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Comparative Analysis of Accuracy to the Establishment of Three Dimensional Models from Diponegoro Prince Statue Using Close Range Photogrammetry Method in Non Metric Camera and Unmanned Aerial Vehicle (UAV) Technology

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Abstract. Diponegoro Prince Statue is one of the important icons in the campus area of Diponegoro University. Because the new statue is in the area of Widya Puraya. Therefore many people visit the statue. Diponegoro statue also experienced erosion by nature (wind, rain water, etc.). Therefore, it is necessary to preserve the Diponegoro statue so that it is not damaged and lost its existence by the times. In this research, two type of surveying instruments will be tested for their accuracy in the Diponegoro statue, namely non-metric cameras (NMC) and Unmanned Aerial Vehicle (UAV). The method used in this research is Close Range Photogrammetry by comparing the results of the visualization of the model and testing the accuracy of the three-dimensional model with a comparison of the distance of the field measurements of the Total Station. From the results of visualization and accuracy of the three-dimensional model, it will be obtained which results are better between non-metric cameras and UAVs. The final results of this study indicate that UAV has a higher level of geometric accuracy compared to non-metric cameras. This is indicated by the results of the accuracy of the the UAV obtained a fairly good level of accuracy compared to the camera that is equal to 0.0162 ± 0.0133 meters for the statue of Prince Diponegoro. Whereas in non-metric cameras, the results of lower accuracy were 0.1615 ± 0.0593 meters in the statue of Prince Diponegoro. Based on the visualization of the three-dimensional model between the camera, UAV and NMC, it was found that UAV produced a better model compared to the three-dimensional model produced by NMC. With the results of the analysis in this study it is expected that the results of 3D modeling with cameras and UAVs can be used as an effort to preserve the Diponegoro statue.

Keywords: *Close range photogametry, non metric camera, diponegoro prince statue, UAV*

1. Introduction

Indonesia has many monuments and statues of heroes. Monuments and statues are made to commemorate the services of the heroes. One of them is a statue of Prince Diponegoro hero at one of Indonesia's universities, Diponegoro University.

Diponegoro Prince Statue is one of the important icons in the campus area of Diponegoro University. Because the new statue is in the area of Widya Puraya, many people visit the statue and take photos of the statue. Therefore, it is necessary to preserve the Diponegoro Prince statue so that it is not damaged and lost its existence by the times. Regarding the research carried out, the steps of reconstruction and conservation are important steps that can be taken to preserve the Diponegoro statue.



These two steps usually refer to the documentation of the statue. The documentation is not only limited to knowing the geometry dimension of the statue, but also related to how much the geometry dimension of the statue changes in a certain period of time. Given these steps can be done by using the 3D Laser Scanner, because it provides very high accuracy to document an object, but this technology requires very expensive costs. By using close range photogrammetry methods (Close Range Photogrammetry) and 3D modeling with UAV is expected to be able to reduce these expensive costs [1].

Close Range Photogrammetry (CRP) method was carried out in this study using a non-metric camera. To process CRP can use Photo Modeller Scanner software. A close range photogrammetry method can be used if the distance between objects with the camera is less than 100 meters [2]. But before taking a photo the camera must be calibrated using the Photo modeller Scanner software. For good and quality 3D modelling, in this study the formation of 3D models using drones or UAVs. Formation of a 3D UAV model using Agisoft Photoscan software [3]. The simple process that is done with UAVs is to use the intelligence flight feature on the UAV to circle the research object with a distance that is determined by the software that is on android, DJI GO. But before taking off, the UAV must first be calibrated as well as non-metric cameras. In this study, 3D Terrestrial Laser Scanner modelling will also be conducted as a validation of 3D visualization with CRP and UAV. This research was conducted to support conservation efforts on the Diponegoro Prince statue at Diponegoro University. It is expected that with CRP with non-metric cameras, UAV and TLS can be used and utilized.

