Topographic Mapping using Unmanned Aerial Vehicle (UAV)Technology - Photogrammetry Method

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Key words: UAV-Photogrammetry, Ground Control Point (GCP), Independent Check Point (ICP), Aerial Triangulation (AT), Topographic map

Engineering survey; Photogrammetry; Positioning

SUMMARY

Photogrammetric mapping survey technology has evolved both in terms of data collection and in data processing, especially on data collection techniques using Unmaned Aerial Vehicle (UAV). This mapping survey uses UAV-Photogrammetry method which is equipped with a non-metric digital camera. This UAV-Photogrammetry method is a combination of photogrammetric methods and terrestrial methods because in some locations there are buildings and tall trees that obstruct the object so it can not be seen in aerial photographs**.** The terrestrial survey is used Total Station instrument for height (elevation) measurement and situation measurement in the required location. Ground Control Point (GCP) surveys using a Global Positioning System (GPS) / Global Navigation Satellite System (GNSS) type geodetic receiver and Aerial Triangulation data processing (AT) using bundle block adjustment method. Independent Check Point (ICP) which is a ground control checkpoint located between GCP and used for quality control of topographic mapping process. ICP is not involved in the Aerial Triangulation (AT) data processing, but ICP coordinates of GPS/GNSS survey are compared with ICP coordinates on the resulting topographic map product. The resulting product is Orthophoto, Digital Terrain Model (DTM), land cover, Digital Surface Model (DSM) and contour as derived product from DTM. Geometric accuracy based on American Society for Photogrammetry and Remote Sensing (ASPRS) 2014 Positional Accuracy Standard for Digital Geospatial Data. The result of map product, horizontally meets the needs of a 1: 1000 scale topographic map, and vertically meet the needs of a 1: 2000 scale topographic map.

RINGKASAN

Teknologi survei pemetaan metode fotogrametri telah berkembang baik dalam hal pengumpulan data maupun pengolahan data, terutama pada teknik pengumpulan data menggunakan *Unmaned Aerial Vehicle* (UAV). Survei pemetaan ini menggunakan metode *UAV-Photogrammetry* yang dilengkapi dengan kamera digital non-metrik. Metode *UAV-Photogrammetry* ini merupakan kombinasi metode fotogrammetri dan metode terestrial karena di beberapa lokasi ada bangunan dan pohon tinggi yang menghalangi objek sehingga tidak terlihat pada foto udara. Survei terestris dilakukan menggunakan alat Total Station untuk pengukuran tinggi (elevasi) dan pengukuran situasi di lokasi yang diperlukan. *Survei Ground Control Point (*GCP) menggunakan *receiver Global Positioning System* (GPS) / *Satelit*

Navigasi Global (GNSS) tipe geodetik dan pengolahan data *Aerial Triangulation* (AT) menggunakan metode *Bundle Block Adjustment. Independent Check Point* (ICP) yang berada di antara GCP digunakan untuk kontrol kualitas proses pemetaan topografi. ICP tidak dilibatkan dalam proses pengolahan data AT, namun koordinat ICP hasil survei dibandingkan dengan koordinat ICP pada produk peta topografi yang dihasilkan. Produk yang dihasilkan adalah *Orthophoto, Digital Terrain Model* (DTM), tutupan lahan, *Digital Surface Model* (DSM) dan kontur sebagai produk turunan dari DTM. Akurasi geometrik produk peta yang dihasilkan berdasarkan standar internasional yaitu *American Society for Photogrammetry and Remote Sensing (ASPRS) 2014 Positional Accuracy Standard for Digital Geospatial Data*. Hasil dari produk peta, secara horizontal memenuhi kebutuhan peta topografi skala 1: 1000, dan secara vertikal memenuhi kebutuhan peta topografi skala 1: 2000.

