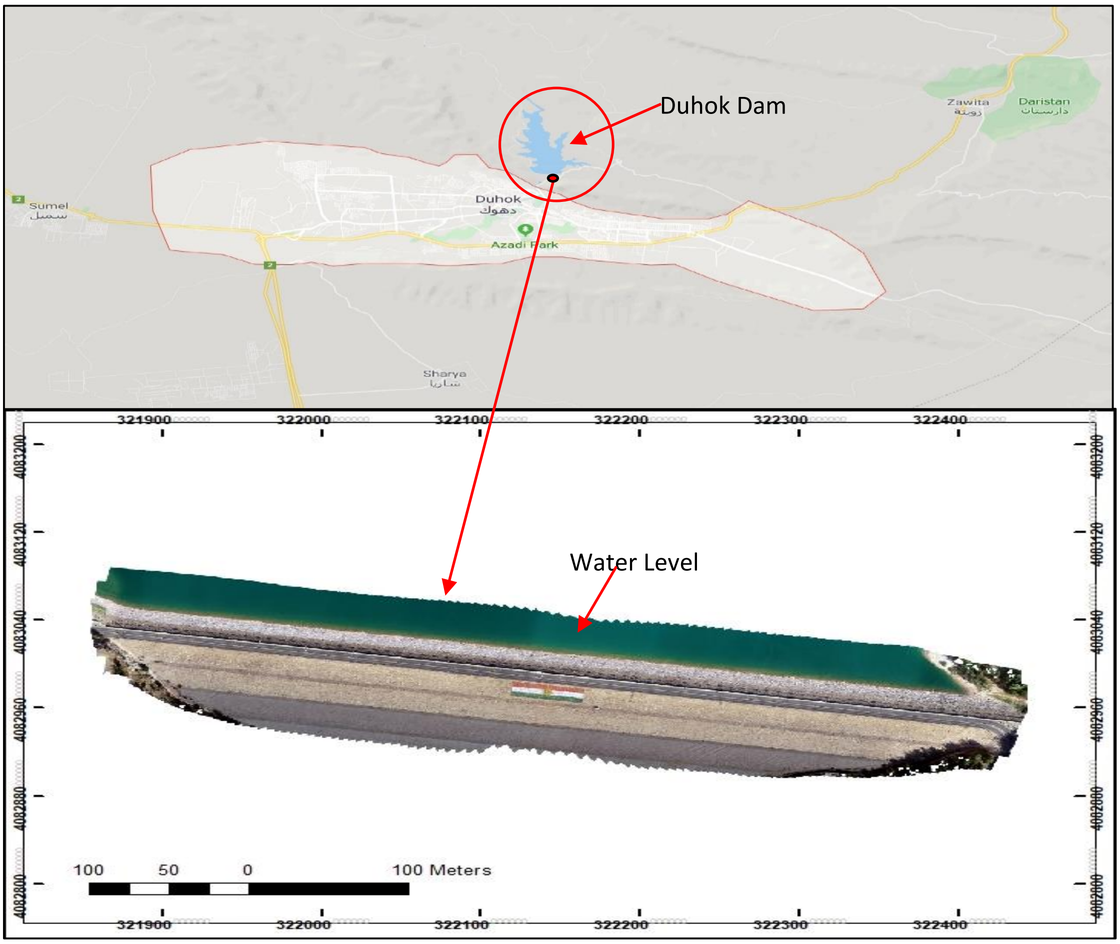
(Arango & Morales, 2015), made a comparison of calculating stockpile volumes between UAV and Total Station with the actual volume. Two techniques were used for data acquisition, the first one with a total station, and the other with a multicopter UAV. Leica TS02 plus, total station with 1" angular accuracy Reflector-less was used to compute volume of the stockpile. Ground control points GCPs were measured with GNSS around the pile for geo-referencing. DJI Phantom 2 vision plus was used to map the test site at altitude of 50m above the ground surface, and Pix4D Mapper software was used to process the captured images. The volumes obtained by UAV and Total Station were compared to the actual volume. It was found that there was difference between UAV-based volume and actual volume by -0.67% error, while 2.88% error between volume acquired by Total Station and the actual volume.

