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Utilization of Aerial Photograph for Spasial Data Using Quadcopter

(Ijo Temple Complex, District Prambanan, Yogyakarta)

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***Abstract*—Ijo temple complex is included in a complex of protected cultural heritage. Documentation of cultural heritage is not only limited to photo archives, relics of historical objects, but also present spatial data. The spatial data of aerial photographs on a large scale is important to get information in detail. Currently, the development of science and technology on the utilization of UAV (Unmanned Aerial Vehicle) is growing rapidly, one of the use of aerial photographs for cultural heritage. The aircraft used is a type of rotary wing quadcopter because it is more stable than fixing wing and narrow study area. Excess use of aerial photography to obtain spatial data that is more efficient job execution time, can reach small areas in a short time, and they cost less. The purpose of this study to determine the level of utilization of the acquisition of aerial photographs using quadcopter as presenters of spatial data. The method in this research that Bundle Block Adjustment to process aerial photography into a mosaic image with the principle patch aerial photographs through point cloud. Shooting is done by using quadcopter with a flying height of 45 meters. Planning to fly that will produce good spatial data. Shooting is done vertically. Orthophoto imagery maps generated can be presented on a scale of 1: 1,400 which can provide detailed information Ijo temple complex region. 1.64 cm spatial resolution. Map of the resulting image has a 99.73% accuracy rate horizontal and vertical accuracy rate of 98.62%. Based on the degree of accuracy that the processing of aerial photographs can have a high rate of data acquisition.**

Keywords*—*Spatial data, cultural heritage, data acquisition, quadcopter

I. INTRODUCTION

Photogrammetry is the art, science, and technology of obtaining reliable information about physical objects and the environment through the recording process, measurement, and interpretation of photographic illustration and radiation pattern of electromagnetic energy were recorded. Mapping and measurement utilizing aerial photographs can be used as an alternative method replaces the mapping and measurement directly in the field. The use of aerial photography and photogrammetric mapping relation to the measurement and is often called the aerial survey. Results of aerial photographs in the form of a map of the photographs cannot be directly used as the data source because it still requires control point field (Ground Control Point) as a reference measurement, so the photogrammetric mapping cannot be separated from land by terrestrial reference measurements. Photos aerial photography is the result of recording that can be remotely sensed data. The advantages of aerial photographs that have high spatial resolution, coverage complete information, in accordance with the original objects, and the ability to represent three-dimensional objects (Sutanto, 1995).

Aerial photographs have the capacity from 0.4 to 0.7 µm so object in the appropriate field the actual color (wave appears). Under the direction of the axis of the camera, aerial photographs are divided into vertical aerial photos and obliq. Warner et al. (1997) to clarify the limits of vertical aerial photographs are aerial photos taken by the axial tilt of 0 ° (perpendicular) to a maximum of 5 °. Obliq photo still can be subdivided into two, photo heeling slightly leaning to the value of more than 5 ° and a very obliq picture where the horizon visible in the photo. Vertical photos interoperability technically has a value higher than the photos obliq. Here is the classification of photography:

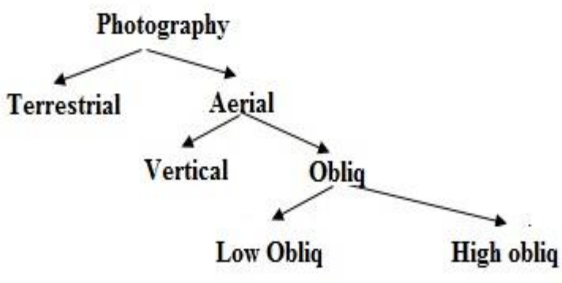

Figure 1. Classification photography (Paine, 1981)

Valuable cultural heritage is important so that necessary documentation for being a cultural asset for a region.