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1. INTRODUCTION

Photogrammetry mapping technique is a mapping and measurement technique that is not done directly but by using aerial photography as an intermediary medium. This technique has long been used in a variety of purposes including for the generation of large-scale base map. This technique is recognized as a fast mapping technique, compared to other techniques and can provide good results. Another added value of photogrammetry mapping technique is, the resulting map provides a description of the ground surface information and the objects above it as a whole. Planners will have easy and flexible planning, interpretation, and understanding of field conditions, not only topographic forms but also objects that exist on the surface of the earth, whether natural objects (such as plants, river conditions) but also objects man made (such as settlements and roads). The obstacles that can be faced by this technique is to map objects that are shaded by high objects such as buildings and trees, obstructing the visibility of aerial photographs. To overcome this process photogrammetry mapping will be followed by field activities, in the form of measurement and field identification. The photogrammetric mapping generation has now come to " Photogrammetry Digital ", a photogrammetric mapping technique where the line map product is produced in digital form (Softcopy) which can later be printed onto a hardcopy sheet. Equipment used for data processing using numerical analytical calculations in data processing. With this approach will be able to reduce errors caused by equipment configuration on conventional photogrammetric techniques performed analogue.

This Photogrammetry–UAV method is a combination of photogrammetric methods and terrestrial methods because in some locations there are buildings and tall trees that obstruct the object so it can not be seen in aerial photographs. Similarly, the measurement of elevation is done by terrestrial method using Total Station instrument.
The aerial photography was performed using a non-metric SLR digital camera mounted on the UAV(Unmanned Aerial Vehicle). Survey of ground control points using geodetic survey GPS, aerial triangulation processing use bundle block adjustment method, digital photogrammetric processing using Digital Photogrammetry Workstation.

Case study of topographic mapping of Photogrammetry–UAV method at Bandung Giri Gahana (BGG) Golf Course, Jatinangor Highway, Sumedang District, West Java Province with an area of about 125 Ha for site-plan purposes. The aerial photography was performed using a non-metric Sony Alpha 6000 digital camera on the UAV Skywalker 2200 type. The ground control survey was determined using Global Positioning System (GPS) / Global Navigation Satellite System (GNSS) a geodetic type receiver, Aerial Triangulation (AT) data processing is done by bundle block adjustment method. Terrestrial survey using Sokkia Total Station SET-550x.
Evaluate the results of the topographic map process using the Photogrammetry–UAV method using the standard accuracy recommended by the American Society for Photogrammetry and Remote Sensing (ASPRS) 2014.

2. METHODOLOGY

The topographic mapping survey methodology using Photogrammetry – UAV method is a combination of terrestrial method and photogrametry method, as follows:

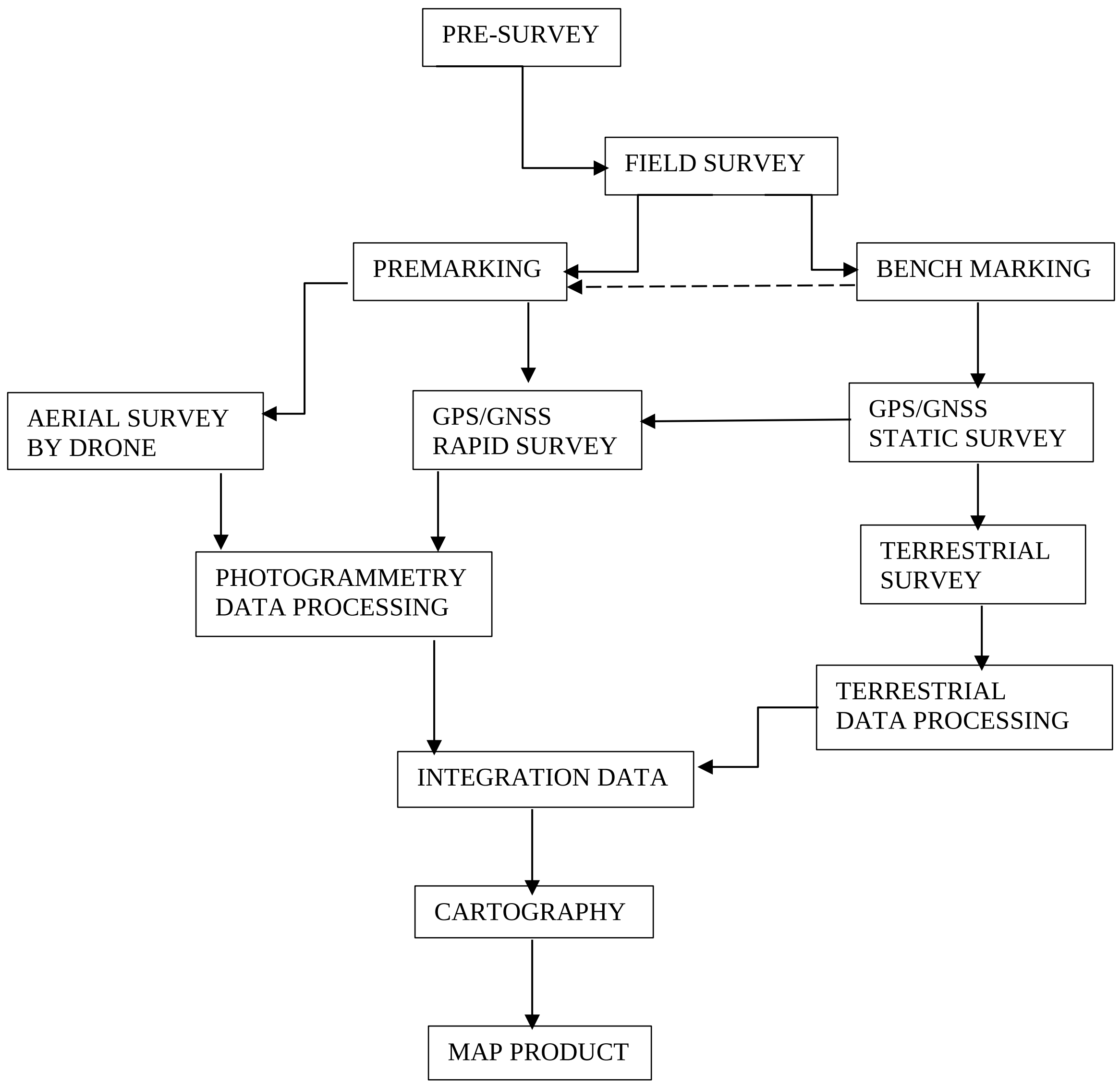

Figure 1. Methodology of Photogrammetry – UAV Method

2.1 Pre - Survey

In the pre-survey, administrative and technical preparations for the mapping area are prepared for the equipment to be used, the reference point search, the flight planning in the area to be

mapped, the distribution plan of the mapping point network, in example Benchmark (BM), Premark distribution plan of Ground Control Point (GCP) and ICP.
The reference point used is ITBJ (ITB Jatinangor01) which has known coordinates in the geographic coordinate system, as in Table 1 as follows:

Table 1. Coordinates of reference point (ITBJ)

No	Point	Latitude	Longitude	Ellipsoid height (m)
1	ITBJ	6° 55' 38,77610" S	107° 46' 13,86560" E	776,3094

For flight planning using Sony Alpha 6000 camera the following information is required:
• Focal length of the camera lens used is fixed 20 mm
• Planning high above ground is 250 meters;
• The size of one pixel is 3.9 microns (CMOS sensor size is 23.4 mm x15.6 mm);
• The size of the CMOS / CCD array sensor is 6000 pixels x 4000 pixels;
• The size and shape of the photo frame on the ground (294 m x 195 m);
• End-lap 80% and side-lap 60%
• Ground Sampling Distance (GSD)
• Average UAV speed is 10 to 15 meters / second

From the camera lens and plan of the flying height, obtained the aerial photograph scale is 1: 12500. The specification of Sony Alpha 6000 camera, the size of one pixel is 3.9 micron and the size of the CMOS sensor is (23.4 mm x15.6 mm), then obtained GSD = 48.75 mm rounded to 4.9 cm. The overlap of aerial photograph = 80% and side-lap = 60%, and from CMOS height obtained then Air Base (distance between exposure point) = B = 39 m. The ground footprint length is obtained from CMOS height and photo scale = 195 m. The distance requirement between Ground Control Points used is 4B = 4 x 39 m = 156 m. The ICP point is located between the GCP points. The distribution plans of GCP and ICP are as follows:

Figure 2. GCP and ICP distribution plans

The location of the area to be mapped is in Jatinaor Sumedang District, West Java Province, Indonesia. Geographically the boundary of the survey location is latitude 6 ° 55' 29.80 S - 6 ° 54'36.05" S and longitude 107 ° 45' 39.83" E - 107 ° 46' 7.06".

