The Low-Cost UAV-Based Remote Sensing System Capabilities for Large Scale Cadaster Mapping

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Abstract. There is at least 190 million hectare of Indonesia’s land part area that should be mapped in large scale cadaster maps. The completion of cadaster maps up to scale 1/2500 are still an open problems. The very high resolution images with spatial resolution less than 10cm can be a good choice to be able to see a parcel boundary. The use of Unmanned Aerial Vehicle-based remote sensing system can produce aerial photograph with spatial resolution less than 10 cm. For keeping UAV-based system low-cost, the system architecture consists of (1) aerial platform from hobby aeromodelling; (2) consumers grade camera sensor; (3) a low-cost GPS logger for ground control survey; (4) an open source structure from motion processing; and (5) an open source GIS software. This system was tested for producing a cadaster base map in a paddy field area at Trimulyo village at Bantul Region. The high resolution image with Ground Sampling Distance up to 7 cm can easily to see a parcel boundary and some of boundary markers. Some of the parcel areas were used for geometric evaluation. The bundle adjustment with 9 Ground Control Points (GCP) shows the error less than 12 cm in all coordinates component. Meanwhile, the percentage of area differences from some parcel samples show less than 5% of differences. In future, the potential use of a GPS kinematic assisted photo flight should be explored in accordance to reduce the need for GCP survey.

Keywords: UAV-Based remote sensing; large scale cadaster maps, parcel area calculation

1. Introduction
Indonesia region is one of the biggest archipelago country which has land part and ocean part areas. This will be a challenge for the completion of cadastral mapping. There is at least 190 million hectare of Indonesia’s land part area should be mapped in large scale cadaster maps. Until 2006 only less than 10 percent of the area has been plotted into maps with a scale of 1:1000 and 1:2500 [1]. The lack of national large scale base map is one of the conditions that have to be resolved for a good land registration. The acceleration of cadastral mapping is an imperative need to be resolved. So, the very high resolution imagery with spatial resolution less than 10cm from remote sensing technique can be a good choice to be able to see a parcel boundary situation. The use of Unmanned Aerial Vehicle-based remote sensing system (UAV-based RS system) can produce aerial photograph with spatial resolution less than 10 cm. in this paper, the UAV-based RS system define as an UAV platform that can carrying a point and shoot digital camera for capturing an aerial photograph in visible band.
The UAV-Based system has not been optimally used for land parcel mapping, since it is less accurate than terrestrial mapping survey. This because in general, the UAV-Based system is obtained by non-metric camera which has some geometric limitation. However, the use of UAV has some advantages, such as: (1) cost-effective, (2) the accuracy can be improved by camera calibration, (3) fast in mapping production, and (4) The UAV platform has less weight that make it more portable (see [2], [3]).

This paper shows one experience of using the UAV-Based system for cadaster mapping in the rice fields’ area of Trimulyo Village, Jetis, Bantul, and D.I. Yogyakarta. The accuracy of orthophoto product in this study has been tested with the existing land registration map from the National Land Agency and the GPS stop and go survey measurements methods also. This study focused on the land parcel area measurement accuracy from the UAV-Based system. More than 27 sample parcels selected among the sites of ± 20 ha. The parcel objects are an area open area of rice fields which a flat topography with little vegetation has covered. Furthermore, The UAV-based system architecture and how it works is also described in this paper.

2. Indonesia Cadaster Survey Needs
According to the regulation of the State Minister of Agrarian Affair/Head of National Land Agency number 3, 1997 [4], the cadaster boundary data acquisition procedure consist of some activities such as registration basic mapping, delineation cadaster boundary, cadaster survey and mapping and registration mapping. The following paragraph shows the need for cadaster survey activities, which are:

1. Cadaster mapping used TM-3 maps projection coordinates system
2. The registration basic mapping use map scale 1/1.000 for residential area; 1/2.500 for agriculture area; and 1/10.000 for Plantation area.
3. The parcel boundary corner should be marking physically with pegs/pipe (monument). The size of the pipe can be varies between 5cm – 20cm for parcel less than 10Ha.
4. The photogrammetric survey product such as photo maps; orthophoto; and blow-up photo can be used for registration basic mapping, especially in open area.

So, to be able to use the UAV-Based system for cadaster survey, it should has capabilities to produce the aerial photo that meet some prequisite, such as

1. The aerial photo should be able to see the boundary and produce a large scale maps up to 1/1.000. So, the aerial photo should has Ground Sampling Distance (GSD) 5cm-10cm to be able to see the boundary marking.
2. The operation in the field of the system should be as simply as possible and cost effective due to the limited infrastructure supporting in Indonesia.
3. Regarding to the large volume of parcel number, the system should fast in production up to 350Ha per day.
4. The UAV-based system should be able to work and collaborate with other existing systems. One of the existing system such as CORS-BPN (Continuous Operation Reference System) can be used for supporting a Ground Control survey during filed data acquisition.
5. The system should work safely.

