Analysis of Geometric Accuracy of Pleiades Satellite Images for Base Map RDTR (Case Study: Mojosari Sub-District, Mojokerto District)

B.M Sukojo1,2, A Maffufah1

1Department of Geomatics Engineering, Institut Teknologi Sepuluh Nopember, Surabaya, 60111, Indonesia

2corresponding author: bangumms@gmail.com

Abstract. Mojosari Sub-district based on Local Government Regulation of Mojokerto District Number 9 Year 2012, concern of Spatial Planning for Mojokerto District 2012-2032 was proposed as the central government and service area of Mojokerto District. With the submission, Mojosari Subdistrict must have a good regional spatial use planning in the form of an Base Map RDTR with high accuracy. Therefore, the aim of this research is to analyze of horizontal accuracy of the pleiades satellite image, so that it can be used for making base map RDTR with a scale of 1: 5000. To produce a high-accuracy base map, the Pleiades satellite image must be processed and corrected geometrically in order to obtain an accurate image accuracy. In this study, geometric correction uses the Rational Polynomial Coefficient (RPC) method. Secondary data needed in this research are 12 points of GCP and 16 points of ICP which are measured using GPS Geodetic method, and administrative boundaries of Mojosari District. The strength of Figure obtained by the GCP points design is 0.546. From the results of the rectification process, the RMS Error value is 0.1 meters. To test the results of the rectification, the accuracy test was carried out using ICP with a horizontal accuracy of 1.5175 x RMSE. The accuracy test obtained a result of 0.095 meters. From the results of the horizontal accuracy of the Pleiades 1B satellite imagery, it has met the requirements to be used as an RDTR base map with a scale of 1: 5000 and class 1.

Keywords: Geometric Correction, Rectification, GCP, ICP, Pleiades 1B, RMSE, Horizontal Accuracy.

1. Introduction

Related to the regional arrangement, to curb governance administration, based on Law Number 23 Year 2014 and Permendagri Number 30 Year 2012, as well as letters from the Minister of Home Affairs of the Republic of Indonesia dated May 1, 2013, resulted in several decisions including the need to relocate the Capital of Mojokerto Regency which is currently located in the city of Mojokerto, and poured into the Regional Spatial Plan (RTRW) of Mojokerto Regency [1]. The relocation of the capital city of Mojokerto must consider various aspects, both physical, social, and policy aspects. So that the selection of the location of the capital city of Mojokerto Regency will be in accordance with the direction of the development of Mojokerto Regency in the future.

In Mojokerto Regency Regulation Number 9 of 2012 concerning Spatial Planning for Mojokerto Regency 2012-2032, one of them is Mojosari Sub-district, which is proposed as the center of government and service area [1]. In the past, the government center was right in Mojokerto City, but now many government buildings and offices have been moved to Mojosari Sub-district east of Mojokerto after Mojokerto was established [2]. Mojosari Sub-District will be used as the administrative center of Mojokerto Regency, regional-scale settlement center, regional-scale trade and service center, regional scale education center, regional-scale health center, tourism service center, and regional-scale
transportation service center [3].

Mojosari Subdistrict is one of 18 Subdistricts in Mojokerto Regency, East Java with an area of 26.65 km². Administratively, Mojosari Sub-district, Mojokerto is located at 7°28’10.4” S - 7°32’6.3” S and 112°31’41.0” E - 112°31’9.2” E. The subdistrict center is 18 km east of Mojokerto City [4]. As one of the regions that is used as the center of government and service area, Mojosari Subdistrict must have a good spatial planning plan and in accordance with applicable laws and regulations. For this reason, in order to avoid confusion that can result in environmental and ecosystem damage, a detailed map of the Spatial Plan (RDTR) is needed. RDTR is the elaboration of a Regional Spatial Plan (RTRW) into a regional spatial use plan by assigning designation blocks to functional areas contained in a 1:5000 scale plan or more [5]. RDTR is a geometric plan of urban space that is prepared to prepare the realization of urban space in the plan for implementing a city development project [6].

The basis for making RDTR maps must come from high-resolution satellite imagery that has a broad scope and can describe physical appearance in accordance with the appearance in the field, so that it can provide accurate information, one of which is high-resolution satellite imagery, namely Pleiades 1B satellite imagery. Pleiades 1B satellite imagery is a high resolution satellite image with a panchromatic and multispectral spatial resolution of 0.5 meters and 2 meters respectively. The satellite image is an image that still has geometric errors [7]. Geometric errors are errors that are caused by the distance of the orbit or path to the object (up to a small angle of view and the effect of the velocity of the vehicle [8]. Geometric errors are caused by two errors, namely systematic and non-systematic errors. To eliminate these errors, it is necessary to do geometric corrections.