2.2 Field Survey

2.2.1 Benchmark (BM) and Premark

BM is a network points of mapping. Premark are marks at ground points so that they can be identified in aerial photographs. Premark is made from a blue-orange plastic material, cross-shaped and installed at points BM, GCP and ICP.

2.2.2 GPS/GNSS Survey

Measurements surveys of BGG01, BGG02, BGG03 and BGG04 were carried out using GPS/GNSS RTK Trimble R4 receiver dual-frequency with radial static method for 1 hour from ITBJ point whose coordinates are known as Table 1. In addition, also done Premark measurements at 73 other points of 53 points as GCP and 20 points as ICP. Premark measurements were performed using GPS / GNSS RTK Trimble R4 receiver dual-frequency with static rapid static method of approximately 15 minutes to 20 minutes.

Figure 3. GPS/GNSS Survey

GPS survey results are calculated using the SkiPro software, obtained the coordinates of BM as in Table 2 as follows:

Tabel 1. BM Coordinates

Point Id	Easting	Northing	Ellip. Hgt.	Sd. Northing	Sd. Easting	Sd. Height
BGG01	805352.971	9235065.592	867.300	0.0004	0.0005	0.0011
BGG02	805400.401	9235076.581	864.061	0.0007	0.0006	0.0014
BGG03	805791.819	9233752.280	787.391	0.0005	0.0006	0.0016
BGG04	805733.177	9233735.324	784.663	0.0002	0.0003	0.0007

2.2.3 Terrestrial Survey

Some mapping areas are covered by high objects such as buildings and trees, making it difficult to identify on aerial photographs, therefore surveying terrestrial measurements in the area to complete ground surface data using Electronic Total Station (ETS) instruments. Similarly, the elevation measurements at the required points are tied to a known BM or GCP point of coordinates.

2.3 Aerial Photography Survey

Equipment used in aerial surveys are as a set of Skywalker 2200 UAV motor-powered with LIPO Battere 10000 mAh and equipped with PixHawk + ArduPilot autopilot system and Sony Alpha 6000 digital camera with 20 mm fixed focus length lens.
Flight height ranges in 250 meters above ground level and GSD average about 4.9 centimeters. The aerial photography survey is divided into 2 blocks sre North and South.
During the flight mission, any current position of the UAV and exposure points will be monitored in real time by telemetry on certain radio frequencies, such as the following figure:

Figure 4 Applications for realtime monitoring during an aerial survey mission

2.4 Data Processing

2.4.1 Terrestrial data

Terrestrial data processing is calculated using existing software on ETS instrument equipment.

2.4.2 Photogrammetry data

The number of aerial photographs produced is excessive (exposure is done per 1 second), therefore it is necessary to compile the aerial photograph to meet the 80% overlap geometry requirement. The compilation of aerial photography is done with software developed by PT. InovaMap.
The first stage in Photogrammetry data processing is to look for tie points between photos automatically using image matching technique. Tie points generated photos with automatic techniques is usually very much, so it needs to be done separation or filtering (filtering) of the big mistake (blunder). Digital photogrammetry process is done with Agisoft PhotoScan software. The average flight height is 281 m, the number of aerial photographs being processed

is 617 photos with ground resolution of 5.34 cm / pix. This aerial photograph survey covers an area of 2.08 km2. The number of points on the photo resulting from processing as much as 3.2 million more points.The Aerial Triangulation (AT) data processing generates the coordinates of vertical and horizontal minor control points photogrammetrically, and by using data are aerial photograph, ground control points, and air-control points.The minor control points are used to control subprocesses of subsequent mapping (plotingstereo, orthophotos, rectification, etc.) either analogue, analytical, or digital. ICP is not involved in AT data processing, but ICP coordinates GPS/GNSS survey results, will be compared with the coordinates of ICP result of photogrammetric data processing or photo map produced. AT data processing with bundle adjustment method, its precision can be evaluated by considering the residual value of GCP coordinate adjustment. The accuracy of AT data processing is evaluated by looking at errors that occur in ICP coordinates.

