Available online www.jsaer.com

Journal of Scientific and Engineering Research, 2020, 7(5):170-177

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Unmanned Aerial Vehicle and Large Scale Topographic Map for Design Purposes

Ngoc Quang Vu[1]*, Van Thinh Nguyen[1], Thanh Hoa Pham Thi[2]

[1]*Department of Surveying, University of Transport Technology, Hanoi, Vietnam
quangvn@utt.edu.vn
[2]Department of Photogrammetry and Remote Sensing, Hanoi University of Mining and Geology, Hanoi, Vietnam
phamthithanhhoa@humg.edu.vn

Abstract For decades, total station and direct measuring method is the main technique for making a large scale map, especially for construction design due to accuracy requirements, and it seems to be an irreplaceable measure. Data acquisition with an unmanned aerial vehicle (UAV) is a new approach and is not strange to the surveyor. The applications of UAV are various and increasingly expanding but due to the high accuracy needs, data collection for design purposes has not been applied much. This paper is an experimental study using an unmanned aerial vehicle (Phantom 4Pro) to collect topographic data and software (Agisoft photo scan) for image processing. The final product is a large scale topographic map of the area. For accuracy assessment, the horizontal and vertical position of the characteristic terrain on the ground will be compared to that using a conventional technique (total station and direct measuring). The results show that the deviation of X, Y direction ranges from 0.2 cm to 8.8 cm and 0.2 cm to 7.6 cm respectively. This number is from 0.2cm to 9.6 cm for the elevation.

Keywords Unmanned aerial vehicle, large scale map, total station, image processing

1. Introduction

In establishing a large scale map, especially for infrastructure design purposes, direct measuring techniques play a key role. Total station and RTK-GNSS with a single base at a short distance or Net-RTK at a longer distance are the main measures and are the most widely used due to the ease of achieving millimeter accuracy [1]. Parallel to accuracy, each method has different advantages and disadvantages [2-3]. In terms of safety, in some specific cases, engineers and workers would have to face risks. Besides, these are exorbitant and time - consuming measures and therefore, it is a big concern for small private companies and individuals. Terrestrial laser scanning (TLS) and LiDAR are the latest techniques for data acquisition. In terms of accuracy, TLS can satisfy surveyors with millimeter levels at a short distance but price and the number of scanning stations in the complex terrains are obstacles. Regarding Lidar, accuracy of elevation still is a difficult problem.

An overview of UAV's applications can be seen in [4]. Particularly, [5] listed a range of applications in marine supervision, especially in monitoring and emergencies. The use of UAV for environment monitoring, disaster supervision can be found in [6-7], and facility management are also listed in [8–10] or disaster response in [11]. In the field of wildlife research and conservation, [12] used UAV for Mesocarnivores supervision or use UAV for the protected areas[13]. This is also an advanced technology for supporting search and rescue operations [14].

Regarding the surveying field, [15]indicated that a UAV with an intervalometer can achieve accuracy as GNSS and conventional survey techniques. [16], [17]conducted further research and concluded that data acquired from

UAV can be used for creating DEM with only three ground control points. A problem is that why surveyors should use UAV as a replacement for conventional methods. The answer to this can be found by comparing them. For conventional methods, they are typically performed on food with a surveying team. Surveying equipment is tripods, total station, GPS.. and measuring data are points, distances, and angles. For others, the limitations are mentioned above. For the benefits of UAV, safety is the top priority of the surveying task. This technique is a safer method for high-risk fields including post-disaster scenarios, mountainous terrain. In terms of cost savings and the ease of use, it is cheaper than helicopter/plane surveys and capable of various kinds of surveying. The ease of use here is easy to transport and carry out. Result quality is the last interest. it provides better information than classical land survey measures [18]. [19] conducted a research and showed that UAV is the most time-effective measures in comparison to other methods and is slightly more expensive than topographic mapping (direct technique).

