Review of Unmanned Aerial Vehicle Photogrammetry for Aerial Mapping Applications

N. M. Zahari[2(✉)], Mohammad Arif Abdul Karim[2], F. Nurhikmah[1,2], Nurhanani A. Aziz[1,2], M. H. Zawawi[2], and Daud Mohamad[2]

[1] UNITEN R&D Sdn Bhd, Universiti Tenaga Nasional (UNITEN), 43000 Kajang, Selangor Darul Ehsan, Malaysia
cikfarahghazali@gmail.com, nurhanani_abdaziz@yahoo.com

[2] Department of Civil Engineering, College of Engineering, Universiti Tenaga Nasional (UNITEN), 43000 Kajang, Selangor Darul Ehsan, Malaysia
mubinzahari@gmail.com, arif970920@gmail.com, {MHafiz, Daud}@uniten.edu.my

Abstract. Unmanned aerial vehicle (UAV) photogrammetry one of the most popular photogrammetry technique due to short period of time for data acquisition and low costs compared to the use of classical manned aircrafts. This technique widely been used in many kind of application that related to aerial mapping. This paper review the UAV photogrammetry used for aerial mapping applications. The previous results by others researchers showed the capability of the UAV photogrammetry captures the complex shape and topography. The application for the image processing uses a sequence of 2-dimensional (2D) images to recreate a scene and built it in 3-dimensional (3D) model. The study will utilize the software for 3D models reconstruction which are open source tools and commercial software packages. The study also describe the brief idea to enchance the uses of the UAV photogrammetry in research. End user will have ideas using of the software for photogrammetry.

Keywords: UAV · Photogrammetry · Aerial · Mapping

1 Introduction

Unmanned aerial vehicles (UAV) or commonly known as drones were initially invented for military purposed, then the uses of drone with additional functional by adding camera, the drone can be used for surveying high level areas or dangerous area (Madawalagama et al. 2016; Ajayi et al. 2018). The creation of structure from motion based method for digital photogrammetry from multiple converging images resulting to an outburst of 3D terrain reconstructions in high resolution (Dering et al. 2019). The UAV systems equipped with photogrammetric cameras have shown enough accuracy for many applications in civil engineering (Díaz-Vilariño et al. 2016). The advantages of UAVs are it require lesser time compared to other techniques for data acquisition and minimize the cost (Aber et al. 2010; Agüera-Vega et al. 2018). From

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the previoues study shows that, UAV photogrammetry is more accurate than Terrestrial Laser Scanning (TLS) when used in terrain mapping (Gruszczyński et al. 2017). Through the leveraging state of the art methodologies, the research mentioned in (Pierdicca 2018) paper shows how a precise reality-based model (compatible for documentation purposes) can be achieved with a robust pipeline, also beginning from unplanned acquisition and rough data sets. UAV photogrammetry monitoring of 3D areal displacements was revealed in (Kemal Özgür Hastaoğlu 2019) study.

The previous study has shown that to produce highly accurate reconstructions and models of land shapes and historic landscape structures, UAV technology can be used as a well-organized and dependable tool. This showed that it is necessary to use of high-resolution UAV-based data for the evaluation of the authentic storage capacity of historical landscape structures, that is essential information for the future application in water management and flood mitigation plans. Besides that, although the UAV imaging is a relatively low-cost technology, it is powerful enough to generate 3D models. The exactness obtained is compared to that obtainable from land survey approaches, Manned Aerial Vehicles and LiDAR data, all of which are more costly. It has been shown in (B. Kršák, 2016) that the surface model generated using a photogrammetric approach using low-cost UAV and low-cost cameras meets the desired accuracy requirements and can generally be considered as a convenient tool for data collection in surface mines. Thus, the objective of this paper is to review the application of UAV photogrammetry used for aerial mapping applications.

2 Reconstructed Point Cloud

Rather than using geo-referencing, UAV photogrammetry use the Ground Control Points (GCP) into a reconstructed point cloud based on UAV, or the camera exposure stations is used based on Real-Time Kinematic (RTK), for direct geo-referencing method. The studies carried out to compare these approaches show that the GCP measurements produce more reliable results in 3D positioning (Stöcker et al. 2017; Forlani et al. 2018; Rabah et al. 2018). In accordance with the same flight plan in the study of (Forlani et al. 2018), four different flights were conducted for each RTK mode over a field trial. Three block control configurations were used to produce the Digital Surface Model: GCP only, camera stations only, camera stations and one GCP. From the result, the first and third configurations offer the greatest accuracy in 3D positioning irrespective of the RTK mode. Moreover, (Stöcker et al. 2017) has reported that thorough investigations of the external orientation variables show that the addition of four GCPs will minimize systemic sensor misalignments and offsets of the image block. On this matter, the application of post-processing cinematic corrections decreases time-consuming field work to estimate the high quantities of GCPs and makes extensive scale UAV mapping a more practicable solution for cm-level practitioners. The research by (Rabah et al. 2018) showed that classical Aerial Triangulation is more reliable than the DG of UAV imagery. These researches show that while drones with on-board receivers capable of positioning RTK are being used, only few GCPs are needed to achieve more precise performance in 3D positions. Furthermore,

the study by (Díaz-Vilariño et al. 2016) also show that the similarity of photogrammetry vs LiDAR as shown in Fig. 1.

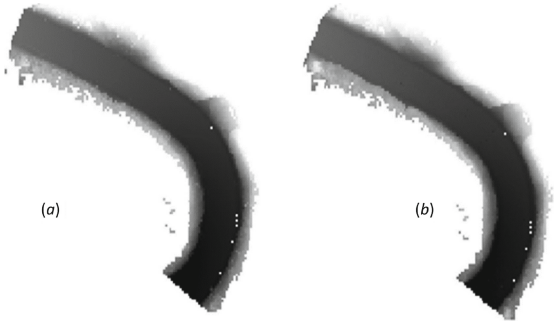

Fig. 1. Digital elevation model (DEM) with resolution of 1 m per pixel from (a) LiDAR and (b) photogrammetric system.