2. Data and Methods

2.1 Research Area

The location of this research was conducted at Diponegoro University Semarang in the area of Widya Puraya at latitude coordinates of 7.0521° S and longitude 110.44400° T. The object examined in this study is the Statue of Prince Diponegoro as shows in Figure 1.



Figure 1. Research Object (Diponegoro Prince Statue) [4]

2.2 Research Data

In this research, we use Sentinel-1A images with type Interferometric Wide Swath (IW) and Level-1 Single Look Complex (SLC) with complex data such as amplitude and phase from October 2014 to January 2017 with monthly data interval can seen in Table 1.

Table 1. Research Acquisition Data

No.	Data	Data Resources	Type of Data
1	Camera Calibration Data Acquisition	Camera Calibration Parameter	Digital
2	Picture Acquisition of Research Object	Field Surveying	Digital
3	Data Validation Acquisition using Total Station	Field Surveying	Digital and Text

2.3 Close Range Photogrammetry Concept

In the digital era, it has become more widespread since computerized technology has experienced rapid development. Current technology has transformed difficult analog systems into easy with the presence of digital technology, especially in the field of close range photogrammetry applications with aerial photography. In this case photogrammetry is divided into 2 types of photos [5], namely: Terrestrial photo and Aerial photos. The terrestrial photo is known by the name or term known as the name or term of Close Range Photogrammetry. The terrestrial photo is produced from a direct shooting of an object using a camera that is landed not on a flying plane. Terrestrial photogrammetry applications include control of building objects, cars, aircraft and others. Besides that it can also be used for shooting historic buildings such as conversions and for some of the benefits and applications. Photogrammetry is art, science and technology to obtain reliable information about physical and environmental objects through the process of recording, measuring, and interpreting photographic images, and recorded patterns of electromagnetic energy radiation [7]. Terrestrial photogrammetry [5] is a branch of photogrammetry by placing cameras on the surface of the earth. The camera can be held by hand, mounted on the foot of the camera or mounted on a tower or with another specially designed support device. The term "short-range photogrammetry" is generally used for terrestrial photos that have objects up to 100 meters [2][6]

2.4 UAV in Photogrammetry Concept

Unmanned Aerial Vehicle (UAV) or also known as the Aircraft (PUNA) is an aircraft that can operate without a flight crew. UAV operates with the presence of aircraft control operators that are outside the aircraft, while the aircraft operates automatically according to the command of the controlling operator. When standard UAV allows tracking the position (tracking positioning) and the orientation of the sensor is implemented in a local or global coordinate system. Therefore, UAV photogrammetry can be understood as a new measurement tool for photogrammetry. UAV photogrammetry can be used for a variety of new applications in the range of close domains, combining air and photogrammetry, but also introduces real time and inexpensive alternative applications for classic aerial photogrammetry. American Society of Photogrammetry defines photogrammetry as art, science and technology to obtain reliable information about physical and environmental objects through the process of recording, measuring, and interpreting photographic images and patterns of recorded electromagnetic energy radiation [7]

2.5 Three Dimensional (3D) Modelling Accuracy

Every measurement must not be separated from mistakes. Likewise in the size data processing process, namely the process of forming a 3D model that is also not free from errors. The magnitude of the error value is indicated by the RMSE value (Root Mean Square Error). RMSE is a value of the difference between the actual value and the result value. The greater the value of the RMSE, the greater the size error of the actual conditions. RMSE is obtained from the process of dividing between square root values in total squared size difference with the number of sizes used. The mathematical definition of RMSE is similar to standard deviation, which is the square root of the average number of residual squares. Standard error is defined as the root of the sum of the residual squares. The formula for calculating RMSE is presented in Equation 1.

$$\sigma = \sqrt{\frac{(x-\bar{x})^2}{n}} \dots\dots\dots (1)$$

In :

σ = standard deviation

x = data value

$\bar{x}$ = mean data value

n = data

2.6 Research Methodology

For a description of the methodology in this study can be briefly seen in Figure 2.

