Geometric accuracy analysis of the measurement Ground Control Point (GCP) in the rectification process of high resolution satellite image with polynomial method (case study: Wlingi Sub-district, Blitar Regency)

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Abstract. High resolution imagery can be used in basic map making process. Basic map is basic data used for Comprehensive Systematic Land Registration (PTSL) making. However, the use of high resolution imagery is still has geometric errors that must be eliminated by performing rectification process. This study took place in Wlingi Sub-district, Blitar Regency. In this research polynomial method orde 1, 2, and 3 are used in rectification process. This method is done to obtain the best results of rectification process. Determination of the number of Ground Control Point (GCP) in orde 1, 2, and 3 are the main focus in this study. Geometry accuracy analysis is done by calculating the Root Mean Square Error (RMSE) of GCP used in this rectification process and testing the statistics of the distance of the image rectification with distance in the field. The results showed that polynomial method orde 1 with 5 GCP points produced 0.487 m RMSE, orde 2 with 8 GCP points produced 0.397 m RMSE, and orde 3 polynomial with 12 GCP points produced 0.326 m RMSE. In this study all of polynomials method orde 1, 2, and 3 are suitable for making basic maps for PTSL baseline data Wlingi District, with a scale of 1:1,000 in grade 3.

1. Introduction

Comprehensive Systematic Land Registration (PTSL) is an activity of land registration which carried out simultaneously for the first time. The activity includes all objects of land registration which have not been registered in the area or part of a village [7]. Wlingi District is one of the selected sub-districts as the location of PTSL 2019 targets in Blitar Regency. One condition is for an area to be selected as a PTSL target, namely a basic map, a photo map, and a line map are available [6]. Where, the basic map is a map that is used in the framework of activities for land registration, spatial planning, and the basis for making other thematic maps [4].

In order to make a basic map, basic materials can be used in the form of satellite images and a small portion of aerial photography [4]. However, the use of high resolution satellite imagery for making base maps has problems, for example data recording by satellite sensors that cannot be used directly because there are still some geometric errors that must be eliminated [1]. To eliminate image geometry errors, geometry correction is performed by rectifying. Rectification is the process of repositioning satellite imagery according to the actual location or coordinates due to the shift in position data [5].

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In this research, a rectification process using the 1\textsuperscript{st}, 2\textsuperscript{nd}, and 3\textsuperscript{rd} polynomial methods will be tested. Each method has different characteristics. In this study 25 ground control points were used. Order 1 polynomial requires a minimum of 3 ground control points. Order 2 polynomials require a minimum of 6 ground control points. Whereas the 3\textsuperscript{rd} order polynomial requires at least 10 ground control points. This is done to compare the results and determine the best. Analysis of rectification accuracy was done by calculating GCP Root Mean Square Error (RMSE) and statistical test of the distance of image rectification results with distance in the field. It is hoped that this research will be able to provide recommendations for making basic maps that meet geometry accuracy in accordance with existing standards and can be used as baseline data for PTSL 2019 in Wlingi District, Blitar Regency.

2. Methodology

2.1. Study area
The location of this research was conducted in Wlingi Sub-district, Blitar Regency, East Java. The region is located at coordinates 8° 02’ 0” - 8° 08’ 0” LS and 112° 18’ 0” - 112° 21’ 0” BT and has an area of 61.6 km\(^2\) which is divided into 9 villages. The area of Wlingi Subdistrict is bordered by the following regions:

- North : Gandusari District
- East : Doko District
- South : Selopuro District
- West : Talun District

![Figure 1. Research locations (source: Google Earth Imagery (left) and GeoEye-1 Satellite Imagery 2014 (right)).](image)

2.2. Data and equipment
The data used in this study is the GeoEye-1 satellite image in 2014 which covers the entire area of Wlingi District with a spatial resolution of 0.5 m [2]. Ground point coordinate data as many as 20 points were measured by the Office of Public Works and Spatial Planning of Blitar Regency and 5 points of measurement results carried out by the author. Both measurements of ground control points use the Real Time Kinematic (RTK) method.

2.3. Data processing
- The distribution of ground control points (GCP) consists of 3 orders, namely, the distribution of first order is needed at least 3 GCP, minimum order 2 distribution is required 6 GCP, and minimum order 3 distribution is needed 10 GCP.
Image rectification is done by order 1, 2, and 3 polynomial methods. Accuracy of image rectification is shown from the GCP RMSE value. GCP RMSE should be \( \leq 1 \) pixel [8]. If the GCP RMSE value exceeds 1 pixel, the image rectification must be done again.