3. THE UAV-Based Remote Sensing System Architecture
The use of Unmanned Aerial Vehicle-based remote sensing system can produce aerial photograph with spatial resolution less than 10 cm. The system consists of instrumentation and personnel who run this system. Personnel team consists of (1) a pilot who operates an aerial platform (model airplane), (2) Assistant navigator that helps pilot, and (3) data processing operator is responsible for survey control points, and processing of digital photogrammetry. For keeping UAV-based system low-cost, the system architecture consists of (1) aerial platform from hobby aeromodelling; (2) consumers grade...
camera sensor; (3) a low-cost GPS logger for ground control survey; (4) an open source structure from motion processing; and (5) an open source GIS software. In the last ten years a number of studies using unmanned aerial vehicle for mapping from the air to produce large-scale map. This system is intended to fill the need for low cost and implementing for small areas (see [5], [6], [7]). Basically, there is no fundamental difference between conventional and UAV-based aerial mapping procedure, except in instrumentation and automation in data processing. The UAV platform do not require high operational costs. In addition, the weight of the aircraft less than 3kg can easily stored and carried. The use of electric UAV platform is also safer and environmentally friendly. The UAV platform can fly below the cloud, then atmospheric disturbances can be minimized. However, the lightweight UAV platform is not quite able to maintain stable flight against the wind with a speed of over 40 km per hour. This making it difficult to be able to follow the flight plan. Limitations of aerial photos to identify objects that covered by high vegetation or other objects are also of particular concern.

Table 1 shows the characteristics of the instrumentation system utilizing aeromodelling aircraft to carry a digital camera and avionics systems with a total payload weight <750 grams. Avionics system consists of GPS 10Hz, and Autopilot (Ardupilot: ATMEGA 8bit). The camera remote shutter release is controlled by script program to be able to run interval shutter.

### Table 1. The characteristic of UAV for mapping system

| Aerial Platform Type | Avionic System | Imaging sensor | Ground Station (Portable) | Data Processing and Visualization |
|----------------------|----------------|----------------|--------------------------|----------------------------------|
| a. RC high wing and Portable Backpack, | a. R/C 7 Ch with 1W UHF 433MHz for range < 10 km | a. Pocket Digital Camera > 12MPix field of view > 60o | a. Laptop Win 32Bit (XP or Win7) | a. Structure from motion software for automatic bundle adjustment; DSM generation; and orthophoto |
| b. Hand launch takeoff and Net landing | b. Autopilot (open source Ardupilot) | b. Anti-vibration mounting system (foam-based or silica gel) | b. Ground Station Software (Ardupilot Mission Planner) | b. MeshLab (open source) for point cloud visualization |
| c. Electric DC brushless lipo battery | c. GPS receiver 10Hz, | | c. Antenna receiver with Omni-directional path 12dB | |
| d. Ground speed 50–66 km/h | d. RF modem 1W 900Mhz range < 10km | | d. Database maps for moving map | |
In practice, flying parallel with the wind direction can be easier than trying to fly in a cross wind direction. A photograph with areas overlapping greater than 80% should be taken for several advantages such as (1) reduce the coverage lost data due to turbulence, (2) a high correlation between adjacent photos can be advantages for automation process. The data processing can produce two types of products, namely (1) orthophoto image mosaic, and (2) digital elevation model (DEM). The orthophoto and DEM products are processed by digital photogrammetric procedures. This procedure requires at least four 3D control points (X, Y, Z) in a bundle adjustment algorithm with self-calibration.

4. Results and Discussion

The single photo flight mission was running to cover almost 80 Ha paddy field area at Trimulyo Village, Jetis, Bantul. The UAV platform carrying a point shoot camera Nikon COOLPIX AW-120, with the flying high 250 m above the ground level and produce up to 68 number of aerial photo with GSD 7.77 cm. The picture resolution is sharp enough to be able to see the boundary marking (see Figure 1). The Pre-mark color should striking colors of the surrounding area, the shape and size of the pre-mark must be considered. Pre marks were clearly visible on the photo will help reduce the error of defining the position of GCP and the determination of the boundaries of paddy fields were measured. The boundary markers use 20 cm x 20 cm and 12 cm x 12 cm rectangular shape paper.

![Figure 1. The Boundary marking image resolution](image)

The post processing aerial photo processing by structure from motion algorithm and bundle adjustment with self-calibration has been done with 9 GCP and 6 check points. The Bundle adjustment reported the error precision 12 cm in all componentor less than 2 pixel. While the Check point error is less than 2 pixel also. This error can fulfill for the 1/2.500 map scale accuracy. Furthermore, the evaluation of area calculation has been done for comparing the area calculation differences between existing parcel maps, GPS Survey, and orthophoto image. There are 27 parcel of rice paddies as sample. All of the 27 paddy fields have been registered or certified. While the GPS stop and go positioning survey have a centimeter to decimeter accuracy. Based on the post-processing of data using software GNSS Solutions, the boundary point consisting of 60 points with a fixed solution that has an accuracy of 1.00 cm - 12.9 cm and 41 points the rest of the solution float with a precision of 6.90 cm –68.3 cm. Coordinate data cutoff point used must have accuracy less than 0.25 m in accordance with the tolerance allowed by the shift point PMNA / Head of BPN No. 3, 1997. Thus, only 88 meet the vantage point of tolerance. Of the 88 point limit was formed 18 field paddy field.

