Mapping the Outermost Small Islands Utilizing Uav-Based Aerial Photography

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Key words: Low cost technology, UAV-Based Photogrammetry, Outermost Small Islands

SUMMARY

This paper shows some experiences in mapping the small islandsnear the outermost Indonesia boundary line that utilizing UAV (Unmanned Aerial Vehicle)-Based aerial photography. Some notes that should be emphasized are described, which are practical advantage and disadvantages in operation; automation in production; geometric accuracy, and potential for future applications. The UAV's aerial platform is made from the regular R/C-Aeromodeling that can carry point and shoot camera type for capturing aerial photo in certain formation with 85% overlap and 25% sidelap. The aerial platform has avionic system (ardupilot open source) that use for autonomous during photo flight. Those instruments are keeping the aerial sub-system cost less than 3000US$. The GPS Surveying with OEM UBLOX-GPS receiver is used for Ground Control Survey and record raw data tracking during photo-flight. More than 300 amount of aerial photos captured in each flight. Furthermore, the structure from motion algorithm is used for processing aerial photo to produce basic Orthophoto and Digital Surface Model (DSM). Then, the DSM data are filteredby slope-based method for deriving Digital Terrain Model (DTM). This technique can produce accuracy less than 2 times Ground Sampling Distance (GSD) for Horizontal position and 5 times GSD for DSM information. Aerial Photography with GSD number 15cm is enough produce map scale up to 1/2500. From those experiences can be founded that aerial photo that captured in the daylight afternoon is more advantages than in the morning, because in the clear shallow water near the beach, some underwater object can be seen. One of the challenges in working at the small islands with the UAV-based is the windy condition. In future, the UAV's system manufactures are increase and the tele-control range is more long distance also. This make UAV-based mapping can be operated in more big area coverage and more stable also.

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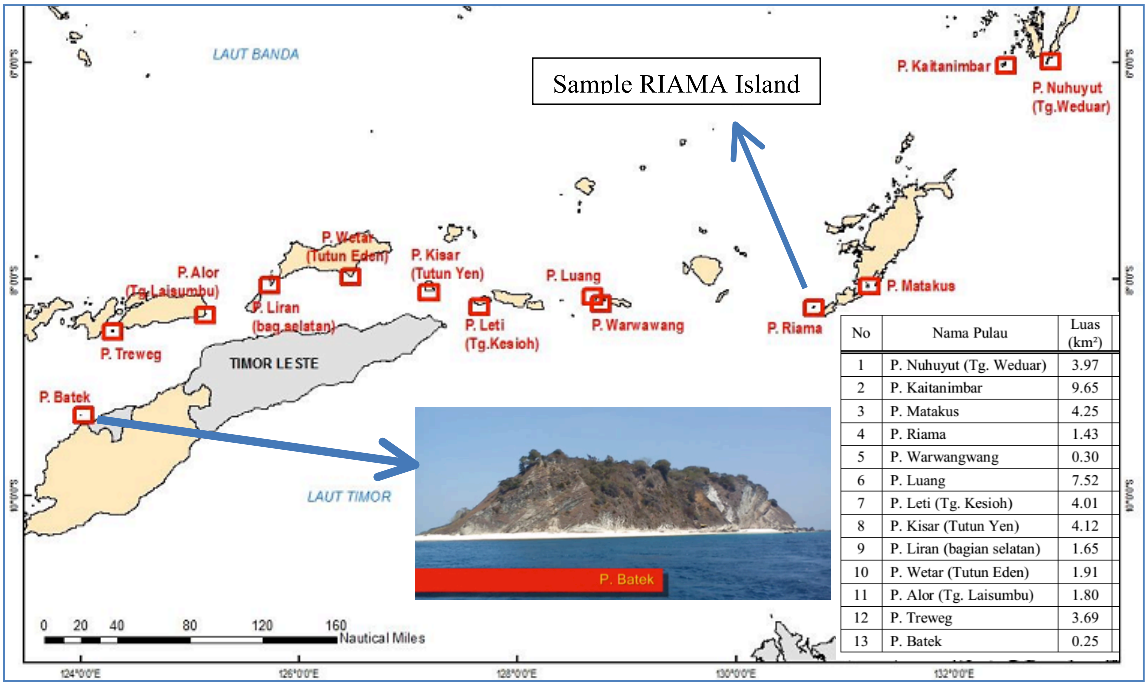
1. INTRODUCTION

