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Potential Use of UAV-Based Mapping System to Accelerate the Production of Parcel Boundary Map in Indonesia

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Abstract

Recently, the Ministry of Agrarian Affairs announces a decree to accelerate a completion of the registration of land parcels of cadaster maps up to a scale of 1:1000. It is known that the use of Unmanned Aerial Vehicle based mapping system (UAV-Map) can produce orthophoto image with spatial resolution less than 10 cm, but it is not yet known whether UAV-Map implementation is able to identify boundary of land parcel in any condition. Therefore, this paper would analyze the planimetric accuracy that is conformed to the regulation of State Minister of Agrarian Affairs/Head of National Land Agency No.3, 1997 both for urban and rural areas. Two testing areas are established which located on urban area and rural area respectively. Flight missions are conducted using a fixed-wing aircraft equipped with a consumer grade camera and a navigational grade GPS-INS system. Orthophoto maps are produced by using Agisoft Photoscan software. Digitizing of parcel boundaries are followed both on an existing map and on the orthophoto maps. Deviations in areas are expressed in terms of the RMSE figures. Planimetric accuracies as indicated by the RMSE value are of 0,044 m for urban areas and 0,122 m for rural area. It is showed that all discrepancies of the parcels area are still below the recommended threshold values of the regulation. It is can be concluded that the orthophoto maps obtained by using a low cost UAV-Map system can be used to identify land parcels boundaries and to determine the parcel area.

Keywords: UAV-Based mapping, Parcel boundary map, Parcel area calculation

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1. Introduction

There are approximately 190 million hectares of Indonesia's land part areas should be mapped in large scale cadaster maps[1], but until 2016 there are only 22.28% percent or it makes up 24.157.000 land parcels that have been plotted into large scale maps with a scale of 1K and 2.5K [1]. Such an enormous challenge for cadaster base maps completion was driven by a utilization of high resolution imagery for providing an alternative solution. Burgeoning Unmanned Aerial Vehicle (UAV) which can carry a consumer grade camera

[2] open the horizon of such a solution due to a very dense ground sampling distance (GSD) provided and particularly it gives a cost effective solution of mapping activities in terms of portability of the platform [3], quick and cheap mapping production line[4, 5], and the images geometric accuracies are readily improved by using well calibrated camera [6, 7].

Meanwhile the governmental regulation of State Minister of Agrarian Affairs/Head of National Land Agency No.3, 1997 stated that there is a possibility to measure the parcel boundaries by using a single orthophoto image or stitched orthophoto images [8] (i.e. orthophoto map). This regulation inspires us to develop a UAV-Map system which is a low cost UAV platform equipped with a Post processing Kinematic (PPK) architecture and with a pocket size non-metric camera that can produce aerial images with the GSD of 10cm or fewer. This paper elaborates the ability of the UAV-Map system to conform with those regulations for delineating the parcel boundaries especially when the boundary is identified with Premark, the boundary without Premark and the blocked boundary by other objects. A planimetric accuracy assessment of the parcel boundaries interpretation generated from the UAV-based orthophoto image is the main focus of this article

2. Methods

This research analyzes the planimetric accuracy of the parcel boundaries delineation derived from interpretation on the Orthophoto image or Orthophoto map. The orthophoto image is obtained from the ongoing development of UAV-Map System Architecture with Post Processing Kinematic. Delineated Land parcel boundaries are compared against those of the base map. Differences are analysed with respect to the regulation requirements. Some case studies are conducted in urban area and paddy fields area. The standardized accuracies stated in the regulation as well as the UAV-Map system architecture are elaborated as follows.

2.1. The Regulation Requirements

According to the regulation of the State Minister of Agrarian Affair/Head of National Land Agency No. 3, 1997, the cadaster boundary data acquisition procedure comprises a base map registration, a cadaster boundary survey, registration and mapping. Prerequisites of the cadaster mapping in Indonesia consist of four requirements which are: it uses the TM-3 coordinate system; it uses a 1K, 2.5K, and 10K map scale for base maps registration of residential area, agriculture area, and plantation area respectively; a physical marking with peg, pipe or monument should be erected at every corner of the boundary for parcels which are less than 10 hectares; and allowable blow-up orthophoto or orthophoto map is designed for open areas only. Furthermore, identified points along the boundaries can be interpreted on orthophoto or orthophoto map with some methods such as by putting marker at boundary point before photo flight (pre-marking), by utilizing some unique adjacent objects for space resection point and by using some natural or man-made objects as boundary line. A planimetric root mean square error (RMSE) between coordinate from orthophoto and GNSS survey at some sampling boundary points is calculated by using:

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\delta_{Ni}^{2} + \delta_{Ei}^{2}\right)} \qquad (1)$$

Where the δ_{Ni} and δ_{Ei} are coordinate differences in the North and East direction. Parcel area differences between areas calculated from the Orthophoto and the ones obtained from GNSS surveys are not greater than:

$$\Delta L_i \leq \frac{1}{2}\sqrt{L} \qquad (2)$$

Where the ΔL is area difference and L is measured area (in squared meter.), or stated otherwise, the differences must be less than 5%. Therefore, to meet those standards, the UAV-Map system should meet some required standards in producing aerial images likes the GSD range should be between 5cm -- 10cm [3] in order to clearly identified boundary markers; the operation budget should be cost effective due to a limited infrastructure supports in Indonesia; production payload of the system should reach a minimum of around 500 Hectares per day; the UAV-System should be highly compatible to collaborate with other existing system such as CORS-BPN [4].

2.2. The UAV-Map System

The UAV-Map system is intended to fill a market segment of low budget and small area for aerial mapping [3], [9], [10]. Its overall weight is no more than 2.5kg for easily storage and handling. It makes up from hobby grade aeromodelling equipped with a consumer grade camera and a low cost single frequency GPS receiver supporting GNSS [11] (Global Navigation Satellite System) PPK [12, 13] (Post Processing Kinematic) mode (Figure 1 and Table 1). An aeromodelling aircraft is utilized to carry a digital camera and avionics systems with total payload weight less than 0.75kg. The avionics system consists of GPS 10Hz, and ATMEGA Autopilot [14] to control the speed of the camera remote shutter release and it is governed by scripting program to run shutter's interval periodically.

Currently, a number GNSS Module sensor that capable for GNSS PPK mode are available in hobby market [15]. The size of GNSS module is small (<7cm) such as a GPS single frequency of L1. This module already has a feature to record GPS phase data and external antenna that it can be mounted on the pocket camera (Table 1) and it is equipped with data logger for storage on micro SD-card media. Then, a post-processing as kinematic survey mode can be done with open source RTKLIB software (https://github.com/tomojitakasu/RTKLIB). This process requires GPS tracking data as input data containing time and point position information in the form of NMEA file format (https://www.gpsinformation.org/dale/nmea.htm). A determination of camera exposure position is done by geotagging process based on synchronization time of data recording. A one second interval of GPS data recording is synchronized with a 3-4 seconds interval of the camera exposure. An outcome of the geotagging process is of geographical position encrypted in an Exif format [16] into each photographed aerial image. A throughout understanding of the system is summarized in Figure 2.

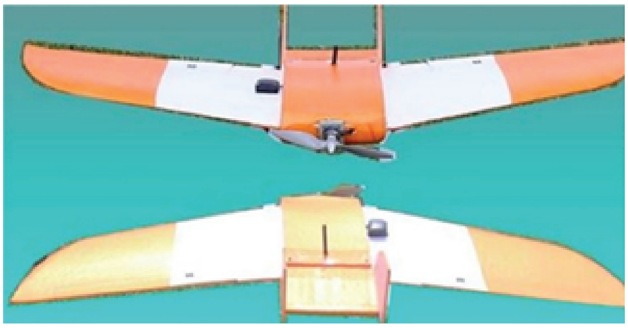


Figure 1: The UAV Platform.

3. Result and Discussion

A field test was conducted at two different locations in Yogyakarta Province which represents urban and rural areas and both make up a total test area of around 100 Ha. Both rural and urban areas are photographed by using a COOLPIX AW-120 Nikon camera at the GSD of 7.15cm and by using a Sony RX 100 camera at the GSD of 8.12cm respectively. Bundle adjustment is performed using 6 Ground Control Points (GCP). A number of Independent Check Points (ICP) is provided for computing the RMSE for a planimetric accuracy test. 13 ICP in the urban area and 15 ICP in the rural area are utilized to give the accuracy of about 0.044m and 0.122m respectively.