(Stalin & Geoinformatics, 2017a), made a comparison between volume computation carried out by both GPS and the UAV in an open pit quarry. Leica viva GS08 plus was used to measure 7 GCPS equally distributed over the study site and other detail points, the volume was calculated using AutoCAD Civil 3D. On the other hand, eBee fixed-wing was used in the process of mapping the study area at 118 m altitude above the ground surface with 75% frontal and lateral overlap of the images. All gained images were processed and volume computed with Pix4D Mapper software. The results illustrated that an agreement within 98.9% of the total volume between both methods.

3. METHOD AND MATERIALS

3.1. STUDY AREA

The test site is located at Duhok Dam in the city of Duhok in Kurdistan-Iraq. The boundary of the study area lies within 36°52'33.41"N and 43° 0'15.34"E (Fig. 2). The place was partially mountainous with size of approximately 80 m wide and 573 m long and an average elevation of 615.5 m above mean sea level. The body of the Duhok Dam was taken as an application site due to the fact that it was bare and with no vegetation such as grass, shrubs and etc.



Fig/(2): Location map of Study Area

3.2. UAV-SURVEY

Rotary wing UAV platform (Phantom 4 PRO) was used for mapping of the survey area as shown in (Fig. 3). UAV platform was equipped with a 1-inch CMOS (Complementary Metal Oxide Semiconductor) 20-megapixel sensor and 8.8 mm focal length, and has a manually adjustable aperture from F2.8 to F11. It also supports auto focus by half-pressing the shutter button, and has a focus range, from 1m to infinity as well as five-directions sensors for avoiding obstacle (DJI, 2018). The aperture adjusted automatically to achieve the desired shutter speed. Three flights missions were flown over the test site at different altitudes of 25 m, 50 m and 100 m, the numbers of captured images for each flight height were 684, 242 and 100 images respectively. The flight lines for each one cover 7, 4, and 3 lines respectively as illustrated in Table 1. frontal and lateral overlap were both set to 80%, Table 1.

In the field study, total 11 ground control points GCPs were signalized using traditional GPS-RTK mode to assist spatial referencing process and geo-tagging of images which implies to compute the scale, orientation and absolute position of the outputs in a desired coordinate system as shown in Figure 5. Control points were measured with the help of Leica viva GNSS GS10, base and Leica viva GNSS GS15, rover considering UTM WGS84- 38N coordinate system. Ground control points (GCPs) were designed by 0.6 m× 0.6 m in size, and printed on the piece of Flex as shown in Figure 4 which is a thin, plastic material coated a fabric at its back giving it extra strength to resist severe weather conditions such as heat, rain etc. Solvent machine is used to print this Flex with a special ink that does not wear out because of heavy rain or sunlight. All GCPs were evenly distributed in somehow that cover the application area as shown in figure 5. The shape of the GCPs was checker pattern with a black and white square so as to provide good contrast and ensure visibility in the images taken at high altitude, and their centers to be reliably identified as well.

Pix4D Capture was used for flight planning which is an autopilot application available on the market for both systems Android and IOS. The software allows the user to select the desired height of flight, percent of overlap of images and shape of the mapping area. After powering on and pressing single button of START, then it will fly the planed mission automatically (Pix4D, 2019).

Table (1): Flight planning parameters.

Flight altitude (m)	**25**	**50**	**100**
Flight time (min)	26	10	5
Surface area (m^2)		45840	
Forward overlap %		80%	
Side overlap %		80%	
GSD cm/pixel	0.68	1.36	2.73
Flight lines	7	4	3
No. of images	684	242	100