Indonesiais an archipelago region that has 13,466 islands with toponimi name (seeMenkokesra, 2013). The geospatial data collection on the border area becomes a necessitywhich is very important as a database for development planningboth in terms of border spatial planning and territorial. In Geospatial Information Agency (BIG: BadanInformasiGeospasial) has Boundary Mapping Center unit that deal withdata collection survey at boundary area.BIG as a national wide instituteof surveying and mapping authoritiescontinue to strive, and become the backbone of the border dispute in accordance with its core competency in mapping.Documenting the outermost islands of Indonesia boundary region is also very important. The boundary areas at the sea, generally definedby baseline point on the outermost islands that those are now recorded almost 92 islands. Until now some of the outermost islands still need to be more intensivelymanaged and organized. It is needed the spatial data for outermost small islands thatserve as the baseline point map in terms of determining the boundaries of the country withmap scale of 1:10,000 or large. To fulfill this purpose,the aerial photography has conducted on the outer islands forpreparation of orthophoto map and topographic contour map. It is planned that this orthophoto map can be interpreted to extractspatial data for inventory and supporting the activitiesmanagement of both sector the natural resource and environmental. Some challenges in mapping at the outermost small island are as follow:

(1) Some of Small Island has area less than 500Ha (see Figure 1);
(2) Some of the island locates in the less infrastructure region (more than 100km from the nearest airfield)or big ocean that has not regular transportation facility yet (see Figure 1);
(3) Some of those areashave no living people;
(5) Image should be fulfill for producing map scale 1/5,000 – 1/2,500; and
(6) Keeping the cost as low as possible.

One of the alternative techniques is utilizing the Unmanned Aerial Vehicle (UAV)-Based Photogrammetry. Many researchers have been using this technique due to its cost effective for implementing in area less than 1000Ha (see Baiocchi, et. al, 2013, Hormigo, T. et.al, 2013, Pérez, M. et.al, 2013, Rokhmana, 2013). This paper shows some experiences in mapping the small islands near the outermost Indonesia boundary line that utilizing UAV (Unmanned Aerial Vehicle)-Based aerial photography. Some notes that should be emphasized are described which are practical advantage and disadvantages in operation; automation in production; geometric accuracy, and potential for future applications.



No	Nama Pulau	Luas (km²)
1	P. Nuhuyut (Tg. Weduar)	3.97
2	P. Kaitanimbar	9.65
3	P. Matakus	4.25
4	P. Riama	1.43
5	P. Warwangwang	0.30
6	P. Luang	7.52
7	P. Leti (Tg. Kesioh)	4.01
8	P. Kisar (Tutun Yen)	4.12
9	P. Liran (bagian selatan)	1.65
10	P. Wetar (Tutun Eden)	1.91
11	P. Alor (Tg. Laisumbu)	1.80
12	P. Treweg	3.69
13	P. Batek	0.25

Figure 1. Sample of the outermost Island in East Part Region.

2. AN APPROPRIATE UAV-BASED AERIAL PHOTOGRAPHY SYSTEM

This describes the UAV-Based aerial photography system that meet the need for mapping purposes. The mapping activities in the outermost island (see Figure 1) have to meet the accuracy for map scale 1/10.000 or larger. Furthermore, the imagery should be sharp enough to see some specific feature as a natural monument in each island. So, the GSD (Ground Sampling Distance) should be less than 15cm. Other consideration is due to lack of transportation and facility in some island that has no living people. The idea is arriving the small island than taking the aerial photograph by UAV, and doing GPS surveying during the photo flight also. All of those activities should be complete in one day work than coming back to the base camp. So, the UAV-Based aerial mapping system should has the following characteristics, such as (see Table 1)

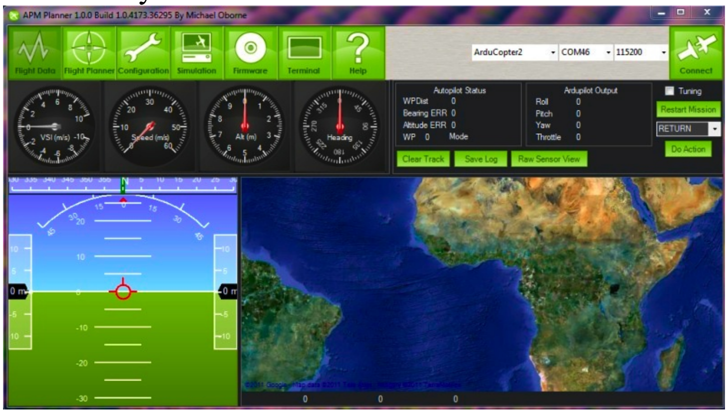
1. All system should be as portable as possible. The best choice to use battery power RC Plane and small generator power for running ground station on the laptop
2. Point and shoot digital camera with GPS Photo Tag capability has chosen as optical sensor with modification for external-extended Li-Ion battery that can handle power up to 8 hour operation.
3. The airframe should be takeoff and landing at limited area or by applying net landing near coast line or at the ship yard. So, the best choice is to use light weight airframe (< 3kg) with pusher (rear) propeller.
4. Regarding to the weather with strong wind condition in coastal zone area, the flight plan should be closely enough to get overlap 85% and sidelap 25%. So this will reduce the risk caused by deviation in flight plan.