DSM from aerial photographs should be corrected with the geoid undulation value of the area. In photogrammetry data processing, geoid undulation value is taken from geoid model EGM 2008 which is ± 22.32 m at mapping location. By using Agisoft Photoscan software is done dense image matching process to get DSM. o obtain orthophoto, geometrical aerial photographs are corrected ("orthorectified") so the scale of the photographs is uniform. Furthermore, the orthophoto map is digitized based on the condition of the land cover (object) cover that exists in the mapping area so that land cover is obtained. Then, DSM filtering is done so that the surface, trees and buildings are removed automatically to obtain spot-height. From the land cover data obtained some additional breakline or fault or spot-height details. Then together with the DSM filtering point points are integrated and interpolated using DTM processing software. From DTM, we can also derive contour lines with contour interval adjusted to DTM quality and technical specifications.

2.5 Data Integration

This is the integration of data from terrestrial data and photogrammetry data.data.

2.6 Carthography

This is the process by which a collection of data is compiled and formatted into a virtual image.

3. RESULT

The result of GCP and ICP accuracy coordinates from GPS/GNSS survey as in Table 3 as follows:

Table 3. GCP and ICP Accuracy Coordinates

	GCP (n=53)		ICP (n=20)	
	Std.Dev. Dxy (mm)	Std.Dev. Dz (mm)	Std.Dev. Dxy(mm)	Std.Dev. Dz (mm)
Average	1.0	1.8	0.7	0.8
Max	10.5	15.6	1.5	3.5
Min	0.2	0.2	0.2	0.3

Average error of camera position, as in Table 4 as follows:

Table 4. Average Error Camera Position

X error (m)	Y error (m)	XY error (m)	Z error (m)	Total (m)
28.687	11.768	31.007	3.202	31.172

The result of data processing using Agisoft software, obtained residual error coordinate GCP as in Table 5, as follows:

Table 5. Residual Error GCP (Agisoft)

The number of points	X error (m)	Y error (m)	XY error (m)	Z error (m)	Total (m)	Error (pix)
47	0.081	0.049	0.094	0.053	0.108	1.216

Calculation of Root Mean Square Error (RMSE) ICP data processing using Agisoft software, as in Table 6, as follows:

Table 6. RMSE ICP (Agisoft)

The number of points	X error (m)	Y error (m)	XY error (m)	Z error (m)	Error (m)	Error (pix)
23	0.079	0.054	0.096	0.138	0.168	1.215

The RMSE planimetric value of the Aerial Triangulation (AT) process is XYerror = 0.096 m or 9.6 cm. The RMSE value of the elevation of the results of the Aerial Triangulation (AT) process, is Zerror = 0.138 m or 13.8 cm.

The accuracy of Orthophoto and DTM products, as in Table 7, is as follows:

Tabel 7. Accuracy Orthophoto and DTM products

	ΔX	ΔY	ΔZ
	(m)	(m)	(m)
Number of Check Points	**63**	**63**	**63**
Mean Error (m)	**0.020**	**0.020**	**0.067**
Standard Deviation (m)	**0.098**	**0.062**	**0.247**
RMSE (m)	**0.099**	**0.065**	**0.254**
RMSEr (m)	**0.119**	**= SQRT ($RMSEx^2$ + $RMSEy^2$)**	
Horizontal Accuracy$_r$ (ACCr) at 95% Confidence Level	**0.205**	**= RMSEr x 1.7308**	
Vertical Accuracy$_z$ (ACCz) at 95% Confidence Level	**0.498**	**= RMSEz x 1.9600**	

The RMSE value of the orthophoto product is RMSE $_{(orthophoto)}$ = 0.119 m and RMSE value of the DTM product is RMSE$_{(DTM)}$ = 0.254 m.