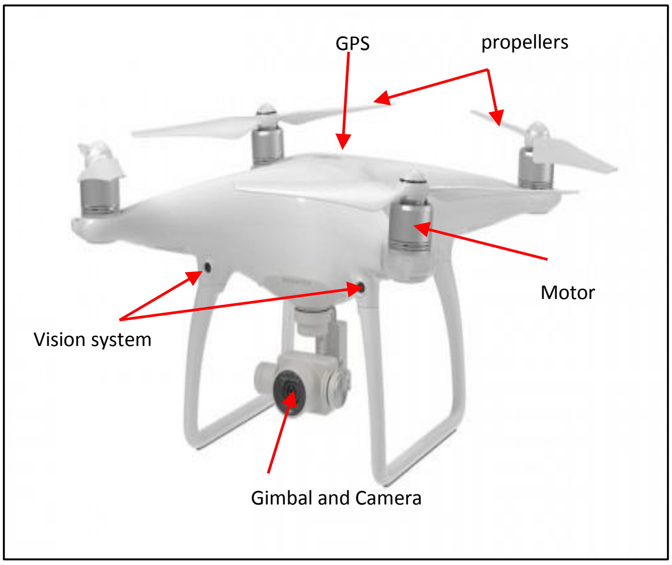


Fig. (3): Phantom 4PRO.

Fig. (4): Sample of the Ground Control Points (GCP)s

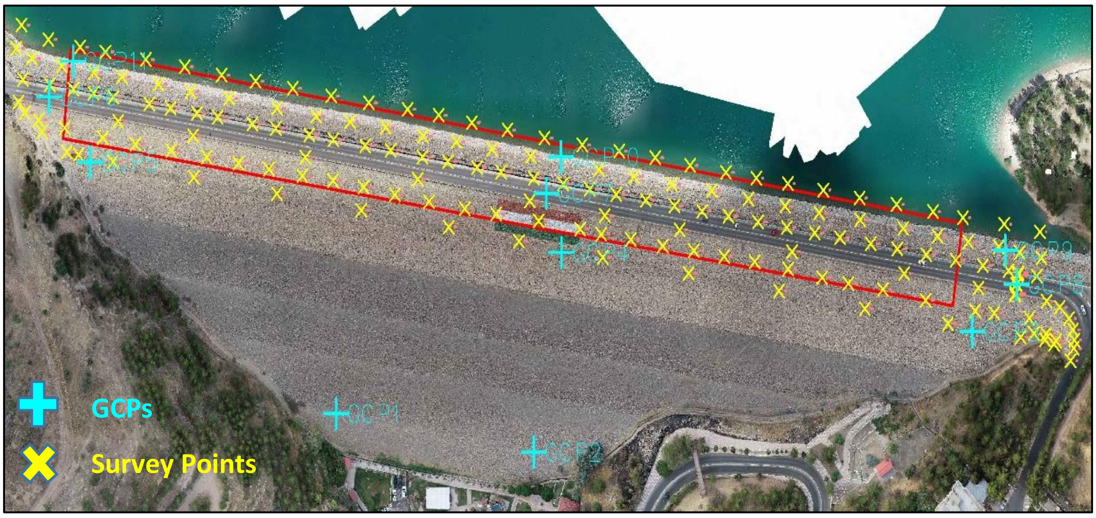


Fig. (5): Study area used for volume calculation with survey points and GCPs.

3.3. GPS- RTK SURVEY

In the recent years, the GNSS technologies have become an important part of the geodetic world. There are various types' receivers for different purposes. Generally, RTK receivers are used for engineering tasks (Raeva, Filipova, & Filipov, 2016). Leica viva GNSS was used in this study, GS10 as a base and GS15 as a rover as shown in Figure 6. The following technical parameters of GNSS, GS10 and GS15 with respect to the accuracy, stated by the manufacturer ±15mm ± 10 ppm RMS horizontal and ±20mm ± 10 ppm vertical. The GPS-RTK mode was used for measuring all GCPs coordinates as shown in figure 6 and about 200 volume survey points along the crest of the Duhok Dam including all characteristic points those create the terrain model such as edges as shown in Figure 5. The space between points did not exceed 25 m. The base was set up on a benchmark point with accurate and adjusted three dimensional coordinates (X, Y, and Z) obtained from manned Aerial Survey carried out by a Germany company named (GEOCART GmbH)(Devers, 2018).the point data were imported into AutoCAD Civil3D for volume calculation.

Fig. (6): Leica Viva GS10, base and Leica viva GS15, rover.

