Study on Using Single UAV's image for Extraction Measurement of Flat Area

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Abstract. A new technology Unmanned Aerial Vehicles (UAV), is increasingly used by land surveyors for various applications. CV software for processing drone images has made great strides in making it easier to use and reducing the need for human intervention. CV method relies on tie point extraction from a set of overlapping images, which used to generate a model for the area of interest. However, using this technique to process large areas at an acceptable resolution requires huge photos and significant computer resources. Therefore, this study aims to assess the measurement accuracy that can be obtained from a single UAV image, taking into account the accuracy and time consumption. Firstly, the multirotor UAV was used to capture the ground at a certain altitude. Then the data were processed using two software packages. The outcomes of both software were compared against actual data for accuracy assessment. The results show that both processing methods provide excellent accuracy result; the ground resolution is within the range of 0.2~3.7cm\pixel, which comply with international standards. In conclusion, this study demonstrates the feasibility of using high accuracy UAV image to extract the measurement of a flat area with reliable accuracy in a short time.

1 Introduction

In conventional engineering survey works, topography information was obtained from land survey using Total Stations and GPS or more advanced technologies such as Global Navigation Satellite Systems (GNSS), Terrestrial Laser Scanning (TLS), and light detection and ranging (LIDAR) [1-2]. The conventional survey requires huge cost, labor, and time and error-prone [3].

A new technology Unmanned Aerial Vehicles (UAV), is increasingly used by land surveyors for various applications. In the last few years, UAVs became readily available tools, low-cost, which can be used for taking measurements from the air [4]. The recent development in sensors and flying platforms equipped with UAV such as GPS, Inertial Navigation System (INS), and flight control have significantly broadened the applications such as engineering surveys, creating orthophoto maps, and generating 3D models [5-6]. UAV shortens the time that has to be spent in conducting surveys in the field from several days to a few hours [4]. It increases the safety of people performing measurements as an operator can be out of a dangerous zone. The high-resolution photos taken by the UAVs are able to obtain metric information on the Earth's surface [6]. [7] Indicated the capability of drone images for data collection and the precise measurement of road applications.

UAV images processing software has taken greats progress toward making it easier to use and to reduce the need for human intervention [8-10]. UAVs aerial images can be processed using conventional photogrammetric methods or software from the field of computer vision (CV). The conventional photogrammetric relies on identified camera positions and designs the model by triangulation [11]. CV technique relies on tie point extraction, which is then used for Image Matching [12]. Generally, they are obtained in an iterative block adjustment that guarantees a robust solution and statistically correct. The whole process is called Structure from Motion (SfM) [13]. SfM is a method of creating 3-dimensional models from 2-D images that were acquired from different locations around the feature. However, even though the SfM technique has many potential applications, some issues still need to be enhanced to improve efficiency and accuracy. The drawback is that processing a high number of photos for large areas consumes a long time and requires significant computer resources, therefore processing large areas at an acceptable resolution is challenging. The number of photos that can be processed by Agisoft Photoscan depends on the available RAM and reconstruction parameters used [14-15]. The digital camera mounted with UAV is a non-metric camera with lens distortion, resulting in a higher geometric distortion of the acquired image and reducing the accuracy of data processing. Therefore, Camera calibration is essential to be done before obtaining the aerial images for recovering all camera parameters for aerial image processing. Few studies have been conducted using a single UAV image in detecting and classification of the object. [16] Used UAV image for detecting and classification of the object to extract the features on the model, features then

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obtained based on the edge information available on applying edge detection algorithm. [17] Used single UAV image on detecting road regions, the road seeds were identified based on the stroke width transformation (SWT) of road image. However, in the extracting of geometric features from a single UAV image, no studies have been conducted in this aspect. Therefore, this study, based on the above shortcoming, used a single UAV image to estimate the horizontal ground measurement of flat area, taking into account the processing time spent and accuracy. The lengths can be extracted based on the ratio between the ground truth lengths to the extracted pixels. In this study, firstly, the Multirotor UAV equipped with GPS used to capture the ground at a certain altitude. Then the Data was processed using UAV Agisoft and MATLAB software, Agisoft used to create an orthophoto from 40 images while MATLAB used to process a single photo for the same selected area. The outcomes were compared to actual ground data for accuracy assessment.