Documentation is not only limited documentation in the form of archive photographs, archival legacy of historic objects, but also can do 3D modeling and mapping of areas of cultural heritage. The temple is one of the cultural heritage is protected. Candi Ijo, District Prambanan, Yogyakarta is one of the temples which is at the top of the hill with an elevation of 450 meters above sea level. Cultural heritage is a cultural heritage that is immaterial whether in the form of cultural heritage objects that exist on land or in the water that needs to be preserved its existence because it has significant value for the history, science, education, religion, or culture through setting process contained in the Act Republic of Indonesia Number 11 Year 2010 article 1. The purpose of this study to determine the level of utilization of the acquisition of aerial photographs using quadcopter as present of spatial data.

II. METHOD

Tools used in this research are quadcopter, laptop, GPS geodetic, agisoft photoscan, and ArcGIS. Location research Ijo temple, district Prambanan, Yogyakarta. Ijo Temple is located on a hilltop at an altitude of 410 mdpal. Large of Ijo temple from the terrace I - XI is 42,000 m2, a special study of this research from the terrace VIII - XI with area of 1.2 ha.This temple Hindu religious backgrounds and have 17 building structures were divided into 11 terraces. Photogrammetric techniques are used to extract the aerial photographs into Digital Elevation Model (DEM). Aerial photograph orientation process is basically used for returning the aerial photography position as when recording then referred to the coordinates ground by utilizing the interaction chamber at corresponding points (tie points) contained in a block of aerial photographs. Transformation technique is called Bundle Block Adjustment. Ground coordinate system is obtained from Ground Control Points (GCPs) obtained in the field using geodetic GPS which will be integrated into the transformation process. Determination tie point by marking the corresponding points on aerial photographs that overlap.

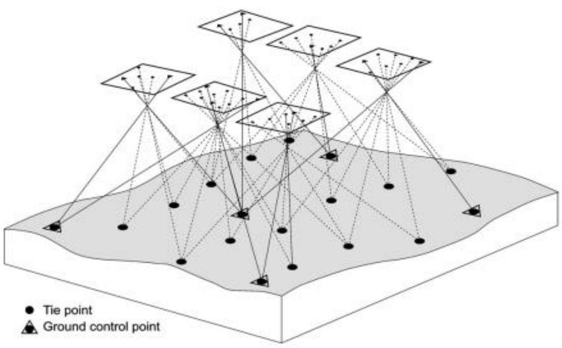

Figure 2. Principle 6 block bundle adjustment (Aber et al, 2010)

Information:

XP, YP, ZP	: ground coordinates of the point P
TXA, Tya, Tza	: station coordinates a photo shoot
TXB, TYB, Tzb	: photo shooting stations coordinates b
Xa, ya, za	: coordinates point P on a photo
Xb, yb, zb	: Coordinates the point P on the photo b

A. *Stage Research*

- Phase Pre-Acquisition Data

  Stages initial activities of planning for aerial photography include: Planning quadcopter system model, camera calibration, time of flight planning, flight planning rides, and planning point of GCP and ICP.

- Phase Data Acquisition

  This stage is used for shooting the object of study using the flight plan that had been planned.

- Post-acquisition Phase the Data

  This phase is to process the results of aerial photographs, among others: Selection of aerial photographs, Geo-registration process, rectification, mosaic image, and DSM and orthophoto imagery.

III. FINDING AND DISCUSSION

A. *Pra-Akuisisi Data*

Used vehicle that is quadcopter. The integration between the tools used, among other things: a camera, a vehicle, and the remote control will form a unitary system of flying. The photo shoot is vertical shoot technique. The position of the camera is orthogonal to the object when recorded. Aerial photography time considering the weather conditions, wind speed, light intensity, direction of light, and others. Here is a vehicle that is used:

Figure 3. Quadcopter

Here is a plan to fly vertical shooting Ijo temple complex:

- Sensors' characteristics

The camera used for mapping purposes is canon Powershot s100. This camera has a CMOS sensor with size 5:52 7:49 x (1 / 1.7 ") and a maximum resolution of 4000x3000 pixels, width and length of the temple Ijo (106 m and 182 m). The size of the pixels on the sensor can be determined by dividing the width size sensors with a wide number of pixels.