The overpriced cost associated with aircraft use and the consumption of time nature makes this strategy an unsuitable solution, particularly for small scale analysis (Al-Rawabdeh et al. 2016). Photogrammetry will create 3D and 2D full-colour terrain models in the different light spectrum that are easier to view. The key outputs of the photogrammetric surveys were raw photographs, ortho photograms, Virtual Surface Models and 3D point clouds created from the stitching and processing of hundreds or thousands of images (Agüera-Vega et al. 2018). Therefore, it is an optional method compare to Light Detection and Ranging (LiDAR), which is expensive but dominant in mid-air, to obtain high-resolution virtual surface models.

3 Method for Image Processing in Photogrammetry

End user will choose the software by of it graphical user interface, friendly user and easy to learn. In addition, basic of photogrammetric triangulation feature where it can process various types of imagery e.g. aerial & close range which also provides easy auto calibration. Software can create dense point clouds where its points classification to customize geometry reconstruction and elaborate model editing for accurate results. The final feature will be the generation and texturing of 3D model that creates photorealistic textures. The ambition is to unravel the figure in a compact image descriptor, which allows computing the gap between all images descriptors effectively. All the features is to match between candidate image pairs and continued to structure from motion where the input images, and infer the rigid scene structure (3D points) that provides the geometric relationship behind all pose observations (position and orientation) and internal configuration of all cameras. After that, depth map estimation is done and then followed by mesh where it creates a scene representing a dense geometric surface. After meshing there is texturing, then ended by localization based on the SFM results. Table 1 listed the method for image processing in UAV photogrammetry.

Table 1. List of image processing software based on previous study.

Name	Authors	Remarks
COLMAP	(Schonberger and Frahm 2016; Cui et al. 2019; Sun and Tao 2019; Wang et al. 2019; Xu et al. 2019; Law et al. 2020; Liu et al. 2020)	• It is a photogrammetry software available to download for free • Can conduct either from the command-line or work it like any other program with a GUI • Can reconstruct 3D objects automatically either from single-camera or stereo setups
Meshroom	(Douglass and Caraça Santos 2019)	• It can perform up to complete 3D construction of textured surface design • The program connects all the steps to generate a 3D model that built around an convenient node-based workflow
MicMac	(Zhou et al. 2020)	• It can create 3D models and orthographic images. Plus, the photogrammetry software can control any type of object or scale desired • As capable of surveying wide-ranging of land as of scanning small items
Multi-View Enviroment	(Kempkens et al. 2000; Kiss and Szirányi 2013; Fuhrmann et al. 2015; Yao et al. 2019)	• Thorough process of pipeline for image-based geometry resetting. Features include Structure from Motion (SfM), Multi-View Stereo and Surface Reconstruction
OpenMVG	(Cui et al. 2017)(Muñoz-Salinas et al. 2018)(Liu et al. 2020)	• It tends to focus on the structure from motion (SfM) photogrammetry technique, with a number of built-in tools around it • All its interface and models are checked to ensure they not only function properly but also perform well in actual situations
Autodesk ReCap	(Peña-Villasenín et al. 2020)	• The software is develop for integration which relies on multiple tools. Users can export the result to CAD and BIM software as a point cloud or mesh • In addition to capturing large 3D structures, this software is also features high-quality analytical tools, advanced editing, UAV/drone flying features and collaborative instruments

(*continued*)

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Name	Authors	Remarks
Agisoft Metashape	(Reu et al. 2013; Li et al. 2016; Kurniawan et al. 2019; Peña-Villasenín et al. 2020; Zhou et al. 2020)	• It provide all-in tools for editing the point cloud before creating a 3D mesh like grading of point clouds automatically to personalize geometry reformation • It can distinguished between different objects like buildings and trees allowing users to filter them
Drone Deploy	(Field et al. 2017; Ezat et al. 2018; Rakha and Gorodetsky 2018; Scarpa and Piña 2019)	• Allow users to define the scan area on interactive map and set the direction of the drone will follow. The app supervise the entire flight starting from take-off until landing • Featuring powerful tools that enable users to calculate lengths, areas, and volumes
iWitnessPRO	(Fraser and Cronk 2009; Jazayeri et al. 2014; Schmitt et al. 2017)	• Without the presence of GPS data, the software can seam together the models and work data from drone photography and stills from videography
Photomodeler	(Green 2002; Lynnerup et al. 2003; Hernán-Pérez et al. 2013)	• Capture precise measurements and create a broad variety of purposes for 3D models • Provides a range of analytical tools
Pix4D	(Liu et al. 2020; Peña-Villasenín et al. 2020; Zhou et al. 2020)	• Provide from start until the end photogrammetry solution. It not only include the generation of point clouds, 3D meshes or imagery elevation maps, at the same time it help in recording the suitable images
Reality Capture	(Risse et al. 2018)	• It can create a geolocation and high-resolution orthographic views photo textured meshes, photo based point clouds with elevation maps. It can also create 3D models of object using object mode.

4 Conclusion

It is very important for the method to produce accurate and consistent data in order to plan the measurements and to select ground sampling distance values according to the expected quantities of displacement. Parameters such as expanding the amount of deformation plates, reducing flight speed and altitude, and using a high-resolution camera would then enable smaller displacement quantities to be determined. With regard to the accuracy of the generated model, it is proven, due to the concept of digital photogrammetry and aerial imagery software processing, these models are much more precise compared to models created only from terrestrially determined detailed point.

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