2 Methodology

2.1 Aerial Image Processing Techniques and Their Limitations

As discussed earlier, aerial images obtained by low-cost UAVs can be processed using conventional photogrammetric methods or software from the field of computer vision (CV). The conventional photogrammetric relies on identified camera positions and designs the model by triangulation [11]. CV method relies on tie point extraction, which is later used for photo matching. The difference between the traditional photogrammetric method and CV approach lies in the fact that the camera positions together with the scene structure are calculated simultaneously, and connections between images are determined automatically [18]. They are generally acquired in an iterative bundle block adjustment that guarantees a robust solution and statistically correct.

Bundle Block Adjustment is a technique to compute the relations between object coordinates and image coordinates. It is required that photos are taken with enough overlap, so a high number of connection images are needed. However, processing a high number of photos for large areas using SfM software such as Agisoft PhotoScan requires a significant computer, particularly graphics card resources. Therefore processing large areas at an acceptable resolution is difficult by using a computer with normal configurations. The number of photos that can be handled by Agisoft depends on the available RAM and reconstruction parameters used [14].

Camera calibration is a technique that has a significant influence on the accuracy of the final photogrammetric product. It is a method of approximating the interior parameters of the digital camera. Generally, it is an individual case and used to be carried out in a laboratory before the photos were obtained and aero-triangulation completed. However, orientation and calibration can be calculated in the same period with practical results; this called self-calibrating bundle adjustment or self-calibration. The whole process of defining 3D structure and camera parameters is called 'Structure from Motion' (SfM) [13].

2.2 Data Acquisition

Flight data acquisition of altitude approximately 67 m above ground level, have been performed using DJI Phantom 4 Pro UAV mounted with a GPS and digital camera to photograph the test area. The selection of this altitude is based on the different ground sampling distance values (GSD). This acquisition captured 40 full-color aerial images with an 80% overlap and 80% side-lap, which are sufficiently for processing by using the photogrammetric approach. This study used direct geo-referencing to perform the measurements without adding GCPs to the selected area. Total Station was used to measure the dimensions and angles of the chosen area for accuracy assessment. The data obtained were then processed using AutoCAD software.

2.3 Image Processing

2.3.1 UAV SfM Method

In this study, SfM software AgiSoft Version 1.4.5 used to process 40 UAV raw images. AgiSoft used to build an orthophoto of the selected area. The processing steps included aligning images, creating a dense point cloud, building a 3D mesh, and building a field geometry. The Agisoft requires camera information such as pixel size, focal length, radial lens distortion, and tangential distortion to carry out the interior orientation. Firstly, it detects points in the images, which are captured from different viewing, and lighting sources, then descript their positions. Finally, the descriptors of the points are used for object reconstruction across the successive images. The AgiSoft processing parameters and environment are shown in Table 1 (Fig. 1).

Table 1. Parameters defined in AgiSoft for UAV imagery.

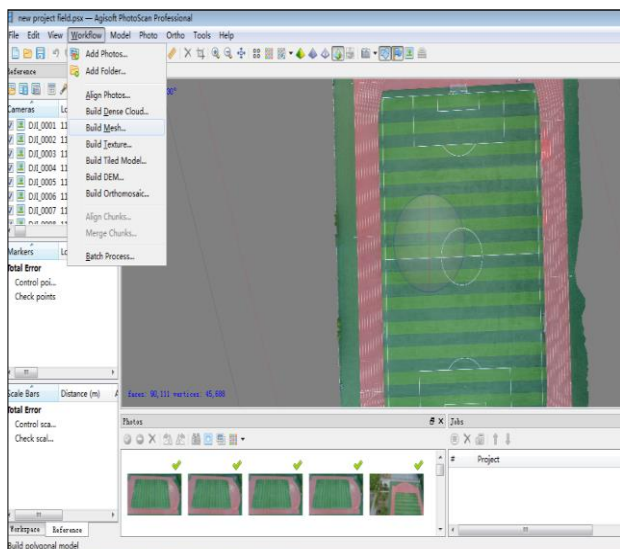| No. of images	40
Coordinate system	WGS 84 "EPSG 4326"
Key points	40,000
Tie points	4,000
Resolution	5472 x 3078
Camera model	FC6310
Focal length	8.8 mm
Ground resolution	3.73 cm/pix
Flying altitude	67 m

Fig. 1. AgiSoft environment during image processing.

The dimensions of the selected area are measured by using a third party software known as the Global Mapper software. A measuring tool used to draw a line on the orthophoto and calculate the dimensions of the model.

