Implementation of Unmanned Aerial Vehicle for Cadastral Mapping

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A B S T R A C T:

Unmanned Aerial Vehicle (UAV) as a photogrammetric platform provides a new domain for engineers and geospatial professionals with a revolutionary tool for collecting a reliable geodata to be implemented for cadastral mapping. The aim of this study was to find the potential of UAV for cadastral mapping using high resolution aerial images. The study included the utilize of eBee PLUS fixed wing UAV flying at 106m altitude over Arab-Kand village. At the GSD of 2.5cm/pixel spatial resolution the site was covered by UAV images of forward and lateral overlap of 60% and 70% respectively. Horizontal accuracy obtained from generated orthomosaic was 4.8cm. This gives a possibility to create a line map with scale of 1:100 or 1:50. This study proved that the UAV based orthomosaic can be used for cadastral mapping due to high accuracy, low cost, less time consuming, rapid data acquisition, and complying with international standards.

KEY WORDS: UAV; Photogrammetry; Orthomosaic; Cadastral; GSD
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INTRODUCTION:

Cadastral mapping is a technique to prepare sets of records in the form of line maps, and digital database to be able precisely describe and to locate particular piece of land on the ground and its ownership. These sets of records will serve the authorities and landholders. The authorities need to know what parcels of land, and where have been granted to a person, so that it does not grant the same parcel to another person. Similarly the land owners would like to have complete knowledge about the boundary extent, in turn they do not exceed these limits, and do not interfere in somebody’s property. From a practical point of view, the cadastral data (line maps and digital database) is not enough to secure the ownership, therefore it is required to have precise methodology to mark the boundary on the ground using corner marks, and to supply the owner a large scale plan of the parcel and its surrounding.

The development of surveying tools and approaches help to prepare the digital maps for cadastral purposes, and processing with these digital maps is useful to prepare a combined maps and database about the title deeds parcel identifiers and ownership permanence and many other details such as the area, number of district and the privies background details. Also the digital maps can easily be georeferenced with other land use maps and added to the master plan of the city or region.

Unmanned Aerial Vehicle (UAV) is an aircraft without human onboard, it’s either operated by human from remote location, or it can work autonomously as preplanned mode. There
are two main types: rotor (single or multi) and fixed wing Fig.1. A UAV system consists of the following components:

- UAV carries navigation equipment (GPS, advanced autopilot module, inertial measurement unit, camera, and battery).
- Laptop or base station on which the flight planning is performed, and which shows the real time navigation of UAV on predefined trajectory, and background satellite imagery.

1. STUDY AREA

As a case study Arab-Kand village was selected for this research. It’s located south west of Erbil city, about 10 km, and covering an area of 67 acres. Since the village was build long time ago without master plan, no legal registration was performed for the ownership of land parcels and houses. Both the houses and land division were made randomly without having a master plan to control the growth of the village. Our study will consists of applying UAV photogrammetry to: prepare line maps and to show the state of art of the existing’s, then to establish a digital database for recording the ownership, delineate the boundaries, and prepare a topographic map of the area to be the starting point for architects to design future master plan.

2. METHODELOGY

The overall workflow adopted in this study was consists of five phases which is summarized in Fig.2 below:

2.1 Establishment of Ground Control Points

Ground Control Points (GCPs) must be established, marked in an appropriate shape and color, then they could be identified in the imagery before actual flying. According to (Pix4D, 2016) the targets should have (5-10) times the GSD. GCPs can be eliminated if the UAV equipped with dual frequency GNSS onboard receiver (Barnes and Volkmann, 2014). All ground control points should be surveyed for determination of their 3D coordinates precisely using differential GNSS instrument to an accuracy of ± 2cm or better. In this case five (5) ground control points were placed on (40 cm x 40 cm) black and white tiles were established and the coordinates were determined on the WSG84 datum/UTM projection/ 38N zone with an accuracy of 1-2cm using Leica GNSS GS15 based on the ISER CORS Tab.1.

2.2 Flight Planning

This stage involves the planning of flight trajectory, take-off and landing position over the study area. The design of flight plan depends on: UAV platform, nature of terrain, Ground Sampling Distance (GSD), flying height, forward and side overlap, focal length of camera (f), wind speed and its direction. Available satellite imageries are utilizing to finalize the flight plan. According to (Eisenbeiss, 2009) the flying height will be determined using Eq. (1):

\[
\text{Flying height (m)} = \frac{\text{GSD (cm). } f(\text{mm})}{p(\mu m)}
\]

(1) \(p\) : pixel size

Flight planning will be performed by using the eMotion 3 software in the office (and/or in the field). This starts by: define the mission area on the specific satellite imagery and avoidance zone if required. The software estimates the total flight needed to cover the mission area, and allows the user to split into multiple flights. In this study, eMotion 3 software was used, flight plan was prepared based on GSD of 2.5cm/pixel, flying height of 106m, forward and lateral overlap were 60% and 70% respectively Fig.3. eMotion 3 will references the flight plan to WGS84 datum, which is the spatial reference used for UAV navigation.

