UNMANNED AERIAL VEHICLE (UAV) APPLICATION FOR UPDATING OF URBAN DATABASE

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Abstract. This paper describes a new approach for urban land use management by using Unmanned Aerial Vehicles (UAV). Experimental result covers 121 ha (1.21 km²) at Binh Tho ward, Thu Duc district of the Ho Chi Minh city and shows that UAV technology is most suitable and cost effective for cadastral mapping and updating the database with high accuracy. In this research, 36 GCPs (Ground Control Points) and 2433 parcel boundaries (GIS data) were used to compare the achieved accuracy of UAV method in which 10381 orthophoto imageries produced had a resolution of 1.8 cm (with flying altitude 70 m) to be used to inform urban database. This technology opens a new way that is most suitable and cost effective for small areas, where digital maps and 3D models need to be produced in a short period of time with high data quality and accuracy. There are no significant barriers to imbed the technology at the local level and it can speed up the process of updating database in developing the Spatial Data Infrastructure (SDI) of the smart city.

1. Introduction

Satellite and Airborne image survey are valid techniques to capture data in broad area that the required measurement accuracy depends on relation to the object/area size. Recent experimental studies [1-3] show that the shortcomings of above-mentioned imaging techniques can be overcome by the remote imaging system based upon unmanned air vehicle (AUV). UAV can be used for mapping and surveying activities at lower costs than the cost of satellite or manned aircraft images [4] in the juridical verification process of cadastral ownership [5] and for land parcels mapping [6].

To develop an UAV approach that is able to provide high resolution, real-time images for updating data and developing the Spatial Data Infrastructure (SDI) of the smart city, is important items of Viet Nam’s strategy in space research and applications. The HCM city is looking the application of innovative new smart technologies for improving land governance. UAV imagery represents one tool to help support this effort, especially over small areas and where land parcels in some districts are small and often
without proper boundary demarcations. Thus, the experimental results of the high-resolution imaging system based upon UAV must be assessed how UAV technology can be deployed across different land use areas and used to inform urban land use and management.

In order to assess potential UAV applications for cadastral mapping and updating of urban database, the vertical take-off and landing-type aircraft is chosen due to its high maneuverability and its capability to flight in condensed area with physical obstacles. The UAV was planned to flight at low altitude (70 m) and taken high resolution images for small and constrained areas in real time at one complete ward (Binh Tho) of Thu Duc District that aims to assess the accuracy of the orthophotos for management cases, including cadastral mapping. The experimental results shown that UAV orthophoto imageries can be used to inform urban database and promisingly applied in urban management. In addition, this paper also describes flight planning procedure, image processing and how to develop the new GCPs for assessing the accuracy of results. This aims to contribute a new approach to apply the UAV technology for cadastral mapping and updating the database with high accuracy.

2. Experiment and Data Processing

The Thu Duc district of the Ho Chi Minh city covers an area of 47.8 km² with 12 wards and Binh Tho ward covers 121 ha (1.21 km²) that were chosen for experiments how to apply UAV for providing high resolution, real-time images for cadastral mapping. Because, this ward has been identified as a suitable demonstration location that covers both dense urban areas, as well as remaining rural fringes and has cadastral maps (established in the year 2003) with scale 1/200 and 1/500. In this study area, there also are 2433 parcel boundaries and 40 GCPs have been identified. However, a significant number of these GCPs have been lost and 05 GCPs are vital to ensuring the geo-rectification of the UAV imagery and evaluating the accuracy of the new approach.

![Figure 1. Location of this study area at Binh Tho ward - Thu Duc District, Ho Chi Minh City](image)

The design research to develop a UAV based image approach for cadastral mapping included three main activities: developing the new GCPs; photos acquisition and image processing; evaluating the accuracy of results that applied in the case study area.
Making the new GCPs and install visible ground markers: In order to transform the acquired data to the national coordinate reference system (VN2000) 40 GCPs were identified by field surveys and ground marker should exhibit high contrast (GCP markings were done by using man-made marks and be visible on the UAV images. DGPS device (SQ-GNSS of Novatel) was used to collect the coordinates for 40 GCPs with average accuracy of each GCP: ~4 cm that are used to evaluate the accuracy of the processed image and Fig. 2 shows 07 GCPs (red points in the map) are used for validation data.

![Figure 2a. GCPs distribution and 7 GCPs (red) as validation points](image1)

Figure 2b. GCP markings

Photos acquisition: The flight time of UAV around 20 minutes (limited by battery capacity), thus flight planning was divided into 5 blocks. Each block was captured in one mission with flying altitude 70 m and ground resolution 2 cm/Pixel. In total images from 5 blocks of Binh tho ward were 10381 images cover 121 ha with overlap along track: 90% (flight direction) and overlap across track: 80%.

![Figure 3. Flight plan for Binh Tho ward with flight parameters](image2)

Image processing: all images of 5 blocks were processed by Pix4D software to create ortho images and mosaicking which already cover the whole fieldwork area of Binh tho ward. After successfully generating the output imagery, 7 GCPs were used to evaluate the quality of the ortho-images
Figure 4. Raw image processing offers the opportunity to publish additional information.

**Evaluate the accuracy of UAV images:** Based on the ground control points (GCPs), the Gaussian formula is used to evaluate the accuracy of the processed image.