3.4. Methods of Volume Computation

There are four most frequently used methods for volume computation for different purposes which are :(Tucci et al., 2019)(Julge et al., 2019):

1. Cross sectional method.
2. Grid method.
3. Horizontal section (contour) method.
4. Prisms method.

The prisms method between two surfaces is discussed in this paper which is the fundamental source of the calculation used with the software.

The prisms method comprises of the definition of two surfaces, determined by using of interpolation of three-dimensional spatial data, one of them is the natural surface (upper surface) and the second one is the reference surface or base surface or design surface (lower surface); the quantity enclosed by these two surfaces is discretized into elementary prisms with a triangular base as shown in Figure 7 or trapezoidal prisms from which volume is computed using the following formula 1 (case of a triangular prism):(Tucci et al., 2019)

$$Vi = P\frac{\sum_{i=1}^{3} Hi}{3} \qquad 1$$

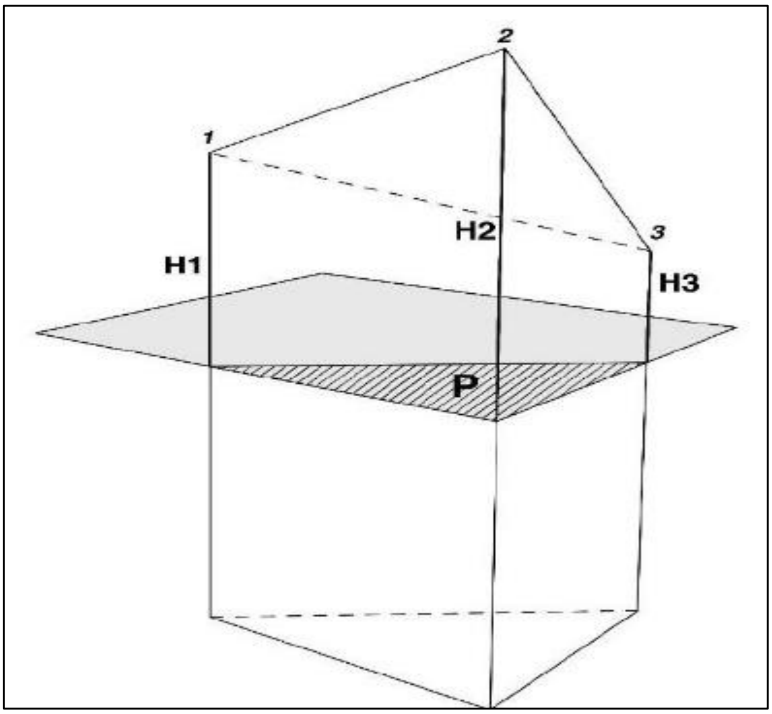


Fig. (7): Elementary triangular prism.

3.5. Data Processing

The GPS data collected using RTK technique were imported into the AutoCAD Civil 3D, and the elevation model was generated from these three dimensional points above MSL. Next, the process of volume computation was performed by comparing the DEM created using the GPS observations and the model that obtained by UAV process (different reference surface).

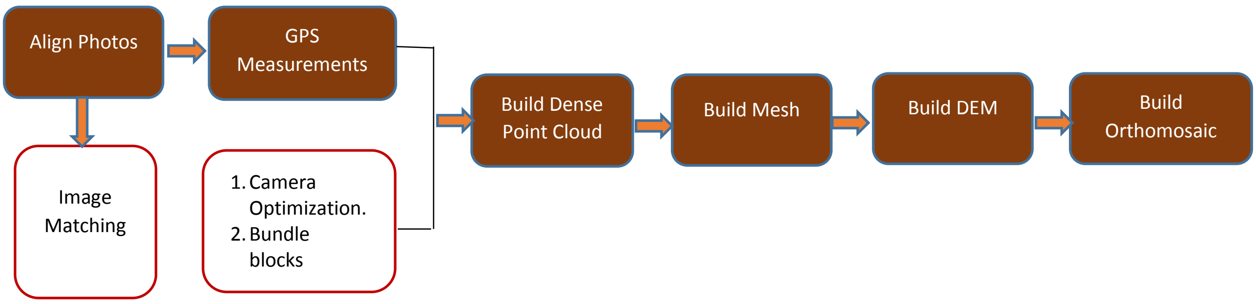


Fig.(8): Agisoft Software Workflow.