2.3 Aerial Image Acquisition

The image acquisition is carried out in the way that the UAV is steered autonomously over the pre-defined flight trajectories and the images are acquiring along these paths without necessity of manual intervention. In this case light weight fixed wing acquisition UAV was employed, called eBee PLUS Fig.4. It’s equipped with SODA camera which is specially designed for UAV photogrammetry. The flight plan was uploaded to the UAV system, which was then launched to capture high resolution images Fig.5. Totally, 310 images were captured during 12 minutes of flight time.

2.4 Digital Image Processing

This stage entails a sequence of photogrammetric operations, which are camera calibration, 3D point cloud and Digital Surface Model (DSM)
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generation. A professional computer vision based image processing software was employed so called Pix4Dmapper Pro. The interior orientation parameters of the camera (focal length, principal point position, and lens distortion parameters) were estimated through a self-calibration process during bundle block adjustment (BBA) (Mumbone, 2015). Also in this step images were georeferenced. Orthomosaic and DSM as photogrammetric outputs were produced once 3D point cloud generation has been performed Fig.6 and Fig.7. Generated orthomosaic was used in the ArcGIS software to create line map through digitizing process manually Fig.8 and Fig.9.

2.5 Accuracy Assessment

The accuracy of generated orthomosaic was assessed by utilizing Root Mean Square Error (RMSE). This has been used by American Society for Photogrammetry and Remote Sensing (ASPRS) within Accuracy Standard for Digital Geospatial Data (ASPRS, 2015). It can be calculated using Eq. (2) and Eq. (3) below:

\[
RMSE = \sqrt{\frac{\sum (\text{observe} - \text{reference})^2}{n}} \quad \ldots \quad \text{Eq (2)}
\]

\[
RMSE_r = \sqrt{\frac{\sum ((RMSE_E)^2 + (RMSE_N)^2)}{n}} \quad \ldots \quad \text{Eq (3)}
\]

Where

- Observe= measured coordinate in the data set
- Reference= reference coordinate
- n= number of points in data set
- RMSE r = RMSE E,N (positional RMSE)

In this study, generated orthomosaic was exported to ArcGIS, the 2D coordinates of the center of five ground markers (40cm x 40cm black and white tile) which are visible on the orthomosaic were measured Tab. 2. The real 2D coordinates of the targets were already measured (article 3.1). Achieved RMSEr (horizontal accuracy) was 4.8cm for generated orthomosaic. According to (ASPRS, 2015) horizontal accuracy for planimetric data at 95% confidence level is 6.1cm for GSD of 2.5cm/pixel. This shows that generated orthomosaic was at acceptable level of accuracy to produce a line map with a scale of 1:100 or 1:50 (ASPRS, 2015).

3.CONCLUSIONS

This study demonstrates that the UAV approach can effectively produce high accuracy orthomosaic from high resolution images taken by UAV. Produced orthomosaic with 4.8 cm horizontal accuracy fulfills the demand of cadastral mapping. Achieved horizontal accuracy allows orthomosaic to be used for updating cadastral maps and for urban planning with less time consuming. Finally, this research shows that the UAV photogrammetry can be an alternative to traditional methods such as GPS and Total Station for cadastral mapping due to high accuracy, low cost, less time consuming, quickly data acquisition, and fulfill the requirements of international standards. Therefore, it’s highly recommended to be implemented for cadastral mapping and preparation of topographic maps of the area for future urban planning.

| Table (1). Measured Ground Control Points |
|----------------------------------------|
| PID | Easting (m) | Northing (m) | Height (m) |
|-----|-------------|--------------|------------|
| GCP1 | 400903.719 | 4000393.944 | 363.986 |
| GCP2 | 401139.933 | 4000529.810 | 362.865 |
| GCP3 | 401242.205 | 4000496.940 | 366.142 |
| GCP4 | 401146.973 | 4000311.683 | 366.118 |
| GCP5 | 400967.820 | 4000115.435 | 357.945 |

| Table (2). Measured planimetric coordinates on orthomosaic |
|---------------------------------------------|
| PID | Easting (m) | Northing (m) | Residuals |
|-----|-------------|--------------|-----------|
|     |             |              | ΔE  | ΔN  |
| GCP1 | 400903.743 | 4000393.989 | 0.024 | 0.045 |
| GCP2 | 401139.977 | 4000529.855 | 0.044 | 0.045 |
| GCP3 | 401242.203 | 4000496.971 | 0.002 | 0.031 |
| GCP4 | 401146.945 | 4000311.665 | 0.028 | 0.018 |
| GCP5 | 400967.852 | 4000115.392 | 0.032 | 0.043 |
| RMSE |             |              | 0.029 | 0.038 |
| RMSEr |            |              | 0.048 |

a-Fixed wing (eBee PLUS)

b-Quad copter (Albris)
**Figure 1.** c-Hexacopter (Aibotix)

**Figure 2.** Research workflow.

**Figure 3.** Flight plan on Bing map imagery.

**Figure 4.** eBee PLUS UAV.

**Figure 5.** Acquired aerial images.

**Figure 6.** Generated Orthomosaic

**Figure 7.** Generated DSM.

**Figure 8.** Digitized line map on orthomosaic (blue lines).
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