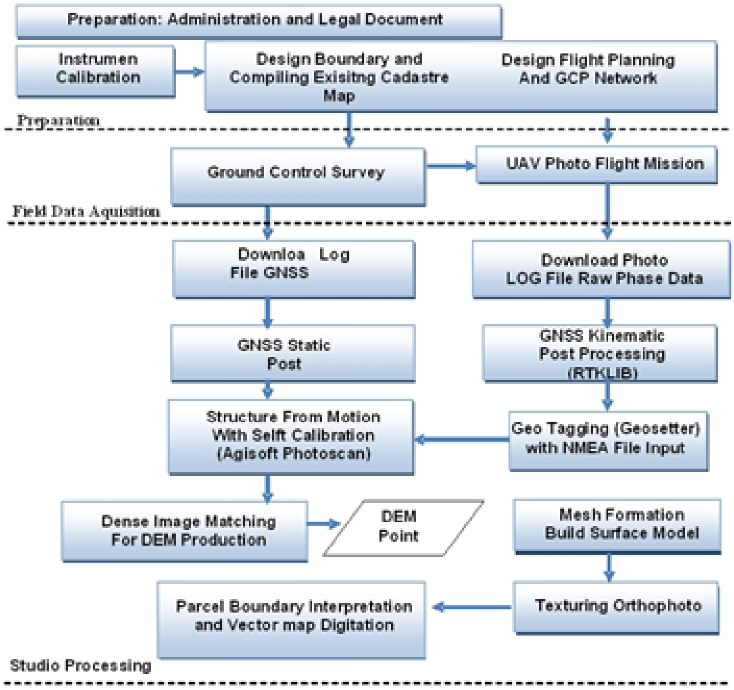


Figure 2: A workflow of the UAV-Map producing parcel boundary map.

Table 1: The UAV-Map architecture.

System	**Specifications/Characteristics**
Aerial Platform	RC Flying 1300mm wingspan equipped with a portable back-pack for hand launch take-off and landing; Electric Maximum ground speed of at 50-- 60 km per hour for 30min effective flight time.
Avionic System (< 350gr)	An R/C-7 channel with 1W UHF 433MHz for range less than 10 km; Autopilot (open source Ardupilot); GPS receiver 10Hz; RF modem 1W 900Mhz for range less than 10km; Supporting GNSS PPK mode with GPS Single L1 Freq.
Imaging sensor (< 350gr)	A non-metric Digital Pocket Camera with 12MPix field of view > 60°; Anti-vibration mounting system (with foam-based or silica gel)
Ground Station (Portable)	Laptop Win 32Bit (XP or Win7); Ground Station Software (Ardupilot Mission Planner); Antenna receiver with Omni-directional path 12dB; Database maps for moving map
Data Processing and Visualization	SfM software for automatic bundle adjustment as well DSM generation and orthophoto production: Agisoft Photoscan Professional and Visual SFM; MeshLab (open source) for point cloud visualization

Factors affecting the horizontal errors variation are the picking point precision and the quality of the ICP coordinates. The parcel boundary line and point identification can be varied due to the surrounding area situation. The parcel boundary point that have Pre-mark are clearly visible on the photo, then it help reduce the picking error (Figure 3). But Parcel boundaries without pre-mark in paddy field area are still easily to digitize because there are manmade line between the fields (Figure 4).

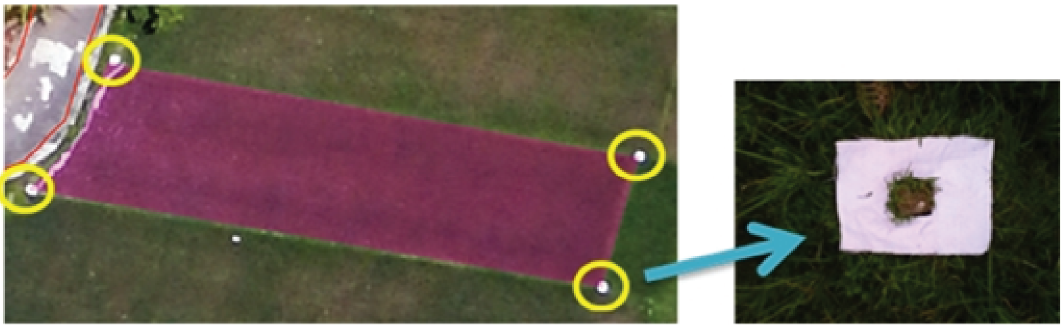


Figure 3: Parcel Boundary with Premark. The boundary markers use 20 cm x 20 cm or letter size shape paper.