2.3.2 Image Processing Using MATLAB

To be able to extract the dimensions from a single UAV image, the image has to be scaled first, to scale the model, the ground measurements of the study area were obtained using the Total Station. Then the data can be extracted from the image based on the ratio between the ground truth lengths to the extracted pixels. This method can be used only in the extraction of the horizontal measurements of flat areas such as roads, lands, etc. The reason for choosing the area with a flat terrain is that the images obtained from UAV are two-dimensional, therefore the proposed method in this study not suitable in the extraction of sizes and heights.

In this study, MATLAB R2018b version was used to process a single UAVs image with a resolution of 5472x3078 pixel, the process steps as flow. First, the camera calibration parameters were used to correct the image distortion. Then the pixel coordinates of the football field's four corners were manually marked. After that, based on the marked points, the four corner points automatically extracted and transformed into a new rectangular image for oblique photograph correction. The football field circle' center x,y pixel coordinates point was then obtained, and the circle radius was fitted using the least-squares fitting method. The radius was obtained based on the ratio between the actual radius ground lengths to the extracted pixels, the obtained radius used as a reference to measure other field dimensions. Finally, the reliability of the proposed method is verified by comparing the obtained result with actual ground measurements. (Fig. 2) shows the process flow diagram of all the steps involved in edge detection, feature extraction, and the outcomes of these processes and (Fig. 3) shows the Grey-scaled and edge detection using MATLAB.
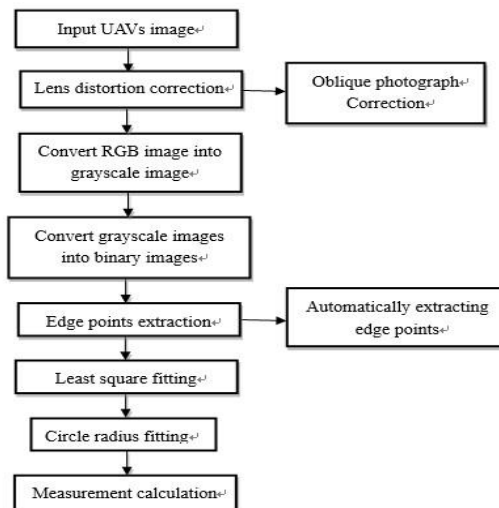

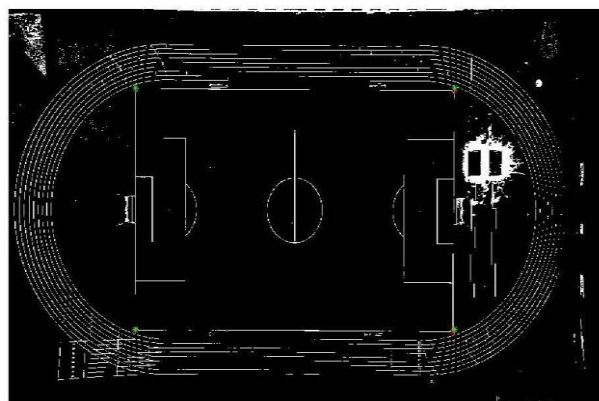**Fig. 2.** The process flow diagram using MATLAB.

Fig. 3. Grey-scaled and edge detection using MATLAB.

3 Case Study, Results and Analysis

In this paper, an area located in Southeast University Jiulonghu campus, Nanjing, Jiangsu Province, P.R. China used to illustrate the proposed method (Fig 4) shows the study area in google earth.

The selected area is a football field inside the university campus; the area chose because its location and terrain are suitable to do the study research. The data acquired by UAVs are ideal for proceeding by different software packages: software like AgiSoft and MATLAB were used in this study.

Fig. 4. Location of the study area in google earth.

The photo camera equipped on the UAV has to be calibrated. Camera implemented can be calibrated in laboratory conditions, or images can be calibrated during image processing. AgiSoft software has some advantages, it has self-calibration, and there is no need to worry about camera parameters before taking images. MATLAB software also has a calibration function, but the camera has to be calibrated in the laboratory, so photo camera parameters have to be known. These parameters have to be entered into the software first.

The computer specifications used in this study are Intel core i5, 4 GB RAM, and 2 GB graphics AMD Radeon 6600M for image processing. The orthophoto generated by AgiSoft consists of 73,286 faces of shape, and about 37,186 vertices from 40 images. The duration of creating an orthophoto took about 34 min and 5 s. For image processing using MATLAB, the whole period to process a single UAV image from input to output took about 7 min, using the same computer specification.