The size of the sensor in CMOS = Width sensor / the number of pixels (width)
The size of the sensor in CMOS = 5.52 mm / 3000 pixels
The size of the sensor in CMOS = 0.00184 mm / pixel

The size of the pixels on the CMOS sensor is 0.00184 mm/pixel

- High Fly

High-flying can be determined by knowing in advance the size of the pixels on the sensor, the focal length of the camera used, and to determine the desired spatial resolution. Spatial resolution is desirable for shooting straight at 16 mm is expected to be able to provide a level of clarity of the object in detail. The result of the calculation is as follows:

GSDs = Pixel Size x Hg / f
= 0.00184 x 16 mm Hg / 5.2
Hg = 45217.3913
Hg = 45, 21 m

Flying height used was 45 meters.

- Area of Recording

The area of the recording is affected by the size of the sensor used, flying height, and the resulting scale. The resulting scale in advance is calculated to obtain the recording area. The scale can be determined by dividing the size of the pixels on the sensor with a pixel size in the field.

Scale = the size of the pixel in the sensor/size pixel field
Scale = 0.00184 / 16 mm
Scale = 1 / 8695.65

Size scale obtained is 1: 8695.65.
The area of coverage recording obtained from the length multiplied by the width of the recording area coverage. Here's the math:

The length of the recording coverage = Length CMOS x Scale
The length of the recording coverage = 7:49 x 8695.65
The length of the recording coverage = 65130.419 mm
The length of the recording coverage = 65.13 m

Wide coverage recording = Width CMOS x scale
The width of the recording coverage = 5.52 x 8695.65
The width of the recording coverage = 47999.988
The width of the recording coverage = 48 m

The extent of recording = Length x width coverage coverage
The extent of recording = 65.13 x 48
The extent of recording = 3126.24 m2

The extent of the recording area is 3126.24 m2.

- Endlap and Sidelap

Endlap and sidelap used to estimate that no less of patch occurrences on aerial photographs. Ijo tample includes the areas affected with topography of hills and the wind being at the top of the hill. For that, the endlap and sidelap was set at 70% and 60%.

Here's the math:

Size endlap = (width x 70% coverage) x length of coverage
Size endlap = (48 x 70%) x 65.13
Size endlap = 2188.36 m2

Size sidelap = (length x 60% coverage) x width coverage
Size sidelap = (65.13 x 60%) x 48
Size sidelap = 1875.74 m2

- Number of Flight Path

The number of flight paths are affected by the distance between the flight paths, wide area, and length of coverage recording. The distance between the flight paths determined beforehand by the length multiplied by 1 minus coverage of its sidelap. Distance flyway obtained is 26 meters.

The distance between the flyway coverage = Length x (1 - sidelap)
The distance between the flyway = 65.13 x (1 - 0.6)
The distance between the flyway = 26 m

Total inter flyway = ((Width region - the length of coverage)) / distance between flyway + 1

Total inter flyway = ((106 - 65.13)) / 26 + 1
Total inter flyway = 2.67
Total inter flyway = 3 (Rounding)

Total flyway is 3 pieces.

- Shooting Interval

Shooting interval is obtained from the determination of the base terrain. Determined from the terrain base width multiplied by 1 minus sidelap coverage so that the base field obtained 14.4 m.

Base coverage field = Width x (1 - endlap)
Base field = 48 x (1 to 0.7)
Base terrain = 14.4 m

- The speed

The vehicle speed that used is 3 m / s with a shutter speed of 1/2000. This condition used vehicle with a camera so there is no blur when shooting.