All of the system can be carried by fewer people in a backpack or portable. Then throw the platform (hand-launch take-off) to fly for 20 minutes at altitude and pattern following the previous flight plan in order to do photo flight mission to cover 3000Ha in each flight. Furthermore, platform will land back automatically to do the downloading image and in-flight orientation data. The imagery is processed by digital photogrammetry to produce orthophoto mosaic and digital surface model (DSM) a few hours after the downloading. Both of these data are the basic products to be able to do visual interpretation for thematic or geo-information extraction later on.

Table 1. General Characteristic instrument for UAV-Based Aerial Mapping

<table>
<tr><td>Airborne Platform</td><td>
- Type High-Wing Semi Glider with Autonomous Flight
• Endurance: < 25 minuteor 20km flightline
• Range R/C dan telemetry: < 10km
- Portable Backpack<3kg with wing span 1.9m
- Take-Off (Hand Launch)
- Landing: nett landing

- Power: Motor electric brushless
- Flying High: 200m – 450m above ground level</td></tr>
<tr><td>Avionic System</td><td>- Autopilot:Atmel 2560, 8-bit (open source: Ardupilot Controller)
- R/C min. 7 CH
- RF Modem for data telemetry (900MHz 1Watt)<10km
- GPS LoggerFreq.5Hz</td></tr>
<tr><td>Camera Sensor</td><td>- Point and Shoot Digital Camera 12-14 MPix, field of view > 65deg Canon S100 with GPS Tag Enabled
- External Extended Battery for 8 hour operate
- Foam based Mounting and anti-vibration system</td></tr>
</table>

Portable Ground Control Station (Laptop and Booster Antenna)	- Open Source Mission Planner for: Flight Planning and Real-time telemetry command  - Antenna >8dBi - Universal Extended Bateraifor netbook dan RF receiver
Post Processing for Orthophoto and DSM Point Cloud	Automatic bundle adjustment with Selft-Calibration (inflight calibration), Based on Structure from Motion Algorithm and SIFT Invariant Image Matching
Editing Cartography	Saga-GIS for DSM to DTM filtering based on Slope-Based Criteria Quantum-GIS for interpretation based on digital on screen digitation

3. SOME NOTES ON CAPABILITIES

Figure 2 shows the typical production line while utilizing UAV-Based aerial mapping. Working with UAV-Based Aerial Mapping has two issues: (1) the platform stability; and (2) the geometric accuracy of Point and shoot camera. The platform stability will cause to the flight plan deviation. While, the point and shoot camera type have two issues: (1) non-metric lens quality; and (2) lens not stable enough (zoom lens can be varied). The best way to improve the camera geometric is to running bundle adjustment with self-calibration camera or "in-Flight" calibration. This can improve the precision up to 0.4pixel by adjustment. The Processing system use Pentium core i7 with 20Gb RAM. This can handle up to 1,000 photo frame to produce Orthophoto mosaic and DSM (Digital Surface Model) with processing time less than 10Hour. Another problem is to filtering the DSM to become DTM (digital terrain model) that can be varies and depend on the landscape characteristic.