The applications of UAV are rich and increasingly expanding but in dada acquisition for construction and design purposes, it does not correspond to its potential due to high accuracy requirements. The application rate of UAV in construction can be seen in [20], and hence it approximately is 9%. For bridge inspection, two works were conducted in [20] and [21]. To test data acquisition for this purpose, an experiment will be carried out in a small area and compare to the total station method.

2. Materials and methods

2.1. Experiment procedures

For this work, the experimental procedure follows these steps.

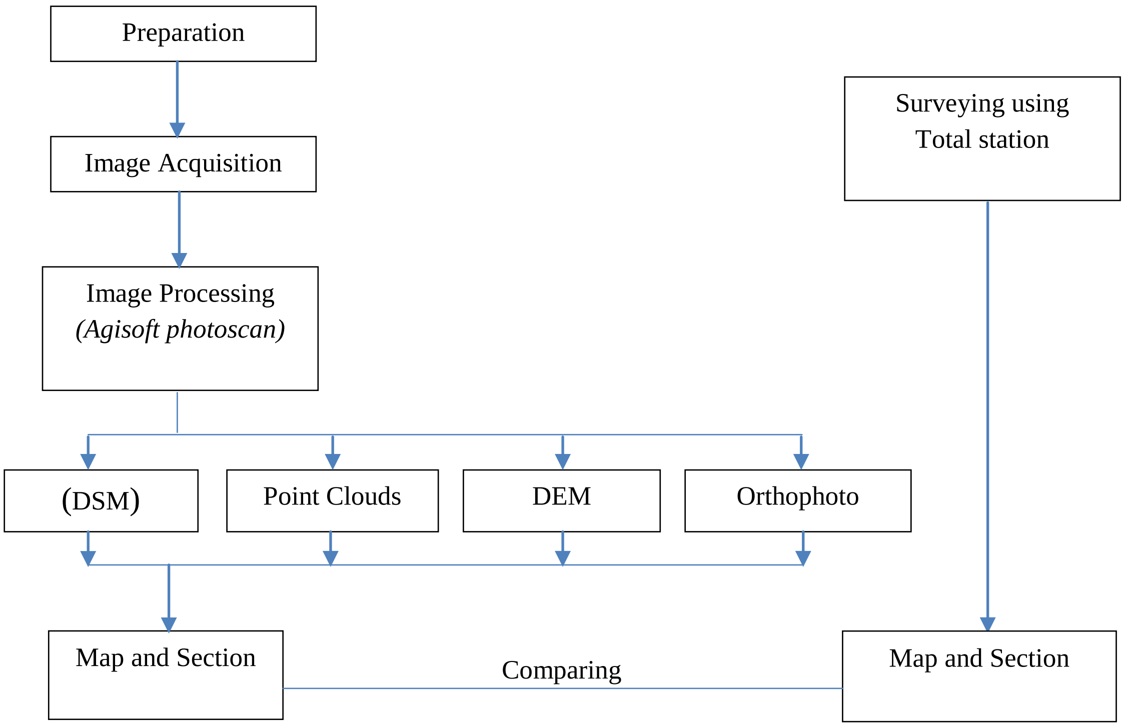

Figure 1: Execution Procedure

2.2. Study site

The image acquisition area is a 500m section of Long Bien – Xuan Quan dike beside the Red River in Thach Ban Ward, Long Bien District, Hanoi. The terrain is not too complex and the number of features is not large. The main feature is a dike section of the Red River. The largest difference height is about 8 meters.

Figure 2: Location of data acquisition

2.3. Equipment

The drone used for this work is a DJI Phantom 4 Pro (Fig. 3). The total weight is about 1380g, flight time is about 28 minutes, mainly depends on wind and payload with GPS/GLONASS positioning. The Camera sensor is 12 MP with a large field of view (94^0). Components and specifications can be seen in [22]. Camera quality plays a key role in image quality[23]

Figure 3: Phantom 4 Pro

2.4. Ground control points

Ground control points (GCPs) have an important role in the last result of the image. The number of GCPs and their quality have a huge impact on calibration image and hence accuracy of horizontal and vertical elements will be changed [24-25]. Therefore, there are 8 GCPs in the study site. These points are marked with the size of A1 paper (Fig 4a), have high contrast and were measured using a Sokkia total station (Fig 4b, c).