Geometric correction is an activity to improve the coordinates that exist in the image to match the geographical coordinates [9]. In general, geometric correction of images is done by requiring 2-dimensional coordinates (x, y) or Ground Control Point (GCP) coordinates as input data. These GCP coordinates are used to give or correct an image where the GCP accuracy point will be seen by looking at the value of Root Mean Square Error (RMSE).

In this study, satellite image data used are Pleiades 1B high resolution satellite imagery with a spatial resolution of 0.5 meters. The satellite imagery data will be analyzed in terms of geometric accuracy that is used to create a basic map of the Spatial Detail Plan (RDTR) scale of 1:5000 Mojosari District. Making a basic map of the Spatial Detail Plan (RDTR) is guided by the Draft Validation Module Map of Spatial Planning 1:5000 Scale Source from the Geospatial Information Agency in 2017.

2. Data dan methods

2.1. Data

In this study using primary data and secondary data. The primary data used is the Pleiades 1B satellite image with recording in July 2017. The satellite image has a multispectral accuracy of 2 meters and a panchromatic accuracy of 0.5 meters. There are two secondary data used in this study. First, the administrative boundary of Mojokerto District with a scale of 1:5000. The data was obtained from BAPPEDA Mojokerto District. Second, the coordinates of the GCP point and the ICP point. GCP points and ICP points are obtained from GPS measurements in the field.

2.2. Research Methodology

The steps of the research are presented in Figure 1. The first stage is to carry out pansharpening on the Pleiades 1B satellite image. Pansharpening is the process of combining panchromatic and multispectral images to produce very high-resolution, color-coded images for easy identification in the placement of GCP and ICP points. The second step is to design the GCP and ICP points. Then, calculate the Strength of Figure to find the geometric strength of a net from the GCP point. The smaller the SoF value indicates that the net design is getting stronger [10]. If the SoF value has been met, then proceed to measure the GCP and ICP points in the field. From these measurements, the values of GCP coordinates and ICP coordinates were obtained.

The coordinates of the GCP points were used for rectification. At the rectification stage, data processing is carried out using image processing software using the Rational Polynomial Coefficient
(RPC) method. Rectification is useful for correcting satellite imagery from geometric errors whose fault tolerance can be seen from the RMSE value ≤ 1.5 pixels [11]. The coordinates of the ICP points are used for the horizontal accuracy test. This Horizontal accuracy-test uses the RMSE and CE90 calculations. This stage will determine the scale and class of the resulting map.

Furthermore, cropping areas are carried out in accordance with the administrative boundaries of the research area. The image that has been cut is then digitized. Digitization is based on image interpretation to produce data files with (.shp) format is done using ArcGIS software. The results obtained are in the form of 5 important elements in making a basic map, which includes waters (polygons and lines), buildings (polygons), road network (Polygons and lines), and toponymy (point). From the results of digitization, the layout was carried out. Layouting is carried out on the results of digitization which displays administrative boundaries, waters, road networks, buildings, land cover, and toponymy according to the base map validation module from BIG in 2017, in order to obtain the RDTR base map for Mojosari District, Mojokerto.
Figure 1. Flow Chart
3. Results and Discussion

3.1. Pansharpening

Pansharpening is a method for merging and sharpening panchromatic mode images with multispectral mode images, which aim to facilitate the process of image interpretation, determination of control points, and display images that have good visuals and high resolution.

![Figure 2. Comparison of pansharpening results for Pleiades 1B: (a) Before pansharpening (b) After pansharpening](image)

Figure 2 is a comparison of pansharpening results for Pleiades 1B. Figure 2a is the image of Pleiades before pansharpening, and Figure 2b is the image of Pleiades after pansharpening, which has a visual image with a higher resolution. Figure 2b shows that the results of pan sharpening produce Pleiades 1B images with better visual appearance and higher resolution.

3.2. Net Design and SoF Value

In this final project research, making a net design using a ground control point or Ground Control Point (GCP) as many as 12 points.