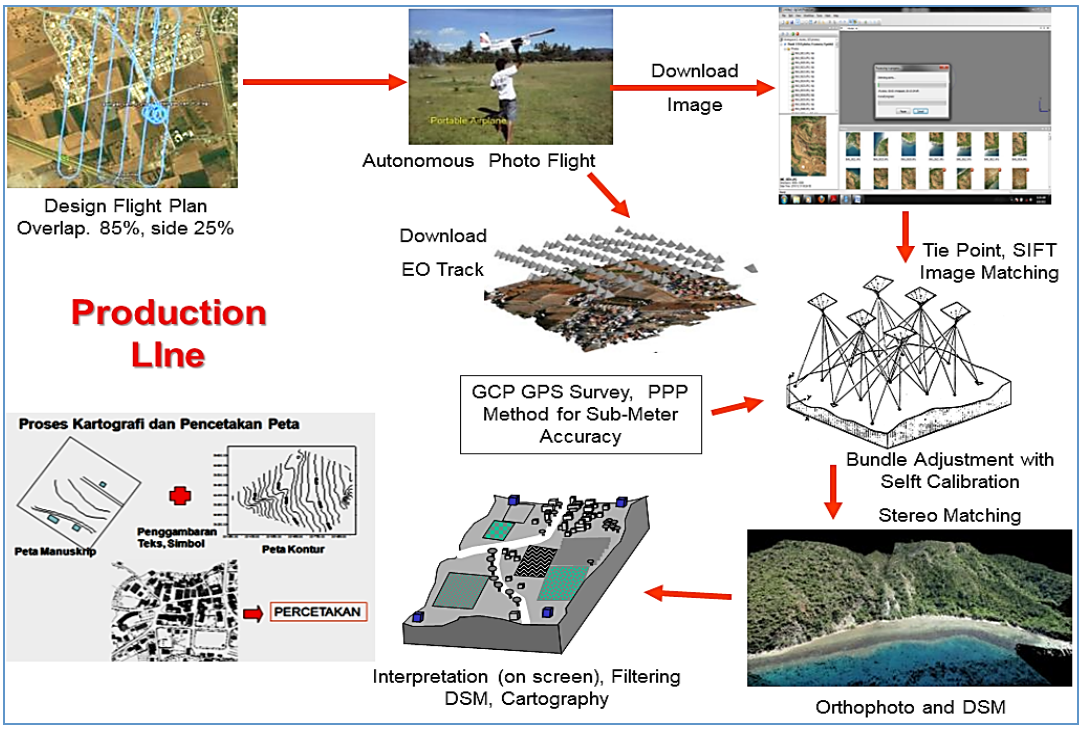


Figure 2. Process Production Utilizing UAV-Based Aerial Mapping

Some notes about the geometric accuracy capabilities as follow:

1. Due to the platform stability, the aerial photograph taken by UAV should has overlap area 85% and sidelap 20%. This is big of redundancy imagery that has advantages for the automation and accuracy enhancement. The adjacent photo with bigger overlap has high cross correlation which is good for identifying tie point image matching.
2. The Aerial Photograph have GSD (Ground Sampling Distance) = 10cm - 15cm, which is fulfill for map scale up to 1/1,000. So, the error geometric processes up to 5 time GSD still acceptable for map accuracy 1/10,000.
3. The Aerial Photograph with landscape orientation have Stereo Angle (parallax) = 20-25 deg. This Base/High ratio is fulfill for Hilly Terrain Type
4. The aerial photograph, Utilizing Point and Shoot camera type with self-calibration process (or In-flight calibration) to produce accuracy = 2 - 3 time GSD or 30cm - 50cm for Hz (X, Y) , and 3 - 5 times GSD or 50cm - 1.5m for elevation (Z) in OPEN AREA
5. The Biggest problem working with aerial survey is cannot see the objects or objects covered by others highest objects. So, “cannot see” means cannot be measured also.
6. The Post processing with stereo matching technique will produce a Digital Surface Model (DSM), not Digital Terrain Model (DTM). So, this needs to apply the Filtering Process to reduce DSM to DTM. The Filtering cannot guarantee the accuracy. In general, the accuracy of filtering is 8 times GSD or about < 2m.

4. SAMPLE RESULT IN SMALL ISLAND

The UAV Platform is relatively light weight (< 3kg), this make difficult to follow the flight plan even with autonomous flight system. Flying with autopilot in parallel to wind direction give more straight path than cross wind flight direction. Figure 3 shows the actual flight tracking during photo flight in Riama Island. This show in Small Island or Beach the wind speed can be more than 40km/h that make difficult for light-weight aerial platform to handle the straight line flight. The high overlap and sidelap area makes no missing stereo coverage; furthermore all of the area has covered more than 4 images.