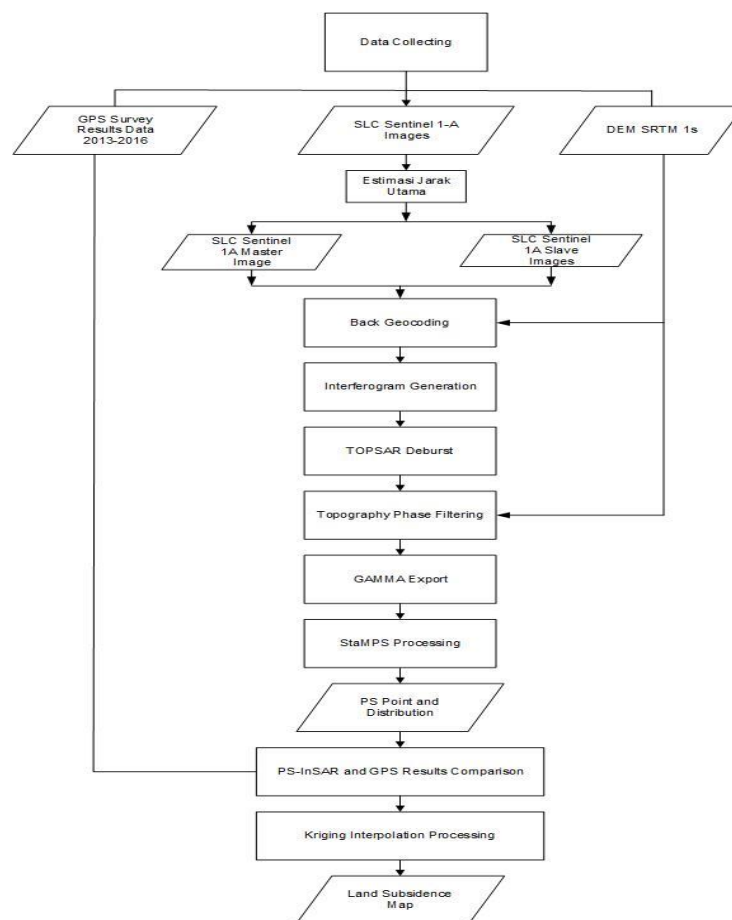


Figure 2. Research Methodology Workflow

3. Result and Discussion

3.1. Baseline and Benchmark Surveying

To get the coordinates of the main polygon net, it is necessary to measure the coordinates of the polygon net using the Total Station survey tools. The coordinates of the polygon net of Pangeran Diponegoro's statue can be seen in Table III-1 and the detail points or allied points can be seen in Table 2 dan Table 3.

Table 2. Polygon Net Point Coordinates of Diponegoro Prince Statue

No	Name	Easting (m)	Northing (m)
1	101	437958,763	9220753,588
2	102	437973,032	9220758,867
3	103	437983,742	9220768,717
4	104	437979,998	9220777,937
5	105	437966,208	9220783,710
6	106	437958,278	9220778,939
7	107	437951,196	9220774,409

Table 3. Koordinat titik sekutu patung Diponegoro

Name	X (m)	Y (m)	Z (m)
DDK	437965,88408	9220769,40129	209,46051
Feet	437966,05236	9220770,36404	209,87193
Eye	437966,64884	9220770,45300	211,11435

After the calculation is done then obtained the results in the form of linear accuracy of the distance of the polygon mesh of Diponegoro Prince Statue of 1: 6867.9 meters. Based on the provisions of the

Geospatial Information Agency (BIG) in the Indonesian National Standard Horizontal Skeleton Net (SNI 19-6724-2002) stated that tolerance limits accuracy linear minimum distance is 1: 6000 meters and is found in 4th order then it can be concluded that the net of polygon of Diponegoro Prince statue has met the linear tolerance limits of distance and can be done for the next research stage. For polygon description can be seen in Figure 3.



