UAV System With Terrestrial Geo-referencing For Small Area Mapping

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Key words : UAV, Cadaster,Surveying,Terrestrial,

SUMMARY

This research designed as the first stage of our research to develope small land parcel mapping or some land parcels mapping where distributed spreadly by combining an Unmanned Vehicle Aerial Mapping using UAV and terrestrial method, terrestrial method used to georefference photograph directly. This step mainly focusing in finding out an appropriate vehicle designed with the research objective, started with study on all capability aspect of total station. UAVs speed designed not exceed tracking ability of total station, extreemely can stop during fly or stop and go flying. For that reason multi rotor UAV type are selected to carry digital camera. According to field observation, UAV position can be determined successfully from the ground and this coordinate position assume coincide with photograph coordinate centre.

The UAV system capabilities to fly with or without runaway make it as a potential application for small area mapping. So that UAV method become a feasible alternative solution to map some cluster of parcels in rural or village area which has less and difficult transportation facility and as the solution to profide spatial data for land administration purpose.

Beside of several benefits, UAV has a major problem in geometric accuracy. In accord with land parcels mapping for instance, geometric accuracy highly required and Indonesia National Cadaster Office has setting up geometric accuracy of land parcels map with government rule. UAV accuracy degradation caused by several factor likes; Platform flight instability and flying height variation as the influence of the wind resulting various photo scale. Modification of existing method must be carried out to solve these problems, which is one our purpose in this research generally.

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1. INTRODUCTION

UAVs in this study is a system which is divided into two sub-systems that are attached to the vehicle itself consisting of a camera, navigation instruments; the second sub-system is system on land composing of digital terrestrial measuring devices. To support the implementation of the study, one should design an instrument/vehicle appropriate to the research requirement; thus, it is allowing modifying the design of instrument in accordance with the requirement specifications.

In the mapping technology, the UAV has provided several options to meet the need for the provision of data, especially the data on parcels. Tendency to derive data from all environmental conditions in "economical", "Up to date", manner and accuracy that meets the mapping standards is base of this research. The tendency can be used for accurately, complete observation and control over of land ownership status or plots in rural areas and small parcels in the area that lies scattered. Development of UAV technology design aims to make the technology more adaptive with low cost and use of the instrument as a carrier vehicle for the camera in aerial photography by combining traditional photogrammetric technology. So far, the massive land parcels mapping still common with high-resolution satellite imagery (Quickbird, Geoeye, World View) and in certain areas is using aerial photograph, but the method is constrained by the high price of the image (if it is related to the size of the area mapped), and the time for ordering images is constrained by several factors, one of the most common obstacles is cloud cover conditions and regulations on the purchase of the image. UAV capabilities in overcoming deficiencies of imaging using the satellite imagery is an excess of UAV technology in mapping parcels, but the main disadvantage in the use of UAVs is lying in the resultant geometric precision of photograph/image, it is associated with unstable camera carrying vehicle/aircraft.

Modification of existing method will be carried out to solve those problems, which is one our objective in this research generally.

1.1 Background

The rapid growth of population led to the need for land for more and more residence or parcels, it is resulting in a change in data on land use, both spatial and attribute, in the land administrative system. The phenomenon suggests the importance of the information on dynamic land ownership along with changes in the population in relation to treatment of land/parcels. Relationship with these changes spawned the need for a system that can record data in right, accurate, not misleading manner in defining the land status. Such changes lead to transformations of land spatial and textual database including data on control, ownership, use, and land utilization. To address the problems, one of measures to take is fast, modern, systematic, complete construction of base map and thematic map covering basic geographic element data, facility/important places and governance possession, use and utilization of land on a large scale.

In his research, Cunningham, K. (2011) found that the quality of the cadastral survey are directly related to population density and variety for each village, so often found in some of the villages with no cadastral maps that meet the standards of cadastral maps. The existence of the cadastral map for each village with diverse characteristics of population and topography is a challenge to seek a method in the provision of cadastral maps in every village in the region of NKRI. Another problem is the presence of a challenge to be able to map the parcels accurately in a small area and between the parcel and the others is not adjacent /distant/ within a single stretch one another.