On the other hand, photogrammetric data were processed using Agisoft Photoscan Professional software (version 1.4.3) founded in 2006 which uses the Structure-from-Motion (SfM) that provides the users an opportunity of low-cost three-dimensional data acquisition (Akgul et al., 2017)(Micheletti, Chandler, & Lane, 2015). Agisoft PhotoScan Professional permits the generation of geo-referenced dense point clouds, textured polygonal models, digital elevation models and orthomosaics from a group of successive of overlapping photographs with the corresponding referencing information (Agisoft, 2017).

The software work flow begins with new project creation, recommended setting configuration and importing images with their metadata (camera details and settings).

Then, the image quality function was performed in order to examine which photo is blurred or distorted that may affect the results. This is an algorithm used to analyze contrast between pixels, the higher the contrast, the sharper the images (Agisoft LLC, 2013). Poor input, e. g. ambiguous photos can influence alignment results badly. This feature helped to exclude poorly focused images from photogrammetric processing.by removing images with quality value of less than 0.5 units, providing that the rest of the photos cover the whole scene to be reconstructed. This function has a scale ranged from 0 to 1, under 0.5 considered distorted or unwanted image (Agisoft, 2019). Fortunately, all images were accepted with a scale more than 0.8. The main processing steps as shown in Figure 8 were executed according to the recommended parameters setting by the Agisoft manual.

The first step which is aligning photos was lunched. At this phase, the software carries out the point matching process among the overlapped images and obtains the rough camera position and orientations for each photo and builds cloud model based on tie point. The next step was importing markers or GCPs into the software with txt supported file for the purpose of geo-referencing and optimization of camera positions and orientation data. The point cloud was transformed to WGS84-38N coordinate system automatically by the software. Furthermore, depending on the estimated camera position, the software computes the depth information for each camera in order to be combined into a single dense point cloud. The medium quality was chosen for dense point cloud building, higher quality takes longer time. After that, build mesh was built by selecting the height field option for the surface type (Samad et al., 2018). Based on dense point cloud DEM and Orthomosaic was generated as a final photogrammetric product (Fig.12).

As the DEM is built, it is possible to measure point, distance, area and volume. The software allows the volume measurement above three planes (reference surface) which are best fit, mean level and custom level planes. Best fit plane is an inclined surface calculated using interpolation of vertices of polygon drawn. Mean level plane is horizontal flat surface calculated using medium height determined by the heights of the vertices of polygon drawn. The third option is custom level plane which is horizontal flat surface at a reference height defined by the user. The last option was used in this study is the elevation levels of (596 to 610 m) at 1m interval. In addition to three polygons or boundaries with different areas, were imported into the software as a shape files as shown in Figure 5 which were the same boundaries used by the AutoCAD Civil 3D for volume computation.

4. RESULTS AND DISCUSSION

4.1. Results

Table 4 demonstrates the calculation of volumes obtained by two different techniques photogrammetric and GPS. In photogrammetric method, the volume obtained at three different altitudes (25,50 and 100) m with the variation of elevations of reference surface. The differences between volumes acquired by both techniques are calculated in cubic meters and in percentages.

Table (2): calculation of volumes obtained by two different techniques GPS and photogrammetric at three different altitudes (25,50 and 100) m.