Root Mean Squared Error (RMSE):

\[ m_{\Delta S} = \pm \sqrt{\frac{[\Delta S^2]}{n}} \]

\[ \Delta S_i^2 = \Delta X_i^2 + \Delta Y_i^2 \]

Where: \( n \) number of GCPs is used to evaluate accuracy

\( \Delta X_i = X_i - X_{0i} \)

\( \Delta Y_i = Y_i - Y_{0i} \)

\((X_0, Y_0) - \) coordinates of the GCPs are measured by the RTK method,

\((X_i, Y_i) - \) coordinates of the corresponding GCPs on the Ortho images, \((i=1\div n)\)
Table 1. Accuracy of the Ortho images - Binh Tho ward

| No. | Name   | Coordinates of GCPs are measured | Coordinates of GCPs on the Ortho | ΔX²   | ΔY²   | ΔS²   |
|-----|--------|----------------------------------|----------------------------------|-------|-------|-------|
|     |        | X₀ (m)   | Y₀ (m)   | X (m)   | Y (m)   |       |
| 1   | BTH4   | 611262.5605 | 1199474.2207 | 611262.5190 | 1199474.1960 | 0.0017 | 0.0006 | 0.0023 |
| 2   | BTH15  | 611052.8501 | 1199640.7462 | 611052.8070 | 1199640.7670 | 0.0019 | 0.0004 | 0.0023 |
| 3   | BTH17  | 611188.3807 | 1199900.5004 | 611188.3490 | 1199900.4760 | 0.0010 | 0.0006 | 0.0023 |
| 4   | BTH19  | 610760.6267 | 1199348.9990 | 610760.6630 | 1199349.0300 | 0.0013 | 0.0010 | 0.0023 |
| 5   | BTH33  | 610611.5492 | 1199688.4199 | 610611.5720 | 1199688.4050 | 0.0005 | 0.0002 | 0.0007 |
| 6   | BTH38  | 610186.9539 | 1200039.2176 | 610186.9910 | 1200039.1870 | 0.0014 | 0.0009 | 0.0023 |
| 7   | BTH40  | 610659.8219 | 1200142.2279 | 610659.8210 | 1200142.1600 | 0.0000 | 0.0046 | 0.0046 |
| Sum |        |           |           |          |          | 0.0078 | 0.0084 | 0.0162 |

Root Mean Squared Errors - RMSE (m)

3. Results and discussion

Application of UAV as a new approach for cadastral mapping:

- The latest MONRE’s regulations on cadastral maps is Circular 25/2014/TB-BTNMT: position error of any point on the boundary of the land plot indicated on the digital cadastral map compared with the location of the nearest surveying points shall not exceed 5 cm for cadastral map of 1: 200 scale and 7 cm for cadastral map of 1: 500 scale. In addition, the position-position error of any two points on the boundary of the land plot indicated on the cadastral digital map compared to the actual field distance measured directly or indirectly from the same station should not exceed 0.2 mm in accordance with the required map scale.

- Results analysis of Binh Tho ward shows that this experimental study is to offer a proof of concept for the way in which UAV technology can be used for cadastral mapping. The value of RMSE = 4.81 cm (between dataset coordinate values and coordinate values from an independent source) can be used to estimate positional accuracy. In this case, the coordinates representing the parcel boundaries from UAV based image approach and traditional approach were processed in total 10 samples to get the difference value between the 2 datasets.
Figure 5. The Ortho imagery produced had a resolution of 2 cm for cadastral mapping

By using ArcGIS to overlay ortho images with the parcel boundaries (vector file available is legal digital cadastral map of 2003) through the digitizing procedure, creating a map with parcel boundary as a second dataset that can calculate position-position error of any two points on the boundary of the land plot. 10 parcels sample were analysed to evaluate the accuracy the parcel boundaries in which \((X_0\) and \(Y_0\)) are original coordinates and \((X\) and \(Y\)) are coordinates of UAV approach. The residuals \(\Delta X (X-X_0)\) and \(\Delta Y (Y-Y_0)\) were extracted to calculate the accuracy the parcel boundaries (RMSE = 4.6 cm) that is performed by the difference of the parcel from the digitizing procedure (UAV approach) and the direct measurement in the field (the existing terrestrial method).

Figure 6. Location of points on the boundary of the samples

Application of UAV as one tool to support urban land use planning and management: The trend for broader public access to information and open data are some of the issues that authorities of HCM city should develop the Spatial Data Infrastructure (SDI) to serve the smart city. UAV technology is most suitable and cost effective for small areas, where digital maps and 3D models need to be produced in a short period of time with high data quality and accuracy. The experimental results shown that all ortho and very high resolution imageries can be used to inform urban land use and promisingly applied in urban management cases. Because, images are stored by normal format files (tiff), acquired on WGS84 (latitude and longitude) and converted onto the standard Vietnam map projection VN-2000. For example, where new infrastructure investments are planned but there are no recent orthophotos and the existing digital or analogue maps are of poor quality. In addition, UAV approach can open new feasible
applications in monitoring the progress of construction works; establishing large scale topographic map or creating a DSM for a small area (few hundred hectares) with low cost.

![Figure 7. Orthophoto map and DSM of Binh Thọ ward in VN-2000 coordinate system](image)

### 4. Conclusions

The main objective of this paper is to introduce a UAV based image approach for updating an existing database of urban and cadastral mapping in Binh Tho ward. Taking results analysis and testing the position error of any point on the boundary of the land plot indicated on the latest MONRE’s regulations in terms of the elements of fit-for-purpose. These results offer a proof of concept for the new way how UAV technology may be deployed as one tool to improve land use and management in the HCM city. The test results show imagery with 2 cm horizontal accuracy and is converted onto the standard Vietnam map projection VN-2000 can be applied in monitoring the progress of construction works; establishing large scale topographic map or creating a DSM for a small area. This research opens a new feasible application that UAV approach is most suitable and cost effective for small areas, where digital maps and 3D models need to be produced in a short period of time with high data quality and accuracy. There are no significant barriers to imbed the technology at the local level and it can speed up the process of updating data in developing the Spatial Data Infrastructure (SDI) of the smart city.
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