- Results flight path planning

The location study has the distinction high that is divided into 2 blocks of the shooting area. The first block is in the patio area XI with an area of 7718 m2 area, study area to record objects in the form of roads, the temple area, and moor. Flyway that is formed by 4 lines in consideration of overlap of 80% and 60%. Much consideration overlap and sidelap to get that many accretion between photos. A height of 45 meters shooting equated with how many locations on the patio home XI. Home is the location of the start and end of shooting a vehicle, when the flight mission has been completed, the vehicle will return to original location. The distance between the flight path of 26 meters with each capture of 2.96 seconds, and the distance between the flight path of 26.31 meters. Here is a look flyway area of Block 1 in the mission planner:

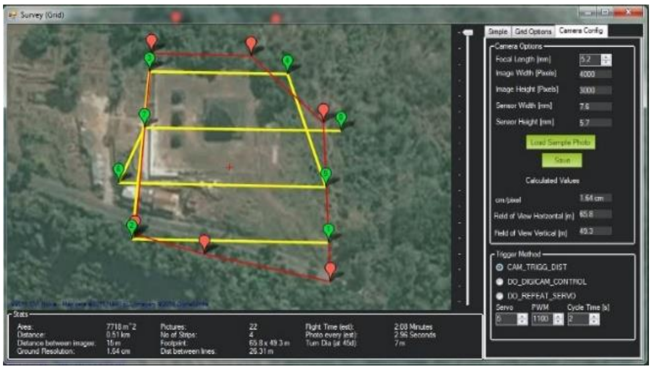

Figure 4. Shooting Blocks 1

Flyway block 2 is a continuation of the study area with the overhead of the shooting area. It aims to get overlay area. The second block is in the patio area VIII-X with an area of 8928 m2 recording area, study area to record objects in the form of roads, the temple area, and moor. Flyway that is formed by 4 lines in consideration of overlap of 80% and 60%. First and second aerial photography overlay made the same so that the characteristics of the same photo. Shooting altitude of 50 meters, the distance between the flight path of 26 meters, each taking photographs of 2.96 seconds, and the distance between the flight paths of 26.31 meters. The camera used in this shoot camera is the Canon Powershot S100.

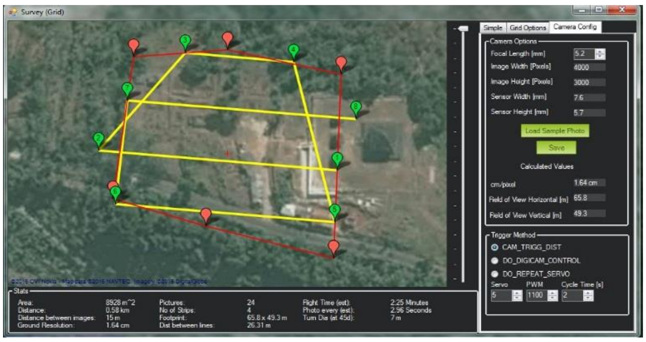

Figure 5. Shooting Blocks 2

GCP Planning and ICP Ijo temple area to be the tie point in the correction of aerial photographs. In planning a typical object or a permanent feature which is used as a marker of GCP are corners Ijo site page. The corners of the temple site page is easily recognizable on aerial photographs, and is not hindered by the presence of vegetation. There are as many as 11 points GCP point spread evenly to the corner Ijo temple courtyard. 6 pieces GCP points and 5 points for the ICP. GCP function for projecting the aerial photographs into a corresponding coordinate in the field. Meanwhile, ICP is used to correct the results of orthogonal photograph that has been created as a horizontal accuracy test. The following GCP placement and ICP at the complex of the temple area:

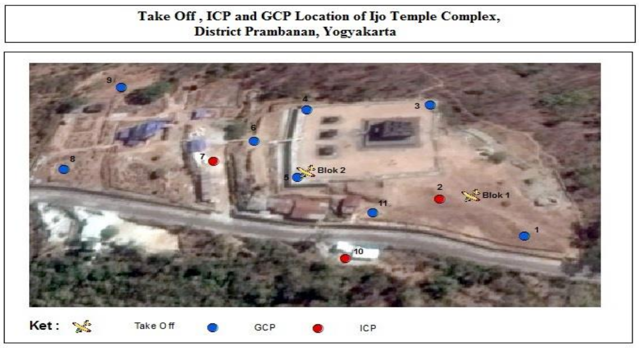

Figure 6. GCP and ICP Location

The results obtained after the treatment, gained 11 points GCP locations that have been corrected. The data contains the coordinates X, Y, and Z. The data used is the data status fix. Coordinates of 11 points will be used as GCP and ICP. Table GCP and GCP coordinate values:

TABLE I. GCP AND ICP COORDINATE

Point	GPS Number	X Coordinate	Y Coordinate	Z Coordinate	Accuracy(m)	Status
1	GPS0005	446,250,653	9,139,511,637	425,642	0.026	Fix
2	GPS0011	446,220,712	9,139,541,538	424,785	0.023	Fix
3	GPS0068	446,213,612	9,139,596,436	424,884	0.032	Fix
4	GPS0074	446,171,287	9,139,593,335	424,981	0.028	Fix
5	GPS0086	446,167,259	9,139,551,014	425,103	0.187	Fix
6	GPS0100	446,132,221	9,139,583,195	416,602	0.030	Fix
7	GPS0102	446,113,359	9,139,571,541	413,938	0.024	Fix
8	GPS0103	446,083,544	9,139,569,432	409,747	0.040	Fix
9	GPS0104	446,098,238	9,139,614,175	411,175	0.035	Fix
10	GPS0094	446,183,590	9,139,514,011	417,418	0.229	Fix
11	GPS0017	446,201,022	9,139,529,179	423,295	0.024	Fix

B. *Data Acquisition*

Data acquisition stage is the stage of aerial photography. Shooting time was held on May 5, 2016. The recording is performed twice, at 8:50 and 10:43. The recording time is divided into two because the study area is divided into two blocks. The photo shoot is divided into two blocks to facilitate consideration of the shooting because of different heights. The difference in height between the upper terraces is the height difference of 10 meters. Reasons of block division include: a photo shoot using quadcopter have a maximum of 15 minutes of shooting time and it is associated with the battery capacity to fly. The second reason it easier to supervise the shooting on autopilot making it easier for the operator.

The first shooting block located in 11th terrace. The first block have flat relief and were the highest terrace of the temple Ijo. Characteristics of the first block of shooting, among others: the area shooting of 7718 m^2, flying time 5 minutes, each shooting speed of 2.96 / sec, the area of the photograph 65.8 x 49.3 meters, the number of flight paths 4, the distance between the flight path of 22 meters, overlap and sidelap 70% and 60%, a height of 45 meters, and a focal length of 5.2 mm.

Photographing the second block is made to shoot down being patio area VIII-X which has a variety of different heights. Shooting time is done at 10:43 pm conducted for 7 minutes. Photographing the second block is more spacious and has a more complicated challenge to monitor the computer screen. Wind conditions are strong enough shooting time is 1.67 m/s. Flying characteristic of block 2: the area shooting of 8928 m^2, 7 minutes flying time, each shooting speed of 2.96 / sec, the area of the photograph 65.8 x 49.3 meters, the number of flight paths 4, the distance between the flight path of 22 meters, overlap and sidelap 70% and 60%, a height of 45 meters, and a focal length of 5.2 mm.

C. After the Acquisition Data

Total photos generated from the shoot upright are 59 photos. Photo selection needs to be done to get the photos that have clear information, detail, and does not blur. All photos captured can be used in the processing. At this stage, the principle invoked all the photos grouped by high point based on the pixels contained in the image. 59 photos have a distinct point in the recording so that the model will be produced according to the results to be expected are corrected automatically.

Geo-registration Photo done on the photographs for mapping purposes. GCP placement on the photo to get the coordinates x, y and z in actual size so that it has the correct reference for photo processing. The data that used are the measured data using geodetic GPS to an accuracy of less than 5 cm. Photo mosaic in this study aims to combine all the photo that has the same overlay. It aims to look at the whole area recorded by the sensor. The process that occurs in a mosaic of photos by equating pixel and improve the position of the photo into areas that have geometricized correctly. Photo mosaic was done by using software Agisoft Photoscan so the process is done automatically. Mosaic that composed is controlled mosaic, meaning that mosaics have GCP coordinate reference system that has a direction, and the actual coordinates.