The main problem in spatial land database updating is the availability of a map with a resolution and accuracy that meets the specifications of land maps. Regulation of the State Minister of Agrarian Affairs/Head of National Land Agency Number 3/1997 on the Implementation of the Provisions of Government Regulation No. 24/1997 on Land Registration in Article 13 stipulates that the basic Map of registration is made on scale 1:1,000 or greater for residential areas, 1:2.500 or greater for agricultural areas and 1:10.000 for large plantation areas, thus the necessary imagery with a resolution greater than 0,5 meters for residential areas, for agriculture is greater than 1,25 meters and 5 meters for plantations or it can be concluded that for needed to map the parcels that have high-resolution imagery. To obtain high-resolution images requisite high cost (if it is related to the mapped area of parcels) and time for procurement over 2 months (more) and are often constrained by cloud cover, so the approach of photogrammetry (using manned aircraft) be an option, but expensive aircraft lease and the requirements to fly a plane as a vehicle carrying the camera causes the method is economically ineffective, especially when the area coverage will be mapped is small (<1,000 ha), especially when the parcels are mapped lies scattered far apart from one another. Another problem commonly encountered with regard to the topographic characteristics. Characteristics of topography in several regions of Indonesia are distinctive challenge in terms of both topographic mapping accessibility and the implementation of mapping. The mapping by terrestrial or direct observation in the field have been recognized for precision that meets the technical mapping specifications; however, constraints of accessibility, weather and the extent of the area surveyed cause such methods are rarely used in areas with characteristics of undulated topography and hard accessibility. These situation led us to modify some surveying technic to meet with the necessity of land parcels map.

1.2 Objective

Based on the description in the background section, the objective of this research to be realized is "**Improving Land Parcels Mapping Method by Integrating UAV System With Terrestrial Direct Georeference System".**

To achieve the objective, the innovation was put in methods of providing spatial data by combining the low cost photogrammetric method using Unmanned Aerial Vehicle (UAV) with terrestrial method that has high accuracy as control point on the ground. Given the research innovation will be resulting the method of mapping parcels with following advantages:

1. Can be used on topography with high risk and hard accessibility.
2. Can be used to map small parcels and some scattered parcels located far apart from each other.
3. Have high temporal and spatial accuracy.
4. At low cost.

2. METHODOLOGY

In general, the availability of aerial photo map for the purposes of making a land parcels map in Indonesia is still far from complete oftenly satellite imagery used to identify parcels boundary with level of resolution accuracy not as it is expected. In addition to not meeting the resolution for the creation of land maps, the parcels to be mapped often are found out in areas that are difficult to map even by remote sensing method as a result of cloud cover or the degree of openness of the land which makes it difficult to be mapped directly in the field. Photogrammetric methods in either large, medium or small formats are generally plagued with problems of availability of aircraft, licensing in the photography, cloud cover requiring aircraft fly so low, the cost in photography, so for small acreage is assessed not effective, thus we need a method to map parcels that can overcome these problems, one of the methods that will be used in this research is the method of unmanned aerial mapping is also known as Unmanned Aerial Vehicle (UAV).

2.1 UAV Vehicle Design

There are several unmanned vehicle designs to be considered in the mapping of plots, as shown in Table 1. At the beginning of this study, we plan to use fixed-wing aircraft. However, after the examination of the signal response capability on the total station instrument is completed, we then use quadrotors.

Types of Vehicle	Range	Endurance	Weather Wind Dependency	Manuver ability	Payload Capaciti
Balloon	0	++	0	0	+
Airship	++	++	0	+	++
Gliders/Kites	+	0	0	0	0
Fixed Wing Glider	++	+	+	+	+
Propeller & Jet Engines	++	++	+	+	++
Rotor-Kite	++	+	0	+	+
Single Rotor (Heli)	+	+	+	++	+
Coaxial	+	++	+	++	++
Quadrotors	0	0	0	++	0