Area3=17322.89 m2										
Elevation m / Altitude m	Photogrammetric volume m^3			GPS Volume m^3	Difference m^3			Differences %		
	A(25m)	B(50m)	C(100m)	D	A-D	B-D	C-D	(A-D/A)*100	(B-D/B)*100	(C-D)/C)*100
610	110186.18	110291.10	110316.10	110030.64	155.54	260.46	285.46	0.14	0.24	0.26
609	127508.64	127614.40	127639.40	127353.52	155.12	260.88	285.88	0.12	0.20	0.22
608	144831.12	144937.70	144962.70	144676.41	154.71	261.29	286.29	0.11	0.18	0.20

607	162153.70	162261.00	162286.00	161999.3	154.40	261.70	286.70	0.10	0.16	0.18
606	179476.18	179584.30	179609.30	179322.19	153.99	262.11	287.11	0.09	0.15	0.16
605	196798.66	196907.60	196932.60	196645.08	153.58	262.52	287.52	0.08	0.13	0.15
604	214121.14	214230.90	214255.90	213967.97	153.17	262.93	287.93	0.07	0.12	0.13
603	231443.70	231554.20	231579.20	231290.85	152.85	263.35	288.35	0.07	0.11	0.12
602	248766.18	248877.50	248902.50	248613.74	152.44	263.76	288.76	0.06	0.11	0.12
601	266088.66	266200.80	266225.80	265936.63	152.03	264.17	289.17	0.06	0.10	0.11
600	283411.14	283524.10	283549.00	283259.52	151.62	264.58	289.48	0.05	0.09	0.10
599	300733.72	300847.40	300872.30	300582.41	151.31	264.99	289.89	0.05	0.09	0.10
598	318056.18	318170.70	318195.60	317905.29	150.89	265.41	290.31	0.05	0.08	0.09
597	335378.66	335494.00	335518.90	335228.18	150.48	265.82	290.72	0.04	0.08	0.09
596	352701.14	352817.30	352842.20	352551.07	150.07	266.23	291.13	0.04	0.08	0.08

Figure 9 and 10 illustrates the relationship between the elevations of reference surface and differences in volumes between photogrammetric method and GPS technique.

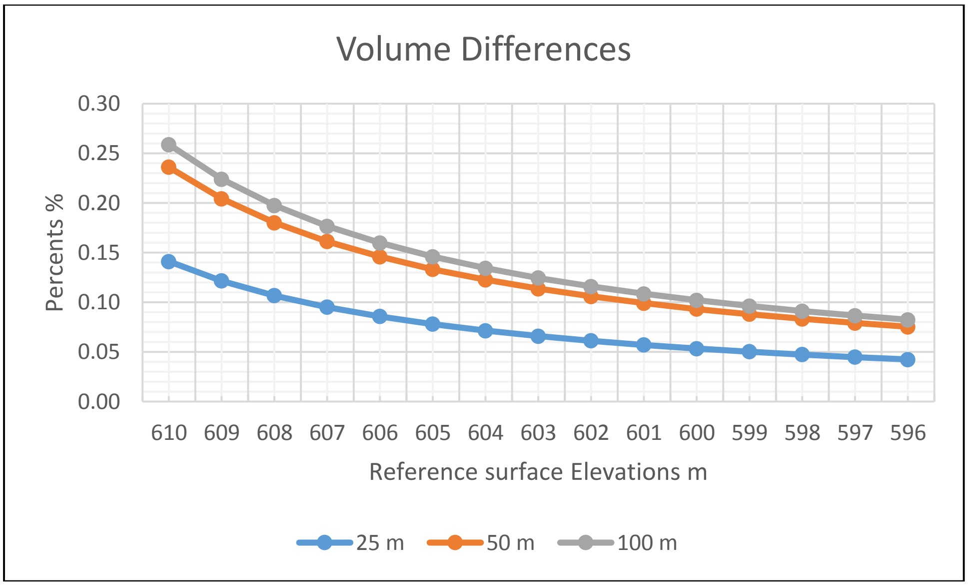


Fig.(9): Relationships of Reference surface levels with differences in percent at (25 m,50 m and 100 m) altitudes.