For orthophoto generated by AgiSoft, the time used to process 40 UAV images took about 34 min and 5 s. The more photos used, the more time spent. While for MATLAB, processing a single UAV image from input to output took about 7 min. On the other hand, the ground resolution of the orthophoto created by AgiSoft was 3.73 cm/pix, while it was 0.27cm/pix for a single image processed by MATLAB. Based on these results, both software provides excellent resolution results, which comply with international standards for horizontal accuracy [19]. MATLAB provides a better result in terms of processing speed. The main reason is that processing a single image by MATLAB can be done using a computer with standard configurations. While AgiSoft required a computer with high configurations to obtain an acceptable result. To extract the football field dimensions from the orthophoto generated by AgiSoft, a third party software known as the Global Mapper was used in this study. The dimensions were measured by using a measuring tool to calculate the regional area of the model. (Fig. 5) illustrates the procedure to measure

The dimensions of the football field and (Fig. 6) shows measurements that were obtained using MATLAB.The

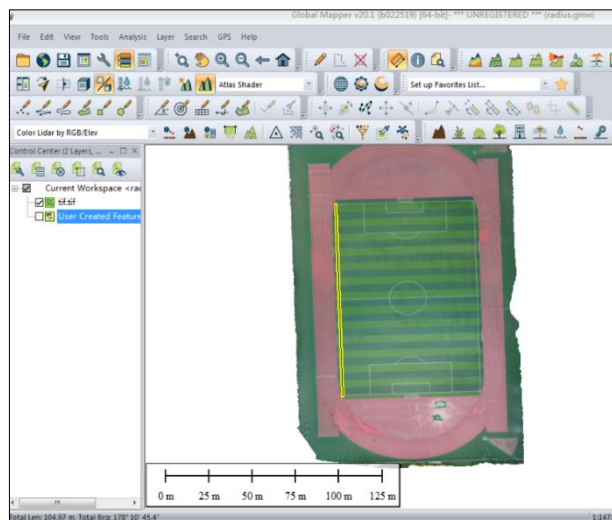outcomes of both software then compared against actual ground measurements for accuracy assessment Table 2.

Fig. 5. Measurement extraction using Global Mapper.
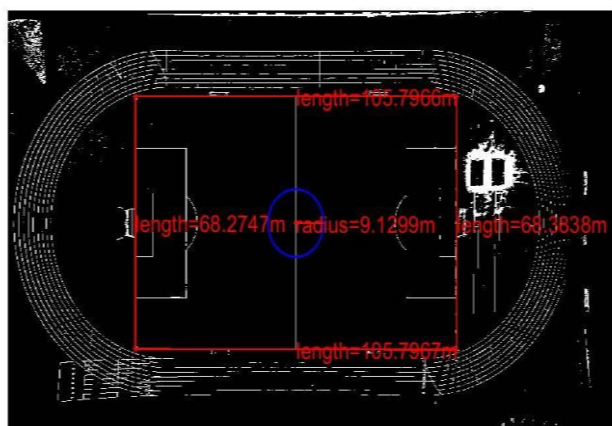

Fig. 6. Measurement extraction using MATLAB.

From the comparison in Table 2, for the measurements extracted by MATLAB, it was found that compared with ground measurements, a higher difference shown in length, which was 0.791 m, while for the lowest deviation, or the error was in the circle, which was 0.000 m. For the measurements extracted from AgiSoft orthophoto, to compare with actual measurements, it was found that the highest difference was shown in length, which was 1.004 m, while the lowest difference was in the circle radius, which was 0.0911 m.

From the comparison, the standard deviations between the extracted data using MATLAB and AgiSoft were

0.212 m for the length and 0.403 m for the width and 0.091 m for the circle radius.

Table 2 . Comparison between actual and extracted data.

Index	In-situ Measurement (m)	Extracted measurement (m) MATLAB	Errors (m)	Errors (%)	Extracted Measurement (m) AgiSoft	Errors (m)	Errors (%)

Length	105.006	105.7966	0.791	0.75	106.01	1.004	0.96
Width	67.9592	68.3292	0.370	0.54	68.733	0.773	1.13
Radius	9.1299	9.1299	0.000	0.00	9.221	0.091	0.99

4 Conclusions

This study used a DJI Phantom 4 Pro UAV mounted with GPS to capture the ground with flat terrain. The images were processed with two software packages AgiSoft PhotoScan and MATLAB. AgiSoft was used to create an orthophoto from 40 of UAV raw images, while MATLAB was used to process a single UAV image for the same selected area. The accuracy assessment was conducted by comparing the extracted measurements of both software with those obtained via field measurements. The results showed that both software provides acceptable accuracy result; the ground resolution is within the range of 0.2~3.7cm\pixel, which comply with international standards. Single UAV image processed by MATLAB consumes less time and is less laborious compared to 40 images processed by Agisoft.