DEM data extraction either the DSM or DTM obtained from the rectification of aerial photographs. GCP coordinates will assist in the extraction of data so the elevation data has coordinates x, y, and z. DSM will continue to represent the topography that are located above the earth's surface either cover or land use to be around the Ijo temple area. The existence of an object with a certain height will be obvious to the DSM. The method used in the manufacture of DSM is to use interpolation is Inverse Distance Weighted (IDW) interpolation point that is based on similar heights on aerial photographs that overlap. Based on the results of GCP will give a height difference on the photo image so that it will generate a block model of aerial photographs. Here is a map of DSM Ijo temple complex:

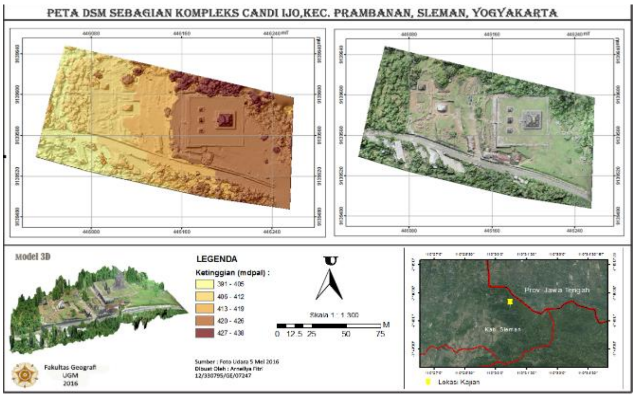

Figure 7. Ijo Temple Complex DSM Map

DEM quality results can be known to test the accuracy of the objects contained in the field. Comparison between DSM with the object in the field will provide the level of accuracy of the results of DSM processing. Value RMSE (Root Mean Square Error) will provide an overview DSM errors in the models built on a sample of building objects on the ground. Test DSM is an accuracy test to check the results of the vertical height value to objects on the ground (z values). The method is done by taking the coordinates in the form of ICP are placed in an area Regional GCP in pairs in the field. ICP will serve as a test to obtain the coordinates of different accuracy values of the photo image that has been mosaic. ICP value has an accuracy rate of 0.1 while the value of the image based on the GCP has an accuracy of 0.3 in the report process in Agisoft. With a difference of accuracy then the mosaic image of the photo with ICP used to test the accuracy of the results of DSM in the field. Elevation measurement performed on the same object at the ICP and GCP.

Vertical accuracy test is to compare the level of detail DSM between measurements in the field with the processing in the laboratory. The formula used is:

$$\% \text{ Error} = ((a-a')/a * 100\%)$$

Where: a = the height of buildings in the grounds
a '= a building height of the processing results of laboratory

Here are the results of the DSM accuracy.

TABLE II. VERTICAL ACCURACY

No.	Nama Objek	Survei Lapangan	DSM	Selisih	%Error	%Akurasi
1	Main Temple	11.54	11.49	0.05	0.43	99.57
2	Temple B	5.14	5.12	0.02	0.39	99.61
3	Temple C	6.32	6.24	0.08	1.27	98.73
4	Temple D	5.47	5.44	0.03	0.55	99.45
5	Temple F	6.3	6.08	0.22	3.49	96.51
6	Temple K	5.71	5.67	0.04	0.70	99.30
7	Werehouse	3.42	3.38	0.04	1.17	98.83
8	Employee Parking	3.07	3.05	0.02	0.65	99.35
9	Tree	3.96	3.87	0.09	2.27	97.73
10	Security Office	5.13	4.98	0.15	2.92	97.08
	Amount	56.06	55.32	0.74	13.85	986.15
	Difference			0.74		
	Mean Difference			0.074		
	Mean Error				1.38	
	Mean Accuracy %					98.62
	Standard Deviation					1.06

Objects that were sampled to represent objects on the ground, among others: A highlight of the main temple, the main temple B, C, D, F, and K, warehouse, employee parking, trees, and security office. Measurement of field survey done by measuring the objects on the ground using the meter. Based on the results of the calculation of the height difference between the field surveys with DSM models in the table above, the value of the vertical accuracy is 98.62%. RMSE calculations obtained high of 3.29 means that the object contained in the DSM has an error of about 1.38 meters, with the assumption that the measurements in the field survey is considered correct.