![Figure 3. Net Design](image)

Figure 3 shows the net design that has been made. In this figure, there are 12 points and 24 baselines. From the net design above, the Strength of Figure (SoF) calculation process is carried out in the Pleiades 1B image as follows:

| Parameter       | Value     |
|-----------------|-----------|
| Baseline Amount | 24        |
| Point Amount    | 13        |
| N_size          | Baseline amount x 3 = 72 |
| N_parameter     | Point amount x 3 = 39 |
| U               | N_size - N_parameter |


\[
\text{SoF} = \frac{33}{\text{trace}(A^TA)^{-1}} = 0.130
\]

From the net design that has been made, the calculation result of the Strength of Figure (SoF) is 0.130. These results indicate that the net design in Figure 3 meets the tolerances and is considered strong. The closer the value to zero (0), the better the Strength of Figure (SoF) value and the stronger the net [10].

3.3. The Coordinates of The GCP and ICP Points

Control point coordinates \((x, y)\) are obtained from measurements in the field using a geodetic GPS instrument with a static differential method using 3 GPS with a measurement duration of 30 minutes for GCP point measurements and 15 minutes for ICP point measurements.

### Table 1. GCP Point Coordinates

| No. | Points Name | X (meters) | Y (meters) |
|-----|-------------|------------|------------|
| 1.  | GCP 1       | 664601.655 | 9174084.700 |
| 2.  | GCP 2       | 671886.025 | 9170490.583 |
| 3.  | GCP 3       | 679612.756 | 9172213.279 |
| 4.  | GCP 4       | 683420.136 | 9166650.185 |
| 5.  | GCP 5       | 680088.775 | 9163730.927 |
| 6.  | GCP 6       | 663786.353 | 9165470.882 |
| 7.  | GCP 7       | 665015.607 | 9158735.711 |
| 8.  | GCP 8       | 668214.743 | 9154444.149 |
| 9.  | GCP 9       | 675394.792 | 9153283.511 |
| 10. | GCP 10      | 679647.193 | 9151885.950 |
| 11. | GCP 11      | 683666.630 | 9154876.717 |
| 12. | GCP 12      | 684461.833 | 9158931.560 |

### Table 2. ICP Point Coordinates

| No. | Points Name | X (meters) | Y (meters) |
|-----|-------------|------------|------------|
| 1.  | ICP 1       | 666570.421 | 9173190.705 |
| 2.  | ICP 2       | 671654.199 | 9169733.436 |
| 3.  | ICP 3       | 668360.560 | 9167348.341 |
| 4.  | ICP 4       | 665564.527 | 9162506.951 |
| 5.  | ICP 5       | 672623.308 | 9165132.183 |
| 6.  | ICP 6       | 669890.743 | 9157729.039 |
| 7.  | ICP 7       | 670537.972 | 9153282.669 |
| 8.  | ICP 8       | 680215.010 | 9165936.094 |
| 9.  | ICP 9       | 683724.496 | 9160003.644 |
| 10. | ICP 10      | 683899.247 | 9153558.253 |
| 11. | ICP 11      | 680270.556 | 9150902.236 |
| 12. | ICP 12      | 668771.047 | 9161137.929 |
| 13. | ICP 13      | 664767.781 | 9170274.246 |
| 14. | ICP 14      | 675323.438 | 9172748.347 |
| 15. | ICP 15      | 679197.958 | 9169899.950 |
| 16. | ICP 16      | 676967.400 | 9152436.403 |
Table 1 shows the coordinates of the 12 points of GCP, and Table 2 shows the coordinates of the 16 points of ICP. This value is obtained from GPS processing using software with post-processing and network adjustment methods.

3.4. Rectification

The rectification process uses the rational polynomial coefficient method found in satellite image processing software.

Table 3. Image Rectification Results Pleiades 1B

| Point Name | Dx (pixel) | Dy (pixel) | D^2 (pixel) |
|------------|------------|------------|-------------|
| GCP 1      | -0.01      | -0.05      | 0.06        |
| GCP 2      | -0.03      | 0.01       | 0.03        |
| GCP 3      | -0.01      | -0.03      | 0.03        |
| GCP 4      | 0.01       | -0.02      | 0.02        |
| GCP 5      | 0          | -0.01      | 0.01        |
| GCP 6      | -0.04      | -0.05      | 0.06        |
| GCP 7      | 0.02       | -0.03      | 0.04        |
| GCP 8      | 0.02       | 0.05       | 0.05        |
| GCP 9      | -0.04      | -0.01      | 0.04        |
| GCP 10     | 0.04       | -0.03      | 0.05        |
| GCP 11     | -0.02      | 0.04       | 0.05        |
| GCP 12     | 0.04       | -0.02      | 0.04        |
| RMSE       |            |            | 0.2         |

Table 3 shows the results of the rectification by showing an RMSE value of 0.2 pixels. The value of 1 pixel of the Pleiades 1B image is 0.5 m or as big as its spatial resolution, then the RMSE value, when multiplied by the spatial resolution of the Pleiades 1B high-resolution satellite image, the RMSE value is 0.1 meter. The resulting RMSE value is less than 1.5 pixels, where these results meet the standards of BIG 2017 Base Map Validation Module and can be continued to the next process.