Table 2 shows the comparison of area calculation between the three methods. The comparison between the existing maps and orthophoto shows that there are some significant differences exist in the parcel boundary with the NIB 05 230, 03 070 and 03 065 with a different area of 70.696 m², 38.427 m² and 18.954 m² respectively. Some of the causes significant area difference, among others; (1) the one side of the corner boundary grow large trees that pre-mark is not visible, (2) some of the boundary monument has been move, and (3) the physical parcel of paddies rice in the field is not clear.
or not match with the existing boundary. Regarding to the statistical t-test, there are only two parcels with significant area difference as mention earlier.

### Table 2. Area calculation comparison

| No. | No. Parcel (NIB) | Existing Maps | Area Calculation (m²) | Orthophoto | GPS Stop and Go |
|-----|-----------------|---------------|-----------------------|------------|-----------------|
| 1   | 02925           | 507,842       | 516,888               | 516,208    |                 |
| 2   | 02931           | 437,971       | 447,046               | 447,957    |                 |
| 3   | 02937           | 1589,657      | 1583,033              | -          |                 |
| 4   | 02960           | 511,641       | 526,937               | 534,790    |                 |
| 5   | 02961           | 516,481       | 503,349               | 497,028    |                 |
| 6   | 02963           | 242,357       | 250,653               | 250,367    |                 |
| 7   | 02964           | 163,739       | 167,485               | 164,955    |                 |
| 8   | 03019           | 532,207       | 526,082               | 505,861    |                 |
| 9   | 03039           | 252,703       | 258,019               | 256,068    |                 |
| 10  | 03065           | 251,839       | 232,885               | 221,206    |                 |
| 11  | 03070           | 82,793        | 121,220               | 127,554    |                 |
| 12  | 03078           | 237,867       | 243,687               | 254,580    |                 |
| 13  | 03079           | 270,373       | 252,362               | -          |                 |
| 14  | 03104           | 207,603       | 210,302               | 212,625    |                 |
| 15  | 03120           | 238,934       | 243,171               | 237,230    |                 |
| 16  | 03135           | 300,584       | 306,760               | -          |                 |
| 17  | 03138           | 601,881       | 612,687               | -          |                 |
| 18  | 03147           | 254,790       | 238,923               | -          |                 |
| 19  | 04278           | 333,865       | 337,780               | 339,143    |                 |
| 20  | 04606           | 391,810       | 397,871               | 394,067    |                 |
| 21  | 04607           | 771,399       | 773,168               | 776,393    |                 |
| 22  | 05048           | 706,375       | 722,272               | -          |                 |
| 23  | 05049           | 553,173       | 544,079               | -          |                 |
| 24  | 05053           | 1060,595      | 1058,324              | -          |                 |
| 25  | 05060           | 864,094       | 862,801               | 877,663    |                 |
| 26  | 05061           | 380,097       | 389,304               | 394,808    |                 |
| 27  | 05230           | 410,150       | 339,454               | -          |                 |

Furthermore, the area calculation comparison between the GPS Stop and Go survey and orthophoto shows that only two parcel has significant area differences. The Biggest area differences is 20.220 m². The biggest parcel error at parcel number (NIB) 03 019, this caused by there is no boundary pre-marking exist. So, that the main error due to the miss-alignment of boundary point picking (digitizing).

The comparison of percentage area difference between existing maps and the digitization orthophoto and GPS measurement shows a good result. Regarding to the regulation, the area differences should less than 5%. Based on the evaluation of different percentage of the average area from orthophoto maps and the existing maps is 4.512%. Meanwhile, the percentage difference between the average area of orthophoto and GPS measurements is 1.804%.

### 5. Conclusion

This paper shows a successful of using UAV-based remote sensing system for producing the orthophoto as a basic cadaster maps. The orthophoto product accuracy is meet the 1/2.500 map scale accuracy. Some notes should be emphasized, regarding to the reason of biggest area differences, among others: (1) pre-mark is not visible or covered by vegetation, (2) some of the boundary monument has been move or missing, and (3) the physical parcel boundary of paddies rice in the field...
is not clear or not match with the existing maps boundary. The bundle adjustment shows the error less than 12 cm in all coordinates component. Meanwhile, the percentage of area differences from some parcel samples show less than 5% of differences. In future, the potential use of a GPS kinematic assisted photo flight should be explore in accordance to reduce the need for GCP survey.

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