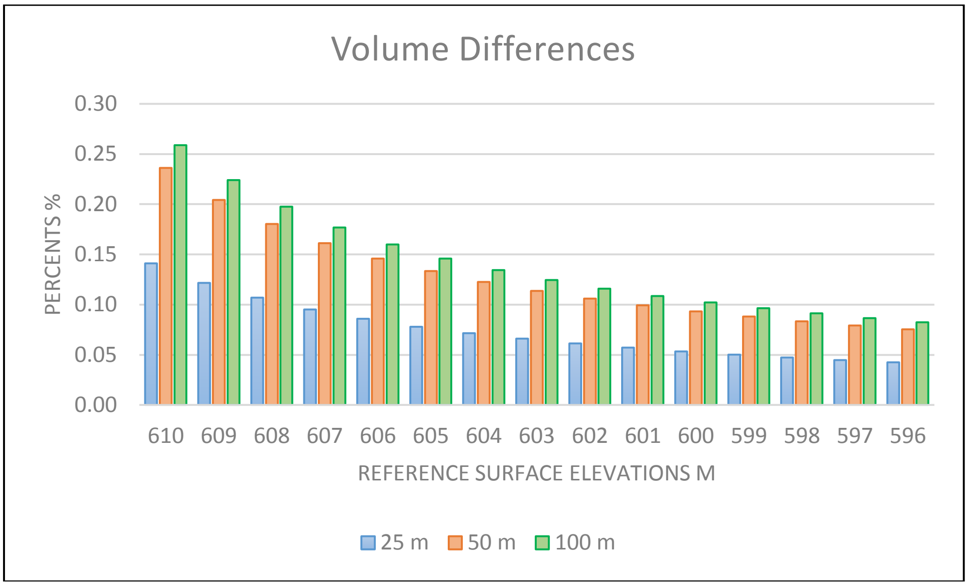


Fig (10): comparison between Volume differences in percent and Reference surface levels.