3.5. Horizontal Accuracy-Test

The horizontal accuracy-test process is carried out using the coordinates of the ICP points.

Table 4. Horizontal Accuracy Test Results

| Point Name | Dx (pixel) | Dy (pixel) | D^2 (pixel) |
|------------|------------|------------|-------------|
| ICP 1      | 0.04       | 0.03       | 0.06        |
| ICP 2      | -0.02      | 0          | 0.02        |
| ICP 3      | -0.03      | 0.01       | 0.03        |
| ICP 4      | -0.01      | 0.03       | 0.03        |
| ICP 5      | 0          | -0.02      | 0.02        |
| ICP 6      | 0          | 0.01       | 0.01        |
| ICP 7      | 0.04       | 0          | 0.04        |
| ICP 8      | -0.04      | 0.04       | 0.05        |
| ICP 9      | 0.02       | -0.04      | 0.04        |
| ICP 10     | -0.04      | 0.01       | 0.05        |
| ICP 11     | -0.05      | 0.01       | 0.05        |
| ICP 12     | 0.02       | -0.03      | 0.03        |
| ICP 13     | -0.01      | 0.03       | 0.04        |
| ICP 14     | 0.01       | 0.03       | 0.03        |
Table 4 shows the results of the horizontal accuracy test. From the calculation, it has been obtained that the RMSE value is 0.189 pixels when multiplied by the spatial resolution of the Pleiades 1B high resolution satellite image, the RMSE value is 0.095 meters. From the RMSE accuracy test, the CE90 value can be calculated to determine the feasibility of the orthorectification results of Pleiades 1B Upright Image for making RDTR base maps. The CE90 value is obtained by multiplying the RMSE value by 1.5175. From this multiplication, the CE90 value is 0.144 meters.

In accordance with the Regulation of the Head of the Geospatial Information Agency Number 15 of 2014 concerning Technical Guidelines for Base Maps [12], the horizontal accuracy of the Upright Pleiades 1B image was calculated. From the results of the CE90 calculation, it means that the rectification results of the Pleiades 1B image have met the requirements and can be used for making RDTR base maps on a scale of 1: 5000 class 1 with 1 meter horizontal accuracy requirements.

3.6. Digitize

The digitization process was carried out using a rectified Pleiades 1B image and cut according to the administrative boundaries of the research area.
Figure 4 shows the results of digitization in which there are several elements of the earth's appearance, including buildings and public facilities, road networks, waters, toponymy, and land cover. The digitization of building elements and public facilities must comply with the stipulation that all buildings must be plotted according to their actual size, the building is plotted on each roof of the building, a collection of buildings or buildings with a tight distance from each other made as one unit and separated using sharing boundaries. In digitizing buildings and public facilities, a rectangle must be used because in the utilization of the spatial pattern it must match the parcel of the built-up area.

Digitization of road network elements must be in accordance with the provisions of BIG. All transportation networks shown in the image must be plotted according to their actual appearance. An important element in digitizing road network elements is the centerline or road axle. Road if there is a road network with a shoulder width of $\geq 2.5$ meters in accordance with the provisions of digitization on a scale of 1: 5000. If the road body is $\leq 2.5$ meters deep enough with the center line as the road network. In digitizing road network elements, there is another important element, namely the road body. In digitizing the road network all elements must be visible so that they cannot be cut off at the intersection of the river. In digitizing the waters, it can be done by interpreting the image by looking at the black image. In a watershed, river line segments must be connected to one another to form a network that empties at one point.

Toponymy data is obtained from the results of interpretation using Google Maps 2020. Toponymy data obtained is in the form of object names and types. Meanwhile, digitizing land cover uses a separate classification, which is made simply by looking at the characteristics of land use in cultivation areas or human activities.