Analysis of the results of image rectification of each polynomial order was carried out based on GCP RMSE obtained during image rectification. So that the distribution of GCP can be determined most optimally from each polynomial order used.

Distance accuracy analysis is done by comparing the distance of the image rectification with the distance of the results in the field. Analysis of distance accuracy serves to find out whether there is a scale change on the X axis or Y axis when the rectification process or has the same change between the X axis and Y axis. Meanwhile, the statistical test is done to find out whether there is a difference between the distance values of the image rectification with the result distance measurement in the field.

Calculation of image accuracy results from rectification using the CE90 value calculated by the formula:

\[
CE90 = 1.5175 \times \text{RMSE}
\]

Classification of the results of rectification with the scale of the resulting image map is divided into 3 classes, namely 1, 2, and 3. In this study, the classification refers to the BIG Regulation No. 6 of 2018 concerning Amendments to the BIG Regulation No. 15 of 2014 concerning Technical Guidelines for Basic Map Accuracy.

3. Result and Discussion

3.1. Selection and Placement of Ground Control Points

Ground control points should be planned on specific objects, clearly visible in the image and easily recognizable in the field or objects on the surface of the earth whose changes are relatively slow or constant, such as roads, street corners, areas that have striking colors, and objects or buildings or monuments easily identified or recognized. The object must be clearly visible in the image and in the field without obstruction as well as being covered by trees.

![Figure 2. BLTR52 ground points in citra and field (source: processing results).](image)

![Figure 3. BLTR44 ground points in citra and field (source: processing results).](image)
3.2. Determination of amount and distribution of ground control points

In planning the image rectification process, it is necessary to have the right number of ground control points so that the measurement in the field is not too long [10]. Determination of the number of ground control points (GCP and ICP) is sought according to needs with a variety of considerations, including area, condition of relief of mapping areas, costs, tools, and formulas to be used in the rectification process so that measurements can be carried out efficiently.

In this study, there were 25 ground control points. Determination of the number of ground control points in this study is adjusted to the first order polynomial method (minimum 3 points), order 2 (minimum 6 points), and order 3 (minimum 10 points) so that the final results can be rectified with various levels of polynomial order.

| Orde 1 | Orde 2 | Orde 3 |
|--------|--------|--------|
| GCP    | ICP    | GCP    | ICP    | GCP    | ICP    |
| 3      | 22     | -      | -      | -      | -      |
| 4      | 21     | -      | -      | -      | -      |
| 5      | 20     | -      | -      | -      | -      |
| 6      | 19     | 19     | -      | -      | -      |
| 7      | 18     | 18     | -      | -      | -      |
| 8      | 17     | 17     | -      | -      | -      |
| 9      | 16     | 16     | -      | -      | -      |
| 10     | 15     | 15     | 10     | 15     | 10     |
| 11     | 14     | 14     | 11     | 14     | 11     |
| 12     | 13     | 13     | 12     | 13     | 12     |
| 13     | 12     | 12     | 13     | 13     | 12     |

3.3. Result of ground control point measurement

The results of measurement of ground control points are obtained from the residual values of the points between 0.018 – 0.350 m for horizontal accuracy (accuracy of positions X and Y) and 0.027 – 0.377 m for vertical accuracy (high component accuracy). From these results the highest accuracy at the BLTR52 point and the lowest accuracy at the BLTR64 point. The residual value is caused by GPS signal noise, namely multipath and cycle slips.

![Image](image.png)
3.4. Image rectification results

To find out the accuracy of the image rectification results can be seen from the value of RMSE (Root Mean Square Error). RMSE shows the error rate by comparing the coordinates of the ground control points as a result of rectifying the image with the actual coordinates, in this case the coordinates of the measurement results in the field. The RMSE value of GCP aims to see whether an image has been used properly for further processing or not. While the ICP RMSE value is used to determine what scale of the map is allowed in making basic maps. This study uses three polynomial orders which aim to find the smallest RMSE value at various levels of polynomial order. The following is the result of rectifying the image using order 1, 2, and 3 polynomials:

| GCP | ICP | X RMS (m) | Y RMS (m) | RMSE GCP (m) | RMSE ICP (m) |
|-----|-----|-----------|-----------|--------------|--------------|
| 3   | 22  | 0.159     | 0.091     | 0.500        | 0.830        |
| 4   | 21  | 0.156     | 0.088     | 0.494        | 0.840        |
| 5   | 20  | 0.152     | 0.085     | 0.487        | 0.839        |
| 6   | 19  | 0.159     | 0.091     | 0.500        | 0.839        |
| 7   | 18  | 0.153     | 0.087     | 0.490        | 0.841        |
| 8   | 17  | 0.153     | 0.086     | 0.488        | 0.842        |
| 9   | 16  | 0.155     | 0.087     | 0.492        | 0.838        |
| 10  | 15  | 0.158     | 0.090     | 0.498        | 0.837        |
| 11  | 14  | 0.155     | 0.088     | 0.493        | 0.836        |
| 12  | 13  | 0.151     | 0.084     | 0.485        | 0.835        |
| 13  | 12  | 0.154     | 0.088     | 0.492        | 0.838        |
Table 3. GCP and ICP RMSE results of order 2 polynomial image rectification.

| GCP | ICP | Polynomial Orde 2 |
|-----|-----|------------------|
|     |     | X RMS (m)        | Y RMS (m) | RMSE GCP (m) | RMSE ICP (m) |
| 6   | 19  | 0,116            | 0,060     | 0,420        | 0,747        |
| 7   | 18  | 0,108            | 0,059     | 0,408        | 0,748        |
| 8   | 17  | 0,102            | 0,056     | 0,397        | 0,749        |
| 9   | 16  | 0,111            | 0,059     | 0,412        | 0,746        |
| 10  | 15  | 0,111            | 0,059     | 0,412        | 0,741        |
| 11  | 14  | 0,103            | 0,057     | 0,400        | 0,740        |
| 12  | 13  | 0,098            | 0,058     | 0,394        | 0,737        |
| 13  | 12  | 0,098            | 0,058     | 0,394        | 0,741        |

Table 4. GCP and ICP RMSE results of order 3 polynomial image rectification.

| GCP | ICP | Polynomial Orde 3 |
|-----|-----|------------------|
|     |     | X RMS (m)        | Y RMS (m) | RMSE GCP (m) | RMSE ICP (m) |
| 10  | 15  | 0,078            | 0,039     | 0,341        | 0,659        |
| 11  | 14  | 0,075            | 0,039     | 0,338        | 0,659        |
| 12  | 13  | 0,069            | 0,037     | 0,326        | 0,655        |
| 13  | 12  | 0,069            | 0,037     | 0,326        | 0,661        |

From tables 2, 3, and 4 above, we can see the optimal distribution of GCP from each polynomial order used, namely, order 1 with 5 GCP produces RMSE of 0.487 m, order 2 with 8 GCP produces RMSE of 0.397 m, and order 3 with 12 GCP produces RMSE of 0.326 m. Of the three polynomial orders, the distribution pattern of GCP is located in the outermost region of the image or near the sub-district boundary and the image overlay area.

3.5. Distance Accuracy and Statistical Test

In this study, statistical tests were carried out with the hypotheses to be tested as follows [9]:

- Ho: There is no significant difference between the distance values of the image rectification results with the distance of the measurement results in the field. Can be written Ho: \( \mu_1 = \mu_2 \).
- Ha: There is a significant difference between the distance values of the image rectification results with the distance of the measurement results in the field. Can be written Ha: \( \mu_1 \neq \mu_2 \).

Table 5. Two sided test results (\( \alpha = 10\% \) and \( \alpha = 5\% \)) polynomial order 1

| Polynomial Orde 1 |
|-------------------|
| GCP Amount | \( F_h \) | \( F_{1-5\%} \) | \( t_{table (-10\%)} \) | \( t_{table (-5\%)} \) | Information |
| 3          | 1,000       | 6,390          | 2,182          | 2,776          | Be accepted |
| 4          | 1,186       | 2,970          | 1,812          | 2,228          | Be accepted |
| 5          | 1,000       | 2,220          | 1,734          | 2,101          | Be accepted |
| 6          | 1,071       | 1,840          | 1,697          | 2,042          | Be accepted |
From the two sided test with $\alpha = 10\%$ and $\alpha = 5\%$, all distance values in first order polynomials that are tested are located in the reception area Ho (Ha is rejected), thus there is no significant difference between distance values the results of rectifying the image with the distance of the measurement results in the field.