Multi-Copters	+	+	+	++	+

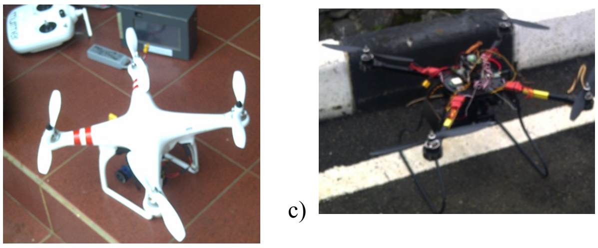
Table 1. Pro and cons of the different type of UAVs (0: Lowest value; +: Middle value; ++: Best) (Eisenbeiss, 2010)

We planned to use type of fixed wing gliders UAV with consideration to overcome the problems of payload capacity limitation and wind factor which are becoming a major problem in maintaining vehicle stability when aerial photo taken, as shown in Table 1. However, to find out more definitely the type of aircraft that is appropriate to this research, firstly we conducted study of aircraft design to determine which vehicle type is adaptable with total station (TS) instrument capabilities that will be used to determine the position of the camera. This study used non-reflector total station's top con GPT 3500 and GPT 7500.

Figure 1. Measure TS capacity in determining the position of moving objects.

To understand the tracking rate of total station instrument in determining the moving objects, we make a simulation measurement with moving cars with different speeds as the targets. In order to obtain position data / coordinates of target in various speed, we carried observation around the freeway which allow cars to move with speed until 100 km/hr, from the observation, we found that for the car with speed about 40 km/hr with a distance of 112 meters to the car TS need 11 seconds to process the signal meanwhile for cars at faster speeds, the longer processing time is necessary. The conclusion of the study on the response of this total station is the most suitable vehicle for this research is the vehicle with ability to fly at speeds below 40 km/h and stable. To meet this specification then it can not be achieved using fixed-wing aircraft/fixed wing. As a solution for the problem we have to consider alternate design and UAV of quadrator type equipped with navigation system and auto pilot is used. To design the type of aircraft, the team collaborates with PT. Terrascan. There were three quadrotor designs prepared in this study: type X650, X450 and type Q800.

a)



b) c)

Figure 2. a) quadrotor type X650 b) type X450 c) Q 800

The vehicle should be designed in such way that makes it able to support time synchronization process between time for photo capturing by onboard camera with the distance and direction angle maesurement time by total station on the ground. Three option offered in order time synchronization :

1. Set the time/timer on camera for the initial photo taken and interval of photo taken.
2. Equipe UAV with LED lights system that will flash on when the camera take the picture.
3. The aircraft can support the aerial photography in Stop and Go.

The third option can not be realized by fix wing UAV, that become the main advantage of quadrotor design is making possible fly and take the photo at very slow speeds < 40 km/hour even stop over area of interest as nedded or do the photography in stop and go way in contrast with fixed winged aircraft. Nevertheless, beside those advantage Quadrotor type has some major drawback in payload and endurance, specially in battery capacity, for this case we have be more carefully monitoring of battery capacity and load. In this study, we use the type of battery Lippo 2200 mAh 3 cellular with respective lifetimes is 5 minutes each.

The quadrotor type X650 body design consisting of metal frame make it more easily to reflect waves emitted by a total station, making it faster to get the vehicle position than type X450 which vehicle body is made of melamine, as the consecuency of this material body a longer time is necessary to get the vehicle position data when type X450 is used. But in terms of flight stability X450 is more stable than X650. UAV operator can maintain X450 position in a point for some minutes to help surveyor on the ground track it easily and take its coordinates. For those reason we will redesigned aircraft type X450 body with aluminum foil coated to reflect total stations wave better in the next research.

2.2 Measurement of Photograph Position

In general, the methodology to be used in this study is illustrated in Figure 3.