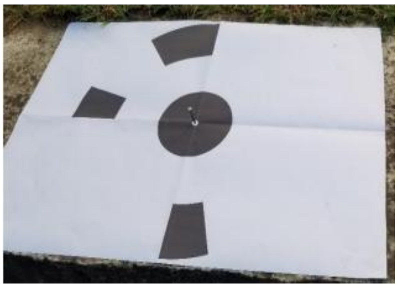

Figure 4a: Control point

Figure 4b: Target on tripod legs

Figure 4c: Measuring

8 GCPs are evenly distributed on the field, connected to 2 GPS points of a construction site and 1 national control point around the survey field. Coordinates are computed in the local coordinate system (VN:2000, zone 3^0). Their coordinates are in Table 1.

Table 1: Ground control points

ID point	X	Y	H
T1	2325085.774	593833.005	16.770
T2	2324999.609	593839.777	17.499
T3	2325197.980	593806.987	16.494
T4	2325222.585	593790.155	17.483
T5	2325053.412	593862.801	10.499

T6	2325232.682	593831.003	9.943
T7	2325145.082	593841.682	10.429
T8	2325255.581	593803.144	9.848

2.5. Image Acquisition and Processing

Drone altitude, image overlap including enlap, sidelap and optical sensor resolution have a huge influence on image quality [26]. For achieving the best conditions, PIX4DCAPTURE which is installed in an Apple tablet was used. The captured images after the flight process will be transferred into a workstation computer for the next processing steps. There is a variety of software to process and analyze the image data from the drone in the market. Each has different advantages [27-28]. For this work, Agisoft Photo Scan is used for image processing due to the highest accuracy it can achieve [29]. After building the needed models including building textures, orthomosaic, DEM, the necessary data (Xyz file, DEM, Orthophoto) are exported for making a large scale map purpose.

Figure 5: OrthoPhoto

Figure 6: DEM

Figure 7: Digitized map

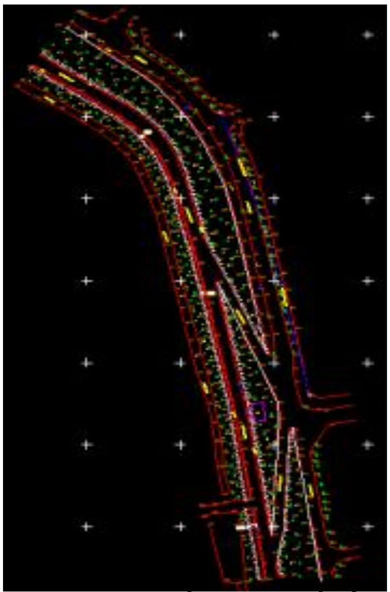

Figure 8: Total station method

3. Results and Discussion

For each measuring task, accuracy assessment is an obligation. It should be noted that there are 8 GCPs and all used in building DSM. As a suggestion in [30], the accuracy of elements including RMSEx, RMSEy, RMSExy will be conducted as follows.

$$RMSE_X = \sqrt{\frac{\sum_{1}^{n}(X_{Oi} - X_{TSi})^2}{n}} \quad , \quad RMSE_Y = \sqrt{\frac{\sum_{1}^{n}(Y_{Oi} - Y_{TSi})^2}{n}} \quad ,$$

$$RMSE_Z = \sqrt{\frac{\sum_{1}^{n}(Z_{Oi} - Z_{TSi})^2}{n}}$$

$$RMSE_{XY} = \sqrt{\frac{\left[\sum_{1}^{n}\left[(X_{Oi} - X_{TSi})^2 + (Y_{Oi} - Y_{TSi})^2\right]\right]}{n}}$$

$$RMSE_{XYZ} = \sqrt{\frac{\left[\sum_{1}^{n}\left[(X_{Oi} - X_{TSi})^2 + (Y_{Oi} - Y_{TSi})^2 + (Z_{Oi} - Z_{TSi})^2\right]\right]}{n}}$$

where X_{Oi}, Y_{Oi}, Z_{Oi}, X_{TSi}, Y_{TSi}, Z_{TSi} are the coordinate elements of *i*th point in the orthophoto and its coordinates measured by Sokkia total station respectively.

