A comparative study of modern UAV platform for topographic mapping

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Abstract. Unmanned Aerial Vehicle (UAV) has emerged as latest and widely used surveying equipment worldwide for topographic mapping. There has been a growing increased in number and type of UAV platform for image capturing. This research aims at analysing the effects of UAV platform on image quality and further on its output products like orthomosaic, Digital Surface Model (DSM), Digital Terrain Model (DTM) and contours. For this study, part of the main campus area of Universiti Teknologi Malaysia has been selected, covering around 0.52 sq. km. Two different types of UAV surveying platforms used are eBee classic fixed wing (eBee) and DJI Phantom 4 Advanced (P4) multirotor quadcopter. Surveying through both the platforms conducted by flying both UAV’s on 300 meters height, with 75% front and 75% side overlap. Both have almost identical camera parameters so as ground sampling distance (GSD). 8 ground control points (GCPs) for image processing and 15 checkpoints (CP) were used for accuracy assessment. Final processing is done by using Pix4D software. The results show that all the UAV output were successfully produced for both type of UAVs. In general, the output of P4 UAV is superior to eBee UAV. As conclusion, the P4 UAV is more practical to be employed for topographic map of small area coverage as shown in this study due to capability of producing accurate result, portable, low cost and offer other advantages.

Keywords. UAV, Fixed Wing, Multirotor, Orthomosaic, RMSE

1. Introduction
Aerial photography and digital photogrammetry is one of the most important modern medium for topographic mapping. Aerial photography for mapping classified can be classified into two broad categories as traditional/commonly known as classical aerial photography with a pilot on board and remotely piloted aerial vehicles capturing images automatically commonly known as drones or unmanned aerial vehicle (UAVs). UAV was first developed for military purposes. However, the potential of UAV for mapping industries was not revealed until the late twentieth century, when a research group performed a test with a three-meter length fixed-wing UAV equipped with a 6×6 medium format camera [1]. Unmanned Aerial Vehicles also termed as Drones, are remote controlled flying robots capable of semi or fully autonomous airborne operations for data capturing and transmission [2]. UAVs have several advantages over traditional remote sensing platforms, such as higher flexibility and
lower cost in collecting images, higher speed and better security. More importantly, the images are acquired with very high resolution (VHR), providing sufficient details for identification and extraction of objects [3].

Nowadays, more and more UAVs are recruited for civilian applications because of its high mobility and flexibility [4]. UAV can be categorized in terms of weight, altitude and range, and other criteria. According to weight we have micro UAV (less than 2kg), mini UAV (2 to 8 kg), small UAV (8 to 25-30 kg) and tactical UAVs (25-30 to 400 kg) [5]. The choice of UAV platform is mainly governed by price and mapping environment. UAVs may be classified into two types on the bases of their take off maethod: Multi Rotor and fixed-wing. The Multi Rotor also known as vertical take-off and landing (VTOL) can easily launch in small spaces that is why easily deployable and more maneuverable in tight spaces. They can easy lift heavy weights sometimes heavier than their own weight. The disadvantage of multirotor is their lower endurance. As far as fixed wing is concerned, the unmatched advantage is its long endurance with large area coverage but it needs vast area for landing and takeoff which is challenging in densely populated or vegetated areas. However both types of Drones are progressively used for high-resolution large scale landscape mapping [2].

Mainly the researchers are with the opinion that fixed wing is a better UAV system than multirotor, because of more endurance and area coverage of fixed wing. This research focuses on the comparison of eBee fixed wing and DJI Phantom 4 Advanced (P4) multirotor (quadcopter) for usage in topographic representation of earth surface. Both platforms belong to micro UAV category having less than 2kg weight. Table 1 provides detailed specifications of the two platforms for comparison.