Figure 3. Diponegoro Prince Polygon Net

3.2. Stages of Formation of 3D Models with UAVs

The method used in processing uses aerial photographs taken from the acquisition of UAV with the DJI Phantom 3 Pro application to form a 3D model of the Diponegoro statue object. The results of calibration are one of the important results in the formation of 3D models. Camera calibration is a process that influences the internal parameters of the camera needed to reconstruct the beam of light when shooting. Therefore, the calibration process is considered very important to do the work. The following is the result of the camera calibration process used in this study which can be seen in Table 4.

Table 4 Camera Calibration Results

Orientation Parameter	Value	Standard Deviation
Focal Length	18.655955 mm	0.001 mm
Xp (center point in master image)	11.837823 mm	9.6e-004 mm
Yp (center point in master image)	7.990893 mm	0.002 mm
K1 (Radial Distortion)	4.731e-004	5.4e-007
K2 (Radial Distortion)	-6.562e-007	3.2e-009
K3 (Radial Distortion)	0.000e+000	0.000e+000
P1 (Tangensial Distortion)	-1.347e-005	7.5e-007
P2 (Tangensial Distortion)	8.783e-006	1.2e-006
Average Photo Point Coverage		90%

After the calculation is done then obtained the results in the form of linear accuracy of the distance of the polygon mesh Pangeran Diponegoro Statue of 1: 6867.9 meters. Based on the provisions of the Geospatial Information Agency (BIG) in the Indonesian National Standard Horizontal Skeleton Net (SNI 19-6724-2002) stated that tolerance limits accuracy linear minimum distance is 1: 6000 meters and is found in 4th order then it can be concluded that the net of polygon Sculpture Pangeran Diponegoro has met the linear tolerance limits of distance and can be done for the next research stage. For 3D model of UAV acquisition and data processing can be seen in Figure 4.

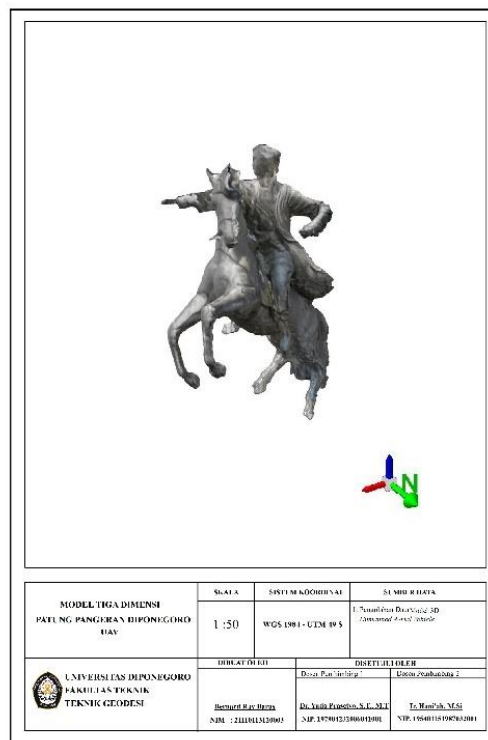


Figure 4. 3D UAV Model

3.3. Stages of Formation of 3D Models with Non Metric Camera

For the processing of 3D model data using non-metric camera equipment, a comparison is made using tie points on the sculpture object. The maximum difference in measurement in the field with Photomodeller software is 0.0277 m and minimum is 0.1007 m, with a distance difference tolerance of 2% or 0.6 m (Photomodeler help) from the measurement that is considered correct. Then the average value of the difference in each sample for direct measurement in the field is 0.1615 m. Based on the Equation 1, the accuracy value is obtained for the comparison of direct measurements in the field with the results through the software of 0.1615 ± 0.0593 m. That way the accuracy value is included in the probable error category, where the category is taken from the help photomodeler which is 0.03 m (probable error), 0.02 (mean error), 0.01 m (standard error). So RMSE in the comparison of the distance with the camera into the category of probable error (low).