Table 2: Error elements of GCPs used in model calibration

Ord	Id Point	X error	Y error	Z error	XY error	XYZ error
1	T1	-0.004	0.005	0.000	0.0064	0.0064
2	T2	0.001	0.003	0.001	0.0032	0.0033
3	T3	0.000	0.003	-0.004	0.0030	0.0050
4	T4	0.005	0.005	-0.003	0.0071	0.0077
5	T5	-0.002	-0.001	0.001	0.0022	0.0024
6	T6	-0.002	-0.003	-0.003	0.0036	0.0047
7	T7	-0.002	-0.002	0.001	0.0028	0.0030
8	T8	-0.001	-0.004	0.002	0.0041	0.0046
RMSE		0.003	0.003	0.002	0.004	0.005

For the next step after a 1/500 scale was done, 17 points on the ground surface are randomly selected for a coordinate comparison between the UAV method and direct measuring by a total station. The error of the components X, Y, Z direction and position precision are in Table 3.

Table 3: The error of tested points

Point	UAV method			Total station method			ΔX	ΔY	ΔZ
	X	Y	Z	X	Y	Z	m	m	m
1	2325085.819	593832.962	16.772	2325085.774	593833.005	16.770	0.045	-0.043	0.002
2	2324999.607	593839.810	17.501	2324999.609	593839.777	17.499	-0.002	0.033	0.002
3	2325197.994	593806.966	16.481	2325197.980	593806.987	16.494	0.014	-0.021	-0.013
4	2325222.566	593790.175	17.489	2325222.585	593790.155	17.483	-0.019	0.020	0.006
5	2325053.446	593862.872	10.521	2325053.412	593862.801	10.499	0.034	0.071	0.022
6	2325232.764	593831.005	9.938	2325232.682	593831.003	9.943	0.082	0.002	-0.005
7	2325145.110	593841.712	10.421	2325145.082	593841.682	10.429	0.028	0.030	-0.008
8	2325255.572	593803.175	9.849	2325255.581	593803.144	9.848	-0.009	0.031	0.001
9	2325238.091	593779.737	17.484	2325238.048	593779.698	17.477	0.043	0.039	0.007

10	2325142.692	593812.052	17.598	2325142.716	593812.065	17.578	-0.024	-0.013	0.020
11	2325149.088	593818.553	16.527	2325149.000	593818.538	16.522	0.088	0.015	0.005
12	2325229.104	593831.198	9.955	2325229.131	593831.190	10.051	-0.027	0.008	-0.096
13	2325222.580	593833.827	10.061	2325222.522	593833.800	10.127	0.058	0.027	-0.066
14	2325205.262	593838.950	10.126	2325205.189	593838.999	10.211	0.073	-0.049	-0.085
15	2325234.345	593828.892	9.863	2325234.283	593828.881	9.953	0.062	0.011	-0.090
16	2325217.855	593835.568	10.099	2325217.847	593835.492	10.151	0.008	0.076	-0.052
17	2325199.284	593840.178	10.124	2325199.319	593840.176	10.212	-0.035	0.002	-0.088

Table 2 shows a fit of the DSM model. This is due to carefulness in measuring ground control points and a flight plan. In this study, image acquisition is carried out at a low altitude, ground control points are evenly distributed and the change of ground surface is not much.

Having a look at Tab 3, the biggest deviation of the horizontal and vertical position is about 8.9 cm (point 11) and 9.6 cm (point 12) respectively. Comparing to current standards which are applied for making large scale map, they are all accepted.