In conclusion, the test outlined in this paper demonstrates the feasibility of using high accuracy UAV images to provide data for geometric design with reliable accuracy in a short time. In future researches, the accuracy of the geometric data can be improved and enhanced by using the advancement of UAV and other sensor technologies. GCPs can be added to the project to improve the final accuracy. Different image processing techniques can also be used to reduce the cost and time spent in image processing progress.

References

1. Lague, D., Brodu, N., and Leroux, J. (2013). "Accurate 3D comparison of complex topography with terrestrial laser scanner: Application to the Rangitikei canyon (N-Z)." ISPRS Journal of Photogrammetry and Remote Sensing. DOI: 10.1016/j.isprsjprs.2013.04.009

2. Sallenger et al., 2003 Evaluation of airborne topographic LIDAR for quantifying beach changes, Journal of Coastal Research 19(1):125-133.

3. Zulkipli, M. A., and Tahar, K. N. (2018). "Multirotor UAV-Based Photogrammetric Mapping for Road Design." International Journal of Optics. DOI: 10.1155/2018/1871058.

4. Aber, J., Marzolff, I., and Ries, J. (2010). Small-format aerial photography: Principles, techniques, and geoscience applications. The Photogrammetric Record.

5. Chao, H., Cao, Y., and Chen, Y. (2010). "Autopilots for small unmanned aerial vehicles: A survey." International Journal of Control, Automation, and Systems. DOI: 10.1007/s12555-010-0105-z.

6. Graça, N., Mitishita, E., and Gonçalves, J. (2014). "Photogrammetric mapping using the unmanned aerial vehicle." International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives.

7. Saad, A. M., and Tahar, K. N. (2019). "Identification of rut and pothole by using a multirotor unmanned aerial vehicle (UAV)." Measurement: Journal of the International Measurement Confederation. DOI: 10.1016/j.measurement.2019.01.093.

8. Küng, O., Strecha, C., Beyeler, A., Zufferey, J.-C., Floreano, D., Fua, P., and Gervaix, F. (2012). "The accuracy of automatic photogrammetric techniques on ultra-light UAV imagery." isprs - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences.

9. Liba, N., and Berg-Jürgens, J. (2015). "Accuracy of orthomosaic generated by different methods in an example of UAV platform MUST Q." IOP Conference Series: Materials Science and Engineering.DOI: 10.1088/1757-899X/96/1/012041.

10. Jaud, M., Passot, S., Le Bivic, R., Delacourt, C., Grandjean, P., and Le Dantec, N. (2016). "Assessing the accuracy of high-resolution digital surface models computed by PhotoScan® and MicMac® in sub-optimal survey conditions." Remote Sensing. DOI:10.3390/rs8060465.

11. Sona, G., Pinto, L., Pagliari, D., Passoni, D., and Gini, R. (2014). "Experimental analysis of different software packages for orientation and digital surface modeling from UAV images." Earth ScienceInformatics.DOI:10.1007/s12145-01301422

12. Colomina, I., and Molina, P. (2014). "Unmanned aerial systems for photogrammetry and remote sensing: A review." ISPRS Journal of Photogrammetry and Remote Sensing. DOI: 10.1016/j.isprsjprs.2014.02.013.

13. Nex, F. & Remondino, F., 2012. UAV for 3D mapping applications: a review. Applied Geomatics. DOI: 10.1016/j.jas.2010.10.022.

14. Agisoft LLC. (2018). Agisoft PhotoScan User Manual: Professional Edition, Version 1.4. Agisoft LLC.

15. Gross, J. W. (2015). "A Comparison of Orthomosaic Software for Use with Ultra-High Resolution Imagery of a Wetland Environment." Center for Geographic Information Science and Geography Department.

16. Ali, A. (2017). "Images classification and feature extraction by using unmanned aerial vehicles (UAV's)." International Journal of Applied Engineering Research.

17. Zhou, H., Kong, H., Wei, L., Creighton, D., and Nahavandi, S. (2017). "On Detecting Road Regions in a Single UAV Image." IEEE Transactions on Intelligent Transportation Systems. DOI: 10.1109/TITS.2016.2622280.

18. Snavely, K. N., 2008. Scene Reconstruction and Visualization from Internet Photo Collections, Washington: University of Washington.

19. "ASPRS Positional Accuracy Standards for Digital Geospatial Data." (2015). Photogrammetric Engineering & Remote Sensing. DOI: 10.1016/S0099-1112(15)30334-7.