The orthophoto results from the aerial photography survey as in Figure 5, as follows:

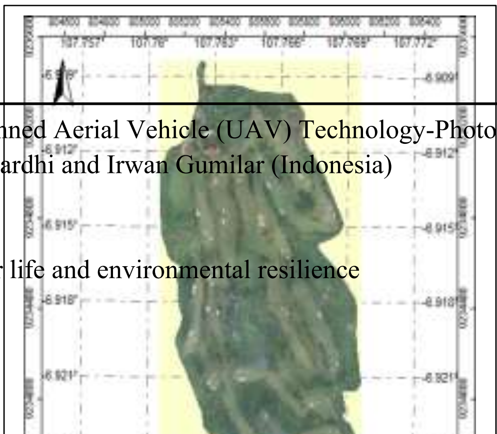

Figure 5. Orthophoto

The DTM results as in Figure 5, as follows:

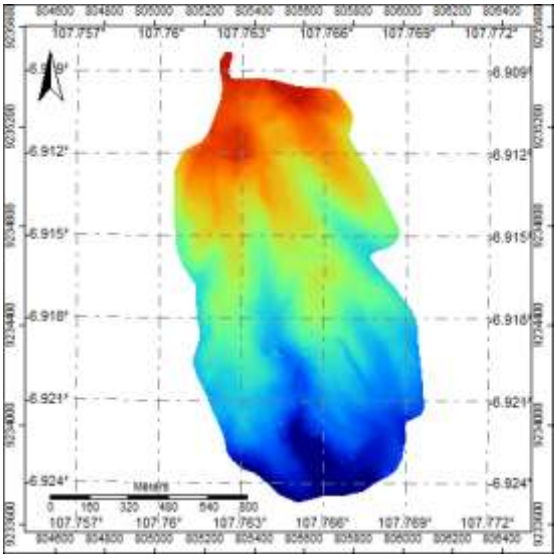

Figure 6. Digital Terrain Model (DTM)

The result of contoured topography map, as in Figure 7, as follows:

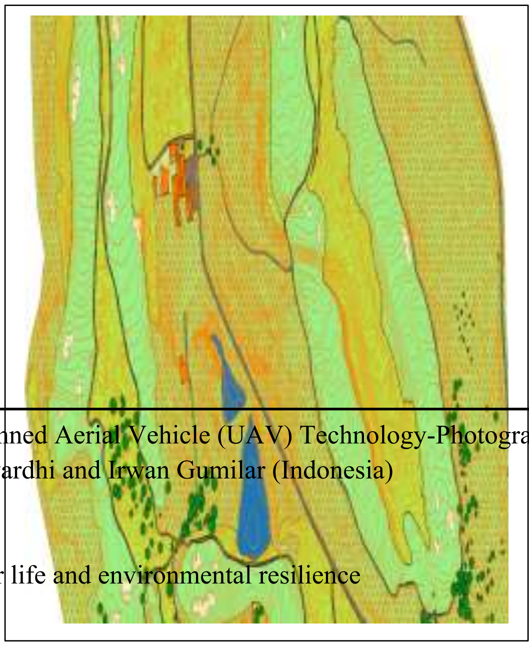

Figure 7. Contoured Topography Photo Map

4. CONCLUSION

From the results obtained and based on American Society for Photogrammetry and Remote Sensing (ASPRS), 2014, it can be concluded that:

- Horizontal accuracy of the equivalent orthophoto product for a 1: 1000 scale map,
- The vertical accuracy of equivalent DTM products for 1: 2000 scale maps,
- The resulting map product meets the need for a 1: 1000 scale topographic contoured photo map, while vertically this product meets the need for a 1: 2000 scale topographic contoured photo map.

REFERENCES

- American Society for Photogrammetry and Remote Sensing (ASPRS), 2014. ASPRS Positional Accuracy Standards for Digital Geospatial Data, Edition 1, Version 1.0, November 2014, Photogrammetry Engineering & Remote Sensing Vol 81, No 3, March, 2015, pp A1 – A26, 0099-1112/15/813-A1.
- Deni S, S Hendriatiningsih, 2016, Survei Pemetaan Topografi metode Foto Udara Format Kecil menggunakan Wahana Udara Nir-Awak Lapangan Golf BGG Jatinangor, Sumedang, Laporan pekerjaan,

BIOGRAPHICAL NOTES

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