The only disadvantage of this method is the number of GCPs. Normally, it is not bigger than 2 or 3 GCPs if the total station is used or even it is not necessary with the RTK method is applied.

4. Conclusions

For this work, some outlines can be made.

Establishing a large scale map for design purposes can be carried out using the UAV method. For the larger areas, the elements including the number of GCPs and its distribution, flight altitude need to be carefully taken account into.

The number of GCPs needs to be reduced because of this task accounts for a large rate of the total cost of a survey project.

Conflict of interest

The authors declare that there is no conflict of interest

Acknowledgment

The authors are grateful for the support of the equipment and operating engineer of Viet Nhat company. Three students Duong, Linh, Chien have a significant contribution to the completion of the study.

References

[1]. J. O. Ogundare, *Precise surveying - The Principles and Geomatics Practice*. John Wi ley & Sons, Inc., Hoboken, New Jersey, 2015.

[2]. A. El-Mowafy, “Precise Real-Time Positioning Using Network RTK,” *Glob. Navig. Satell. Syst. – Signal, Theory Appl.*, pp. 161–188, 2012.

[3]. N. Q. Vu and V. T. Nguyen, “‘ Single Cors ’– An Experiment Study with Low-Cost GNSS Receiver,” *J. Sci. Eng. Res.*, vol. 6, no. 11, pp. 91–95, 2019.

[4]. S. Siebert and J. Teizer, “Automation in Construction Mobile 3D mapping for surveying earthwork projects using an Unmanned Aerial Vehicle (UAV) system,” *Autom. Constr.*, vol. 41, pp. 1–14, 2014.

[5]. G. Duan and P. Zhang, “Research on Application of UAV for Maritime Supervision,” *J. Shipp. Ocean Eng.*, vol. 4, pp. 322–326, 2014.

[6]. T. Chou, M. Yeh, Y. Chen, and Y. Chen, “DISASTER MONITORING AND MANAGEMENT BY,” in *ISPRS TC VII Symposium – 100 Years ISPRS*, 2010, vol. XXXVIII, pp. 137–142.

[7]. C. Luo, H. Ullah, S. I. Mcclean, and G. Parr, “Unmanned Aerial Vehicles for Disaster Management,” in *Geological Disaster Monitoring Based on Sensor Networks*, no. August, 2019, pp. 83–107.

[8]. T. Fráter, T. Juzsakova, J. Lauer, L. Dióssy, and Á. Rédey, “Unmanned Aerial Vehicles in Environmental Monitoring—An Efficient Way for Remote Sensing,” *J. Environ. Sci. Eng.*, vol. 4, pp. 85–91, 2015.

[9]. J. Yu, Z. Gan, L. Zhong, and L. Deng, "Research and Practice of Uav Remote Sensing in the Monitoring and Management of Construction Projects in Riparian Areas," in *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 2018, vol. XLII, pp. 2161–2165.

[10]. G. M. Bolla, M. Casagrande, R. D. Moro, and M. Destro, "ARIA : Air Pollutants Monitoring Using UAVs," in *IEEE International Workshop on Metrology for AeroSpace*, 2018, no. June.

[11]. S. Chowdhury, A. Emelogu, M. Marufuzzaman, and S. G. Nurre, "Drones for Disaster Response and Relief Operations : A Continuous Approximation Model," *Intern. J. Prod. Econ.*, vol. 188, no. April, pp. 167–184, 2017.

[12]. J. D. Bushaw, K. M. Ringelman, and F. C. Rohwer, "Applications of Unmanned Aerial Vehicles to Survey Mesocarnivores," *drones*, pp. 1–9, 2019.

[13]. J. J. López and M. Mulero-Pázmány, "Drones for Conservation in Protected Areas : Present and Future," *Drones*, vol. 3, no. January, 2019.