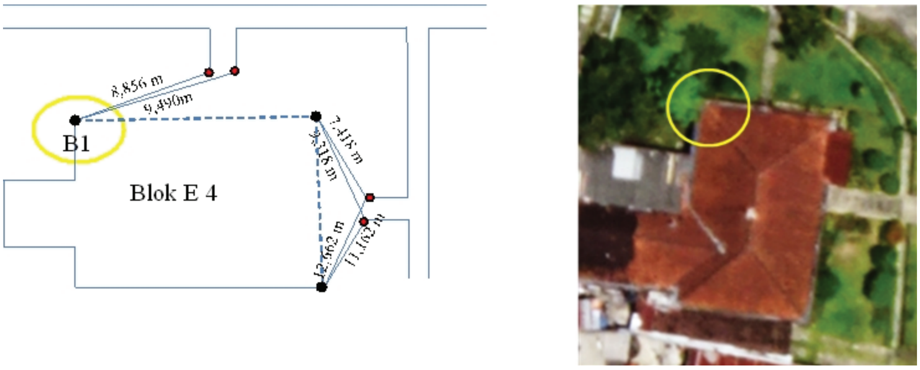
Figure 4: Parcel boundary line from paddy field boundary.

In urban area, however, there is some Parcel boundary point that covered by another objects, such as trees. In this case, the surrounding objects can be used for a graphical resection technique to determine the obscured point location as illustrated in Figure 5.

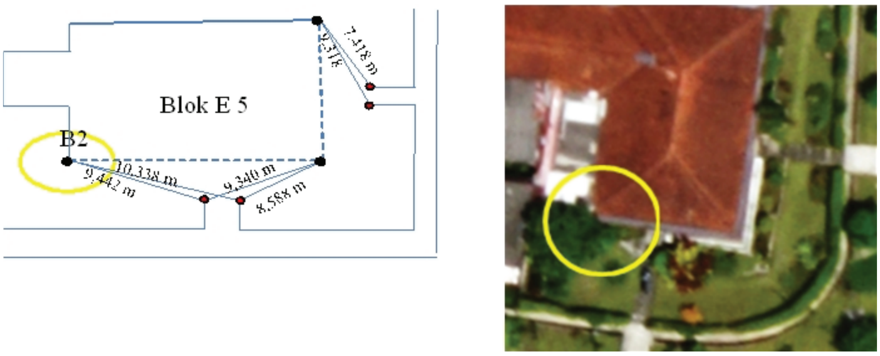
3.1. Quantitative Parcel Area Comparison

Some area calculation comparison between the orthophoto and the existing boundary cadaster map from the National Land Agency is presented in the following Table 2. The comparison between the existing map at a scale of 1K and orthophoto shows that there are no significant differences.

Table 2 clearly indicates that deviations of parcel area between them are no more than 3% which is fewer than that of stated in the regulation that is 5%. A noteworthy experience gained in this research is that when the boundary is partially obscured by other object or the use of a non-up-to-date map, the difference might have been out of tolerance. There is a no guarantee that the physical boundary in the field always



(a)



(b)

Figure 5: Graphical resection from surrounding objects: (a). A determination of point B1; (b). A determination of point B2.

TABLE 2: Evaluation of parcel area accuracy in rural area only.

No.	Area Ortho (m2)	Area Map (m2)	Tolerance (m2)	Difference (%)	Notes
1	256.050	252.502	7.945	1.4	accepted
2	332.286	328.685	9.065	1.1	accepted
3	178.231	180,703	6.721	1.4	accepted
4	249.543	250.821	7.919	0.5	accepted
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
130	215.591	216.581	7.358	0.5	accepted
131	468.288	458.758	10.709	2.1	accepted

represents the same objects in the existing parcel boundary map. Furthermore, a Fit for Purposes (FFP) method announced by the Head of National Land Agency in 1997 to accelerate the completion of the cadaster base map production at various scales would be greatly take advantages of UAV based parcel boundary delineation technique. The generated orthophoto product by the UAV-Map system meets the regulation requirements up to a 1K map scale.

4. Conclusion

The FFP method by utilizing the UAV-Map would speed up the orthophoto production for land parcel registration and mapping. The accuracy standard of the generated orthophoto meets the regulation requirements. A conducted field test proves that the horizontal accuracies as indicated by the RMSE value are of 0,044 m for urban areas and 0,122 m for rural area. It is showed that all discrepancies of the parcels area are still below the recommended threshold values of the regulation. It is can be concluded that the orthophoto maps obtained by using a low cost UAV-Map system can be used to identify land parcels boundaries and to determine the parcel area. In the near future, this method will help to accelerate the completion of the registration of land parcels of cadaster maps up to a scale of 1:1000.

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