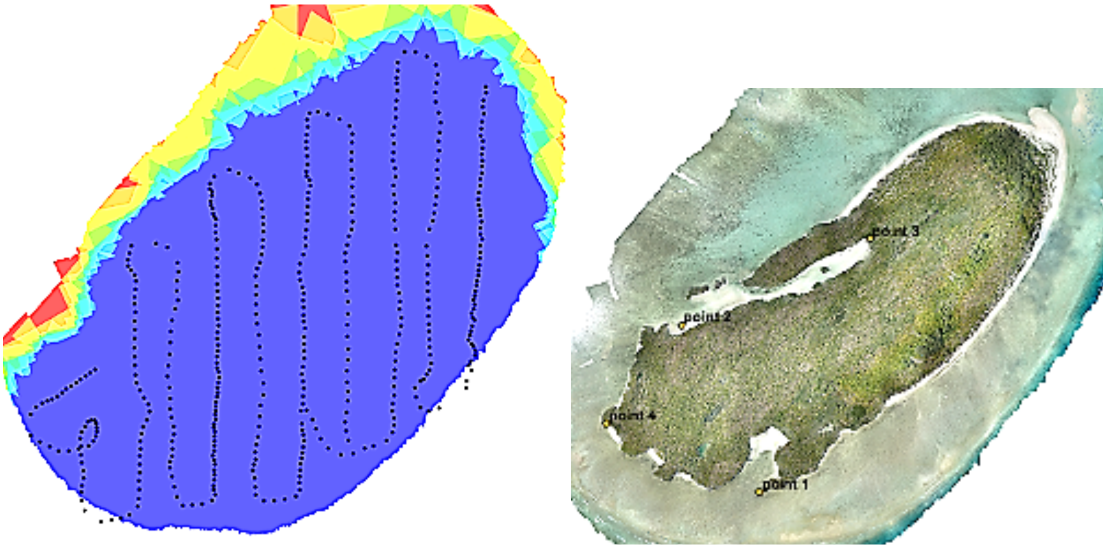


Figure 3. Actual flight tracking of UAV Platform

In General, the automatic aerial triangulation is successfully implemented by SIFT-Invariant algorithm for detecting tie-points. This algorithm make possibility to auto detects tie point more than 15,000 point in each overlapping area. This because the high overlap area makes high cross correlation between photos.

Error Number in Check Point GCP

Label	X error (m)	Y error (m)	Z error (m)	Error (m)	Projections	Error (pix)
point 1	-0.192820	-0.061007	-0.002534	0.202257	38	0.000001
point 2	0.336762	-0.098015	-0.005003	0.350772	32	0.000000
point 3	-0.086978	0.177180	0.002623	0.197395	35	0.000000
point 4	-0.056931	-0.018158	0.005013	0.059966	32	0.000000

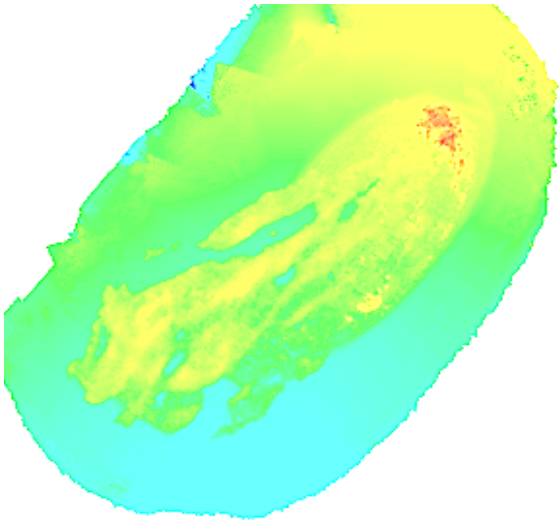


Figure 4. Result from automatic aerial triangulation and DSM

The automatic aerial triangulation use bundle adjustment with self-calibration that can produce less than 2 pixel error precision (see Figure 4). Some noise in product DSM happens in some homogenous area such as water/sea area and sandy beach area. Then, both of Orthophoto image and filtered DSM information are used for producing vector map and contour map. This technique can produce accuracy less than 2 times Ground Sampling Distance (GSD) for Horizontal position and 4 times GSD for DSM information. Aerial Photography with GSD number 15cm is enough produce map scale up to 1/2500.

In Future, there should be another potential application because in clear shallow water area, the aerial photograph can see the underwater object also (see Figure 5). This underwater object can be classified by visual interpretation.

Figure 5. Sample photo of underwater objects

5. CONCLUSION

This paper shows experience of utilizing UAV-Based aerial photography for mapping the Outermost Small Island (sample Riama Island). This can produce accuracy less than 2 Ground Sampling Distance (GSD) or less than 30cm for Horizontal position and less than 4 GSD or less than 60cm for elevation. One of the challenges in working at the small islands with the UAV-based platform is the windy condition. From those experiences can be founded that aerial photo that captured in the daylight afternoon is more advantages than in the morning, because in the clear shallow water near the beach, some underwater object can be seen. In future, the UAV's system manufactures are increase and the tele-control range is more longer distance also. This make UAV-based mapping can be operated in more big area coverage and more stable also. In clear shallow water area, the underwater object can be seen for visual interpretation.

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BIOGRAPHICAL NOTES

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