3.7. Map Sheet Numbering

The results of this base map are divided according to the Map Sheet Number (NLP) on the Earth Map of Indonesia. According to the map index numbering system by the BIG map with a scale of 1: 25,000 it will be divided into 9 NLP parts to become a 1: 10,000 scale map. Then, the 1: 10,000 scale map will be divided into 4 NLP parts to become a 1: 5,000 scale map so that the Mojosari sub-district base map produces 11 sheets of Mojosari District RDTR map. The distribution of the Map Sheet Numbers refers to the BIG Regulation No. 3 of 2016 concerning Technical Specifications for Presentation of Village Maps [13].
Figure 5 shows the results of dividing the RDTR base map sheet numbers. There are 11 map sheet numbers including 1608-1337A, 1608-1337B, 1608-1337D, 1608-1338A, 1608-1338B, 1608-1338C, 1608-1338D, 1608-4111B, 1608-4111D, 1608-4112A, and 1608-4112C. The following is an example of the results of the RDTR map at a scale of 1: 5,000 in Mojosari District with map sheet numbers 1608-1337D.

Figure 6. RDTR map scale 1: 5000 Mojosari District map sheet number 1608-1337D

4. Conclusions
Based on the results of the horizontal accuracy test of the Pleiades 1B satellite image, the image has an RMSE value of 0.095 meters and a CE90 value of 0.144 meters. From these results, the Pleiades 1B Image has met the requirements for making a 1: 5,000 scale Detailed Spatial Plan (RDTR) base map for Mojosari District. 11 sheets of RDTR map with a scale of 1: 5,000 in Mojosari District have been produced. These results can be used as recommendations by the government in making a base map for a detailed spatial plan.

5. Acknowledgment
The author would like to thank all those who have helped in this research. Thanks to family and friends who are always helpful in many ways. As well as BAPPEDA Kabupaten Mojokerto for the data used in this study.

6. References
[1] Pratama, Iman Tunas, dkk. 2018. Penentuan Alternatif Lokasi Ibukota Kabupaten Mojokerto Berdasarkan Stakeholder. Jurnal Tata Kota dan Daerah 10 (1) : 47-56.
[2] Wijaya, Muhammad Handy Dwi. 2018. Kehidupan Sosial Santri Bekas Molimo Dengan “Gus” Dalam Jamaah Telulasan (Studi Fenomenologi Pada Jamaah Telulasan di Desa Ngimbangan
Kecamatan Mojosari Kabupaten Mojokerto. Malang : University of Muhammadiyah Malang.

[3] Peraturan Daerah Kabupaten Mojokerto. 2012. Rencana Tata Ruang Wilayah Kabupaten Mojokerto Tahun 2012–2032. Mojokerto : Pemerintah Kabupaten Mojokerto.

[4] Badan Pusat Statistika. 2019. Kecamatan Mojosari Dalam Angka 2019. Mojokerto : Pemerintah Kabupaten Mojokerto.

[5] Peraturan Menteri Pekerjaan Umum. 2011. Pedoman Penyusunan Rencana Detail Tata Ruang Dan Peraturan Zonasi Kabupaten/Kota. Jakarta : Menteri Pekerjaan Umum.

[6] Puspita, Atik Indra. 2017. Pembuatan Peta Skala 1:5000 Sesuai Dengan Peraturan Kepala Big Nomor 16 Tahun 2014 (Studi Kasus: BWP Lumajang, Kabupaten Lumajang). Surabaya : Teknik Geomatika, ITS.

[7] LAPAN. 2015. Retrieved From Perekaman Berulang Citra Satelit Resolusi Tinggi Pleiades. Jakarta : Deputi Bidang Penginderaan Jauh.

[8] Hartati, Sri. 2009. Aplikasi Penginderaan Jauh Untuk Ilmu Kebumian. Bandung. Bandung : Institut Teknologi Bandung.

[9] Mahmudi, Alfan Rozy. 2018. Studi Analisis Ketelitian Geometrik Citra Satelit Resolusi Tinggi Sebagai Peta Dasar Rencana Detail Tata Ruang Perindustrian (Studi Kasus : Kawasan Pt Sier Surabaya). Jurnal Geoid 14 (1) : 89-94.

[10] Abidin, H. Z. (2006). Penentuan Posisi Dengan Gps Dan Aplikasinya. Jakarta: PT. Pradnya Paramita.

[11] Badan Informasi Geospasial. 2017. Draft Modul Validasi Peta Rencana Tata Ruang. Bogor : Badan Informasi Geospasial.

[12] Peraturan Kepala BIG. 2014. Pedoman Teknis Ketelitian Peta Dasar. Bogor : Badan Informasi Geospasial.

[13] Peraturan Kepala BIG. 2016. Spesifikasi Teknik Penyajian Peta Desa. Bogor. Badan Informasi Geospasial.