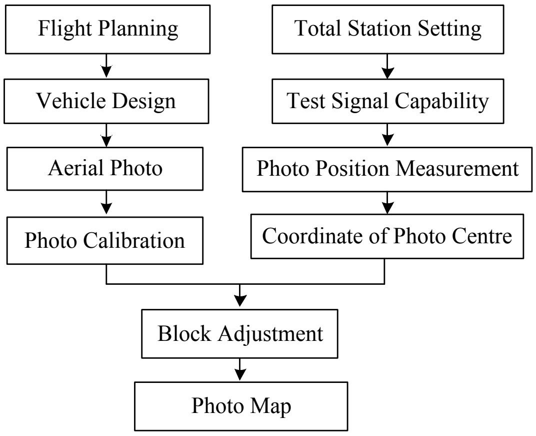


Figure 3. The methodology of research

As the measurement beginning with study on vehicle construction design to be used for photography and the digital camera used is a regular digital pocket camera such as canon 100s onboard in vehicle body. UAV also equiped with GPS navigation to monitor UAV system status and its position during flight, specially to direct the vehicle to some interest target / land parcel. Camera position measured using a non-reflector total station instrument GPT 7500 or GPT 3500 where installed just above the ground control points of known coordinates as refference, so that by knowing the distance and angle to the camera, cameras coordinates can be determined using polar coordinate and trigonometric system.

Basically, the land parcel photography using UAV is photogrammetric method where the photography carried out using digital camera attach on vehicle, but the vehicle used is small unmanned aircraft managed by the remote control. The relationship between the aircraft and the total station is depicted in figure 4. The combination of polar and trigonometric method in photo coordinates determination are the key of this method.

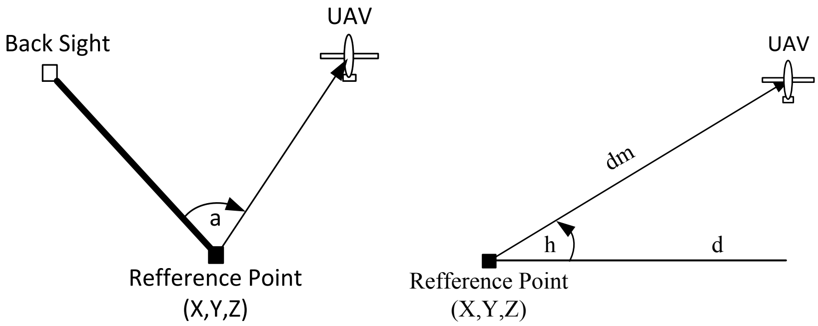


Figure 4. Measurement of UAV Position

As illustrated in figure 4, α is the measured horizontal angle of UAV/Camera from Back sight point. In the sametime total station perform trigonometric method with measuring vertical angle (h), slope distance (dm) and horizontal distance (d) and process all simultaneously to produce coordinates (x,y and z) of photograph.

Figure 5. Measurement of vehicle position using Total Station

Although UAV can be managed up to the range > 20 km, but the length of strip in one photo session is limited by the range of total station. For example, the maximum range of the total station Topcon of GPT 3500 Type to its target is ± 2000 meters, so UAV can't be further than 2.000 meter from total station. The limitation of total station range is a major consideration in the photography flight planning, so this method implemented only suitable for small area and plane topography (up to this research).

UAV is unmanned aircraft controlled remotely by using a remote control in crossing over the area to be mapped so that the entire area is covered. The camera used is comprised of many types and brands likes canon S100 and GoPro; even almost all pocket cameras can be used as imaging sensors, while to obtain high-resolution level can be offset by vehicles flying high. Problems commonly persist in using the camera mounted on a UAV is regarded to image geometric accuracy of images produced, this is due to the slant position of the camera at the time of the photography caused by wind, the stronger the wind the bigger slant angle, so that when resulting image directly used to develop a mosaic photo, it will not meet the accuracy standards of map scale of 1:1,000. To reduce the effects of these problems, the camera was equipped with a gyro system to compensate tolarable slant angle.

Position of camera/vehicle is tieded up to the known ground control points / refference points around the location of the research that is the point. The refference points named P1 with coordinate (0806171 ; 9233373) in UTM systems and backsight point P2 (0806196 ; 9233391) selected as control points and conjugate backsight or in other case local coordinate system are aplicable too.