[14]. M. Półka, S. Ptak, and Ł. Kuziora, "The use of UAV ' s for search and rescue operations," in *International scientific conference on sustainable, modern and safe transport*, 2017, vol. 192, pp. 748–752.

[15]. M. Manyoky, P. Theiler, D. Steudler, and H. Eisenbeiss, "Unmanned Aerial Vehicle in Cadastral Applications," in *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 2012, vol. XXXVIII-1/, no. September, pp. 57–62.

[16]. M. Uysal, A. S. Toprak, and N. Polat, "DEM generation with UAV Photogrammetry and accuracy analysis in Sahitler hill," *Meas. J. Int. Meas. Confed.*, vol. 73, pp. 539–543, 2015.

[17]. S. Gindraux, R. Boesch, and D. Farinotti, "Accuracy assessment of digital surface models from Unmanned Aerial Vehicles' imagery on glaciers," *Remote Sens.*, vol. 9, no. 2, 2017.

[18]. B. Kunkel, K. Cohen, and M. Kumar, "Route Planning for Multiple Land Surveying Drones," in *42nd Annual AIAA Dayton-Cincinnati Aerospace Sciences Symposium*, 2017.

[19]. B. P. Fitzpatrick, "Unmanned Aerial Systems for Surveying and Mapping: Cost Comparison of Uas Versus Traditional Methods of Data Acquisition," University of Southern California, 2016.

[20]. E. Ciampa, L. De Vito, and M. R. Pecce, "Practical issues on the use of drones for construction inspections," *J. Phys. Conf. Ser*, 2019.

[21]. N. Hallermann and G. Morgenthal, "Visual inspection strategies for large bridges using Unmanned Aerial Vehicles (UAV)," in *IABMAS 2014, At Shanghai*, 2014, no. July.

[22]. *User Manual*. 2016.

[23]. J. Torres-Sánchez, F. López-Granados, A. . De Castro, and J. M. Peña-Barragán, "Configuration and Specifications of an Unmanned Aerial Vehicle (UAV) for Early Site Specific Weed Management," *PLoS One*, vol. 8, no. 3, 2013.

[24]. D. T. Bui, N. Q. Long, X. Bui, and N. V. Nghia, "Lightweight Unmanned Aerial Vehicle and Structure-from-Motion Photogrammetry for Generating Digital Surface Model for Open-Pit Coal Mine Area and Its Accuracy Assessment Lightweight Unmanned Aerial Vehicle and Structure-from-Motion Photogrammetry for Gene," in *Advances and Applications in Geospatial Technology and Earth Resources*, Springer International Publishing AG, 2018, pp. 18–32.

[25]. K. N. Tahar, "An evaluation on different number of ground control points in unmanned aerial vehicle photogrammetric block," in *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives*, 2013, vol. XL-2/W2, no. November, pp. 93–98.

[26]. E. Seifert *et al.*, "Influence of drone altitude, image overlap, and optical sensor resolution on multi-view reconstruction of forest images," *Remote Sens.*, vol. 11, no. 10, 2019.

[27]. D. Kaimaris, P. Patias, and M. Sifnaiou, "UAV and the comparison of image processing software," *Int. J. Intell. Unmanned Syst.*, vol. 5, no. 1, pp. 18–27, 2017.

[28]. J. S. Visockiene, D. Brucas, and U. Ragauskas, "Comparison of UAV images processing softwares," *J. Meas. Eng.*, vol. 2, no. 2, pp. 111–121, 2014.

[29]. G. Sona, L. Pinto, D. Pagliari, D. Passoni, and R. Gini, "Experimental analysis of different software

packages for orientation and digital surface modelling from UAV images," *Earth Sci. Informatics*, vol. 7, no. 2, pp. 97–107, 2014.

[30]. F. Agüera-Vega, F. Carvajal-Ramírez, and P. Martínez-Carricondo, "Accuracy of digital surface models and orthophotos derived from unmanned aerial vehicle photogrammetry," *J. Surv. Eng.*, vol. 143, no. 2, pp. 1–10, 2017.