Orthophoto imagery illustrates the object is in the correct position which can be used as a source mapping. Based on the results orthophoto imagery maps that have been made, the overall area of cultural heritage of the ijo temple complex. The level of detail of aerial photography is high. The resulting spatial resolution of 1.64 cm so that the smallest objects such as tourists, trash, rock relic temple, and recognized easily. The other form of appearances like temples, offices, parking areas, irrigation canals, roads, stalls, moor, and the temple courtyard formed. The following orthophoto maps are produced:

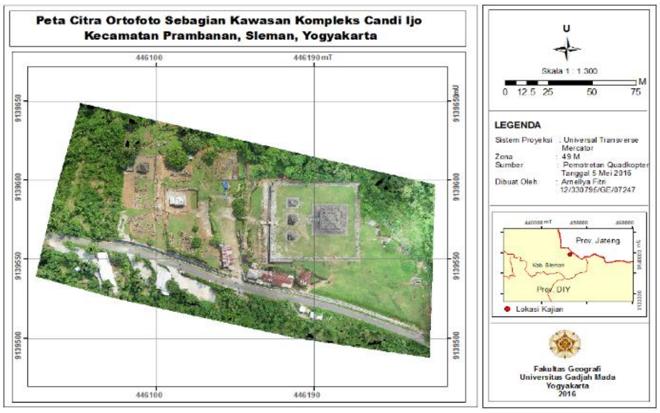

Figure 8. Ijo Temple Complex Region Map

Horizontal accuracy test

Horizontal accuracy test is to compare the level of detail between the measurements in the field with the processing in the laboratory. The formula used is:

$$\% \text{ Error} = ((a-a')/a * 100\%)$$

Where:

a = the height of buildings in the grounds
a' = a building height of the processing results of laboratory

Horizontal accuracy test is done by comparing the length of the data object field with object length data contained in ortho-photographic imagery. The object that is measured as much as 10 objects, among others: the width of the road, the fence, the main temple (width), Temple B, C, D, F, K, a car park and offices maintain. Differences were obtained ranging from 0.01 - 0:06 meters. The resulting RMSE values of 0.27 and 99.73% accuracy.

TABLE III. HORIZONTAL ACCURACY

No.	Objek Name	Field Survey (m)	Ortophoto Imagery	difference	% Error	%Accuracy
1	Street wide	4	3.97	0.03	0.75	99.25
2	Fence	77.6	77.54	0.06	0.08	99.92
3	Main Temple	18.42	18.42	0.01	0.03	99.97
4	Temple B	5.29	5.28	0.01	0.19	99.81
5	Temple C	5.21	5.20	0.01	0.25	99.75
6	Temple D	5.21	5.19	0.02	0.44	99.56
7	Temple F	7.29	7.27	0.02	0.27	99.73
8	Temple K	5.31	5.29	0.02	0.43	99.57
9	Car Parking	10.76	10.74	0.02	0.19	99.81
10	Maintain office	9.45	9.45	0.00	0.03	99.97
	Amount	148.54	148.33	0.21	2.66	997.34
	Difference			0.21		
	Mean Difference			0.02		
	Mean Error				0.27	
	Mean Accuracy %					99.73
	Standard Deviation					0.22

IV. CONCLUSIONS AND SUGGESTIONS

A. Conclusions

Acquisition rate of aerial photographs using quadcopter produce spatial data has a high degree of accuracy. Map of the resulting image has a 99.73% accuracy rate horizontal and vertical accuracy rate of 98.62%. Spatial data that will help to further spatial analysis.

B. Suggestions

Suggestion from this study, the value of overlap and sideslip for shooting at larger hilly topography. It is useful to anticipate the lack of overlap in the area photography.

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