Figure 6. The reference point

Another issue of this research is related to the measured target, UAV designed in various lengths according with requirement or observation objective, the question is which part of vehicle should be targeted from the ground to be consider as camera centre ?, since very difficult to exactly centering the target to the camera. Whether it should be in the right position of camera or anywhere across the vehicle body position with assume that target deviation from camera centre can be tolerated. These situation can be described as follows:

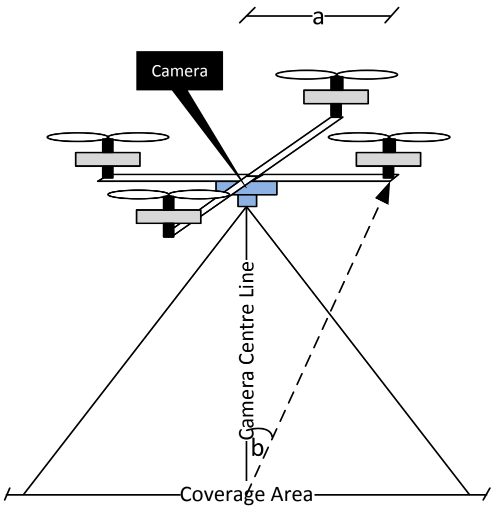


Figure 7. Direction of the shot at the target

When total station shots slip from the camera central with deviation angle (β), where the picture scale is comparison between focus camera (f) with flying height (h) and the magnitude of the error due to slipping of the photograph by the total station in photo image is (b), then relation between target diviation (a) and (b) can be described as :

$$b = \frac{f}{h} \; x \; a$$

From the above equation can be concluded that the target in the area of the vehicle body can be assumed to coincide with the center of camera, if we consider airframe size < 2 meters (1 meter to left and right side), the deviation from the camera center on the image photo can be considered coincident, so surveyor can shoot any location on the body of UAV to measure camera posistion.

The problems that may arise in the determination of the distance and angle of each photo image is synchronization between photo taken occurrence / exposure with distance and angle data retrieval by total station, so that necessary to consider UAV design and planning specifically related to the implementation of the photo shoot time by arranging the photographic interval timer in the camera and use a beam signaling LED (Light-emitting diode Emitting) were helped as a cue for surveyors to retrieve the distance and angle data of the camera position on the ground. Similarly, the design of control point distribution, it must accomodate relationship among land parcels to be mapped, total station capability and design and nature of UAV. Some example of aerial photo with its x,y coordinate and z (flying height + instrument height) are listed in the table below :

(08061139 ; 9233342 ; 72)

(0806104 ; 92333411 ; 75)

(0806194 ; 9233294 ; 72)

(0806166 ; 9233409 ; 75)

Figure 8. Coordinates of photo centre

Pictures recorded are still containing distortions, in which the circular-shaped pictures/arched as the effect of the lens. For photogrammetric processing stages, each photograph calibrated beforehand so that the data has the flat form. The post process of each photogtraph are presented in the form of mosaic image as follow.

Figure 8. Land parcels image

2.3 Control Point Design

Control points tied up photograph to coordinate system on Earth, so that the process of reconstruction of the photo of the vehicle UAV will greatly depend on the quality and the distribution of these control points. In this study selected control points must be close to the parcels will be mapped. In order to distribute it in the correct manner, Control points location must cover parcel boundaries, located in the stable place during measurement, consider total station range to UAV and for this research we still avoid undulated topography. In addition of the small area being measured, it is possible to use terrestrial method in ground control points position measurements.

3. CONCLUSION

The UAV technology can be used to map a small area economically, but the quality of the resulting map is always constrained by the geometric accuracy problems as a result of the instability of the vehicle while taking the photos, so aerial photography mapping method using the usual UAV can not be used to create an accurate map. To overcome these problems, we try to modify fashion mapping methodology which in this research by integrating vehicle UAV systems photogrammetry with terrestrial systems.

The initial phase should be done is to conduct a study about vehicle design which accomodate the characteristic of total station to determine camera position accurately, a vehicle must be able to fly in stop and go, stable against wind thrust and the outer body material should be made from perfect reflector like metal. These specification facilitates observers on land to get the reflection waves perfectly which is then convert it onto slope distance, vertical angle, and the coordinates x, y, z of camera at the end.

The deviation between camera centre and shooting target on UAV body can be ignored, so we can assume that coordinate resulted coincide with coordinate of the photo centre.

4. REFFERENCE

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