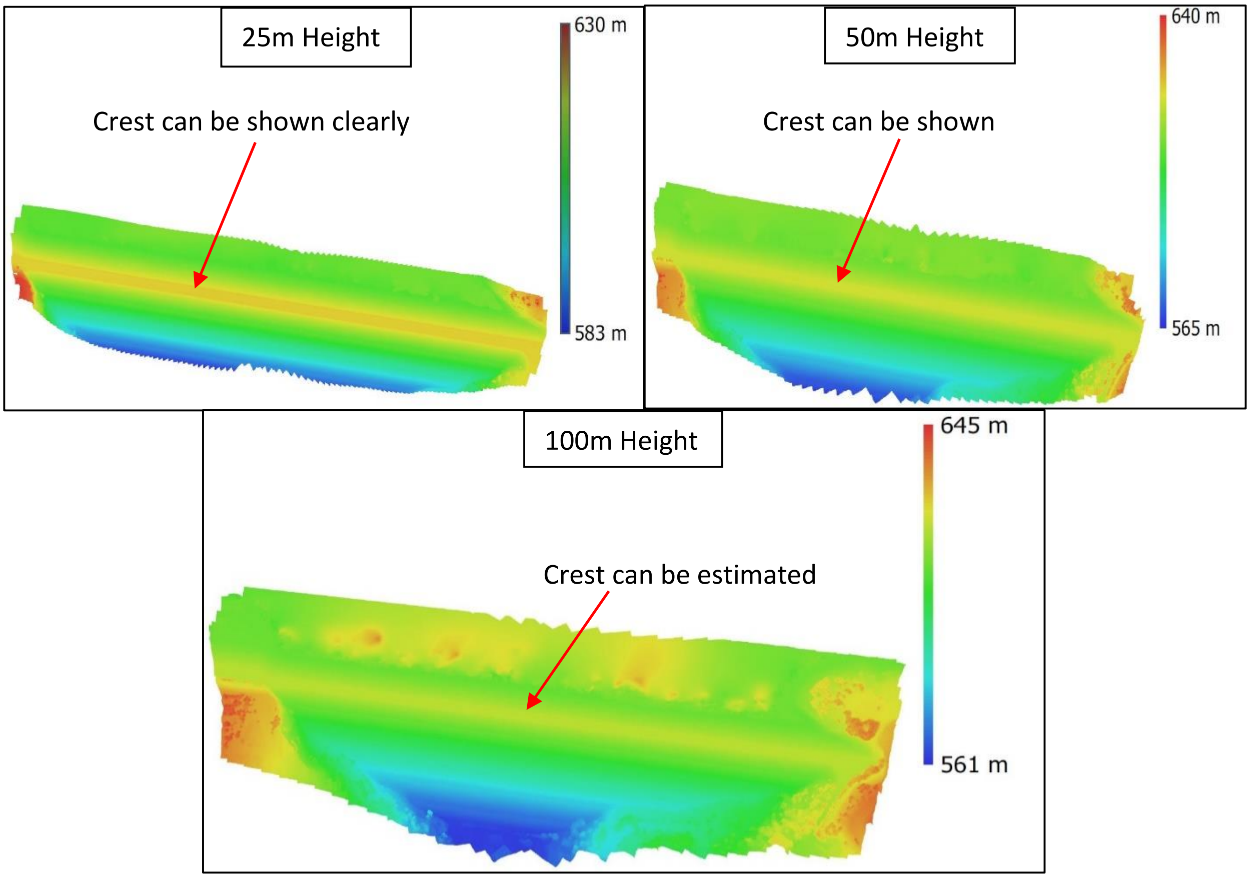


Fig. (11): Digital Elevation Models DEMs for 25m, 50m and 100m altitudes.

4.2. Discussion

In this paper, digital elevation model DEM generated by means of UAV images was assessed by comparing the volumes obtained by two different data acquisition techniques which were UAV and GPS. an area of (17322.89 m^2) was selected (Fig.5) with different elevations of reference surface ranged from 596m to 610m in one-meter interval. As the elevation of reference surface is increased, the difference in volumes increased as shown in figure (9 and 10).

The accuracy of volume calculation depends on many factors such as flight height, surface-volume ratio, surveying method, DEM, type of software used for processing and etc. Therefore, the final volume quantities are determined in relative terms not absolute terms. Surface-volume ratio is one of the factors that taken into account in this study, the smaller the surface volume ratio, the more accurate the volume as shown in (table 2). This is also explained by (Tucci et al., 2019), as the surface-volume ratio decreases, the computed volume will be more accurate. The impact of flying height is also considered, the higher flight provides larger area coverage, but with larger value of ground sample distance GSD too. However, the higher flight altitudes affect the value of GSD and level of details of the model, but it doesn't create systematic shifts (Julge et al., 2019).The lower the flight height, the more accurate the volume. The maximum difference occurred in the case of flight height 100m which was 0.26% difference (99.74% agreement) between volumes calculated by both methods, or 4.4 cm thickness over the entire surface area. In contrast, minimum difference was 0.14 % in the case of 25m altitude when elevation of base surface was 610 m. Generally, the best flight height among the three flight altitudes was 25m, while there was no significance difference between 50m and 100m altitudes in volume computation.

Accuracy of DEM is an important factor for volume computation. Previous studies indicated that it is possible UAV images for estimating volumes with sufficient accuracy (Stalin & Geoinformatics, 2017). Accurate DEM generated using UAV images provides cost effective data and proved that it is time-saving for earthwork in engineering works especially in road designing on lands with low vegetation or bare ground (Akgul et al., 2017).(Ulvi, 2018) accentuated that, there was a fourfold increase in the time required for volume calculation using classical methods than using UAV techniques as well as there was 99.33% agreement between volumes calculated by UAV and GPS methods. (Arango & Morales, 2015), demonstrated that volume estimation by means of UAV-based DEM is more accurate than traditional method with total station as well as it is faster than total station by six times in term of data acquisition.(Wang et al., 2017), also proved the suitability and preference of UAV in computing actual earthwork amounts compared to the traditional GPS method with an error ranged from 0.1% to 0.9% of the total earthwork quantities.

5. CONCLUSION

In this study, the accuracy of the Unmanned Aerial Vehicle UAV photogrammetry for volume computation comparing to the traditional GPS method was analyzed. The results showed that, the volume calculated using UAV-based DEM agreed with the volume obtained by GPS-RTK technique in the ratio of 99.74% (0.26% error),99.76 and 99.86 for flight heights (100,50 and 25) m respectively as shown in table 2. The worst ratio that is acceptable according to the latest literature ranges from 0.1% to 5% of the total volume. Flight heights lower than 100 m improve the general accuracy of the results, and provide a better achievement of some finer surface details too.

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