For the processing of 3D model data using unmanned aerial vehicle equipment, a comparison is made using tie points on the sculpture object. The maximum difference in measurement in the field with software is 0.053 m and minimum is 0.001 m, with a distance difference tolerance of 2% or 0.6 m (Photomodeler help) from the measurement that is considered correct. Then the average value of the difference in each sample for direct measurement in the field is 0.0162 m. Based on the Equation 1 the accuracy value is obtained for the comparison of direct measurements in the field with the results through software of 0.0162 ± 0.0133 m. The accuracy value on the UAV is better than the non-metric camera and also the same as the tolerance standard of 0.011 m or 95% confidence level where the results of the UAV is 0.0133 or ± 1 cm. For 3D model of non metric camera acquisition and data processing can be seen in Figure 5.

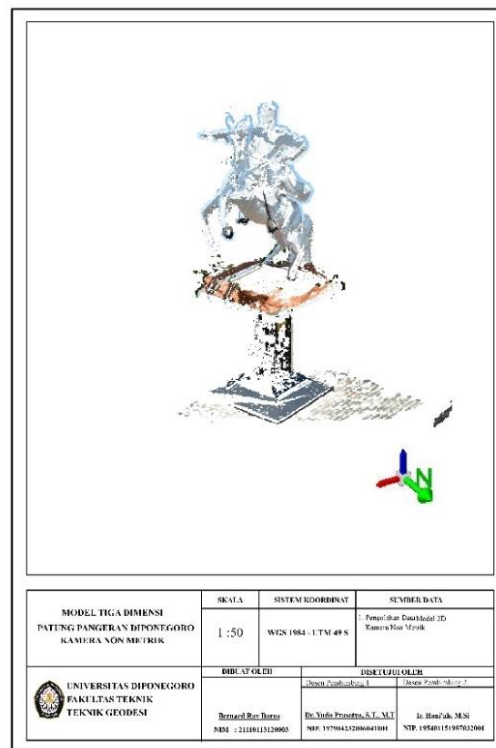


Figure 5. 3D Non Metric Camera Model

3.4. Comparison 3D Model Between UAV and Non Metric Camera Processing

The maximum difference in measurement in the field with software is 0.053 m and minimum is 0.001 m, with a distance difference tolerance of 2% or 0.6 m (Photomodeler help) from the measurement that is considered correct. Then the average value of the difference in each sample for direct measurement in the field is 0.0162 m. Based on the Equation 1, the accuracy value is obtained for the comparison of direct measurements in the field with the results through software of 0.0162 ± 0.0133 m. The accuracy value on the UAV is better than the non-metric camera and also the same as the tolerance standard of 0.011 m or 95% confidence level where the results of the UAV are 0.0133 or ± 1 cm.

After testing with SPSS based on Paired Sample t Test with a confidence level of 95%, obtained the results of significance between the camera variables, UAV and Non Metric Camera to the Total Station with the Sig. (2-tailed) of 0,000; 0,458; 0,788. The requirement to fulfill the data is Sig. (2-tailed) > 0.05 can see in Table 5. From these results it can be concluded that the variable data on the camera there is a significant difference because of the results of the accuracy that has been calculated previously does have a low accuracy.

Table 5. Significance Level

		df	Sig. (2-tailed)
Pair 1	TS - UAV	11	.458
Pair 2	TS - TLS	11	.788

4. Conclusion

Based on the results of the processing and analysis of research data, conclusions can be drawn, as follows:

1. Qualitative visualization results from UAV are better than Non Metric Camera because the object of research is not large and not broad. Quantitative visualization results in terms of RMSE values, UAV is better than non-metric cameras.
2. Of the three tools used, namely non-metric cameras and UAVs, the results show that UAV is better in accuracy compared to non-metric cameras. This is indicated by non-metric cameras the results of the lower level of accuracy is 0.0593 meters on the statue of Diponegoro Prince Statue. Meanwhile on the UAV the results are quite good compared to the camera which is 0.0133 meters.

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