| Table 1. Specification of DJI Phantom 4 Advanced and eBee classic UAVs. |
|-------------------------------------------------|
| **Type** | DJI Phantom 4 Advanced | eBee Classic |
| Endurance | 30 minutes | 45 minutes |
| Landing | Vertical | Belly (need big area) |
| Camera | Fix | Interchangeable |
| Camera Resolution | 20 MP | 18 MP |
| Image dimension used | 4864 x 3648 (17.7 MP) | 4896 x 3672 (17.9 MP) |
| Ground sampling distance | Down to 0.7 cm | Down to 1.5 cm |
| Gimbal | 3-axis (pitch, roll, yaw) | N.A |
| Flight planning | Open source | eMotion |
| Radio Link | 4 km nominal (up to 7 km) | 3 km nominal (up to 8 km) |
| Wind resistance | 10 m/s | 12 m/s |
| Price | $1,649 | $17,990 |
| www.theverge.com (April 2017) | www.newatlas.com (Oct 2016) |

2. Study Area
The test area used for this study is located in southern part of peninsular Malaysia to be exact it is the main campus area of University Technology Malaysia. The study area geographically extends between the latitudes from 1.556731°N to 1.563133°N and from longitude 103.634682°E to 103.641662°E covering an area of approximately 0.52 km² (Figure 1). It is a challenging study site because this area is built on a hill and it has all modern developments like buildings and roads as well as terrain variations.
3. Data Acquisition

Two types of UAVs were used for image acquisition: a rotary-wing quadcopter (quadcopter) (Phantom 4 Advanced from DJI, Shenzhen, China) and a fixed-wing eBee Classic from Sensefly (Cheseaux-Lausanne, Switzerland). Fieldwork for eBee was done in October 2018 and for P4 was done in February 2019. This selection of the season was to ensure the minimum cloud coverage, to avoid shadows and image blur due to poor light conditions. For data acquisition the first step was flight planning. Flight planning refers to the initial determination of flight geometry, given the area of interest and the required end-product, and thus the desired accuracy [6]. Prior to this, it was a difficult task to plan a flight to cover whole study area but thanks to the modern flying planning software as their main advantage is to require minimum user interferences. After the parameters such as overlapping of photos, waypoints, flight path, and altitude had been defined on an online map and uploaded, the UAV carried out the flight plan automatically [7]. P4 flight was planned by using DroneDeploy (Figure 1) and total 57 images were found usable rest were deleted, total 7 flight lines used to cover the whole area, eBee flight was planned in eMotion (Figure 1) with eight flight lines and 59 images were found usable rest of the images were also deleted. Table 2 provides details for flight planning and execution parameters.

4. Data Processing

Close range photogrammetry techniques are increasingly exploited in geosciences, thanks to the consumer friendly technical handling and robust and fast image processing technologies [8]. Mainly the UAV image processing software relies on SFM (Structure from Motion) technology. The SFM technique has feature extraction, matching, bundle block adjustment, and dense matching steps to derive a high resolution 3D point cloud of the area solely based on images [9]. The acquired images from the two platforms were processed in Pix4D software.
Table 2. Flight line planning parameters used in the study.

| Platform          | DJI Phantom 4 Advanced | eBee Classic |
|-------------------|------------------------|--------------|
| Study Area        | UTM Ring road          | UTM Ring road|
| Study Area Size   | 53.8 Hectare           | 53.8 Hectare |
| App Used          | DroneDeploy            | eMotion      |
| Flight Height     | 300 m                  | 300 m        |
| Survey Date       | 06/Feb/19              | 07/Oct/18    |
| Survey Time       | 11:20 pm               | 10:45 am     |
| Avg. GSD (cm)     | 8.43                   | 8.56         |
| Front Overlap %   | 75                     | 75           |
| Side Overlap %    | 75                     | 75           |
| No of GCP’s       | 8                      | 8            |
| No of CP’s        | 15                     | 15           |
| No. of images     | 58                     | 59           |
| Image Format      | .jpeg                  | .jpeg        |

Pix4D mapper is one of the leading software package in computer vision domain. With its completely automated photogrammetric process and enhanced accuracy Pix4D mapper has contributed to increased use of drones for professional surveying. The Pix4D software has been widely used in the UAV community and can process huge numbers of images into georeferenced point clouds, digital elevation models (DEMs), and orthophoto mosaic [10]. Pix4D mapper autonomously calculates the original image exterior geometry. It simultaneously utilizes Pix4D algorithms and traditional bundle block adjustment technology for automatic image calibration. Pix4D mapper creates a quality report for quick and correct evaluation of the results automatically. Software provides accuracy details of automatic aerial triangulation, regional adjustment and ground control point [11].

Figure 2 outlines the detailed methodology of this research. Firstly, P4 images were processed in Pix4D mapper. Total 57 images were selected after discarding blur images for further processing. After completing the initial processing 8 GCP’s were used for the accurate georeferencing (Figure 1). Georeferencing forms a fundamental part of topographic surveys and, for SFM work, dense deployments of carefully-measured ground control points (GCPs) are generally used [12]. After GCP’s insertion, dense 3D point cloud, Orthomosaic, DSM, DTM and Contours were generated. Identical GCP has used in eBee data processing (Figure 1) and same data output generated. Only one difference in data is that the total number of images for eBee were 59.
Figure 2. Methodology flowchart.
5. Results

The output for both P4 and eBee UAVs are shown in Figure 3 and 4 respectively which include orthomosaic, DSM, DTM and Contours. In general, it can be seen that the output are quite similar. However, in term of accuracy based on CP as shown in Table 4, the accuracy of P4 is superior to the accuracy of eBee.

![Figure 3. Output of P4: Orthomosaic, DSM, DTM & Contours.](image)
6. Comparative Analysis

6.1 Pix4D Report
Pix4D have mean reprojection-error values below 2 pixels across all spatial scales [13]. This could be a great significance but research needs the verification of the outputs. So along with Pix4D RMSE (Root Mean Square Error) values calculated for Check Points (CPs), which are as per Table 3. Accuracy of the outputs also analyzed through checkpoints.

Table 3. RMSE GCP from Pix4D Report.

|      | RMSE    |
|------|---------|
| P4   | ±0.107 m|
| eBee | ±0.104 m|
6.2 Accuracy Assessment
After completing the step one, 15 checkpoints used for accuracy assessment Figure 1 showing the location of the CP’s in study area. One can easily see the even distribution of CP’s in the study area. Table 4 is showing the RMSE values calculated by using observed values and by identifying the same locations in both the data set.

|         | Easting(m) | Northing(m) | Elevation(m) |
|---------|------------|-------------|--------------|
| P4      | ±0.31      | ±0.12       | ±0.14        |
| eBee    | ±0.34      | ±0.14       | ±0.23        |

6.3 Visual Interpretation
SFM provides an automated method for modeling the relative 3D geometry of a scene by image matching a series of overlapping 2D images, which may then be georeferenced to map coordinates. This is performed using patterns of image brightness and color gradients (i.e., variations in image texture) which can be identified at various different scales [14].

If the image has clear and brighter picture then definitely in further processing steps in Pix4D, which mainly based on SFM, can produce better outputs. Among all the following clipped images from orthomosaic of both the data sets. The quality of P4 data is clearly showing that it is superior to eBee data as shown in Figure 5.
7. Conclusion
Topographical mapping is one of the oldest surveying application and still this technique is approaching new horizons. Therefore the requirement of very high resolution topographic datasets is of growing interest and also its applications throughout the geographic sciences [15]. UAV photogrammetry introduced a low-cost alternative to the time consuming classical manned aerial photogrammetry for large-scale topographic mapping or detailed 3D recording of ground information [16]. In this study we have tested that, can we replace the low cost P4 drone with high cost fix wing eBee drone. The results are quite remarkable. We have come to know that if your area of study is within 2 km² the use of P4 has much better results as compared to eBee. P4 can handle easily in small areas, picture quality is also better because of its stable flight geometry and last but not the least its price difference has notable impact on the choice of UAV. The only advantage of eBee is its endurance. If we look in to the 3D point cloud produced by Pix4D by using the same parameters for both UAV’s the 7,883,821 number of point cloud for P4 and 7,882,879/- for eBee data generated. The RMSE results clearly indicate that the P4 output is more accurate as compared to eBee.

Figure 5. eBee and P4 images for visual comparison.
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