**Table 6. Two sided test results ($\alpha = 10\%$ and $\alpha = 5\%$) polynomial order 2**

| GCP Amount | $F_h$ | $F_t$ | $t_{table}$ (-10%) | $t_{table}$ (-5%) | Information |
|------------|-------|-------|---------------------|-------------------|-------------|
| 6          | 1,071 | 1,840 | 1,697               | 2,042             | Be accepted |
| 7          | 1,000 | 1,690 | 1,684               | 2,021             | Be accepted |
| 8          | 1,000 | 1,558 | 1,680               | 2,015             | Be accepted |
| 9          | 1,000 | 1,503 | 1,661               | 1,984             | Be accepted |
| 10         | 1,000 | 1,406 | 1,664               | 1,989             | Be accepted |
| 11         | 1,000 | 1,314 | 1,668               | 1,996             | Be accepted |
| 12         | 1,000 | 1,294 | 1,652               | 1,970             | Be accepted |
| 13         | 1,000 | 1,242 | 1,650               | 1,975             | Be accepted |

From the two sided test with $\alpha = 10\%$ and $\alpha = 5\%$, all distance values for the 2nd order polynomials that are tested are in the Ho reception area (Ha is rejected), thus there is no significant difference between distance values the results of rectifying the image with the distance of the measurement results in the field.

**Table 7. Two sided test results ($\alpha = 10\%$ and $\alpha = 5\%$) polynomial order 3.**

| GCP Amount | $F_h$ | $F_t$ | $t_{table}$ (-10%) | $t_{table}$ (-5%) | Information |
|------------|-------|-------|---------------------|-------------------|-------------|
| 10         | 1,000 | 1,406 | 1,664               | 1,989             | Be accepted |
| 11         | 1,000 | 1,314 | 1,668               | 1,996             | Be accepted |
| 12         | 1,000 | 1,294 | 1,652               | 1,970             | Be accepted |
| 13         | 1,000 | 1,242 | 1,650               | 1,975             | Be accepted |
From the two sided test with $\alpha = 10\%$ and $\alpha = 5\%$, all distance values in the 3rd order polynomials tested are located in the reception area Ho (Ha is rejected), thus there is no significant difference between distance values the results of rectifying the image with the distance of the measurement results in the field.

3.6. Geometry Accuracy
In BIG Regulation No. 6 of 2018, the provisions on the accuracy of the horizontal geometry of the RBI map are divided into 3 classes, as follows:

| Accuracy | Class 1 | Class 2 | Class 3 |
|----------|---------|---------|---------|
| Horizontal | 0.3 x scale number | 0.6 x scale number | 0.9 x scale number |

The results and analysis of geometry accuracy for each order of 1, 2, and 3 polynomials can be explained as follows:

| GCP | ICP | CE90 (m) | Kelas 1 | Kelas 2 | Kelas 3 |
|-----|-----|----------|---------|---------|---------|
|     |     |          | Skala Peta | Skala Peta | Skala Peta |
| 3   | 22  | 1,260    | 01:04.0  | 01:02.0  | 01:01.0  |
| 4   | 21  | 1,275    | 01:04.0  | 01:02.0  | 01:01.0  |
| 5   | 20  | 1,273    | 01:04.0  | 01:02.0  | 01:01.0  |
| 6   | 19  | 1,273    | 01:04.0  | 01:02.0  | 01:01.0  |
| 7   | 18  | 1,276    | 01:04.0  | 01:02.0  | 01:01.0  |
| 8   | 17  | 1,278    | 01:04.0  | 01:02.0  | 01:01.0  |
| 9   | 16  | 1,272    | 01:04.0  | 01:02.0  | 01:01.0  |
| 10  | 15  | 1,270    | 01:04.0  | 01:02.0  | 01:01.0  |
| 11  | 14  | 1,269    | 01:04.0  | 01:02.0  | 01:01.0  |
| 12  | 13  | 1,267    | 01:04.0  | 01:02.0  | 01:01.0  |
| 13  | 12  | 1,272    | 01:04.0  | 01:02.0  | 01:01.0  |

In the table above, it can be seen that 1st order polynomials are suitable for making a 1:1,000 base map in class 3.
In the table above, it can be seen that 2\textsuperscript{nd} order polynomials are suitable for making a 1:1,000 base map in class 3.

| GCP | ICP | CE90 (m) | Kelas 1 Skala Peta | Kelas 2 Skala Peta | Kelas 3 Skala Peta |
|-----|-----|----------|---------------------|---------------------|---------------------|
| 11  | 14  | 1,123    | 01:03.5             | 01:01.5             | 01:01.0             |
| 12  | 13  | 1,118    | 01:03.5             | 01:01.5             | 01:01.0             |
| 13  | 12  | 1,124    | 01:03.5             | 01:01.5             | 01:01.0             |

In the table above, it can be seen that order 3 polynomials are suitable for making a 1:1,000 base map in class 3.

4. Conclusions

Based on the results and analysis that have been described, the conclusions obtained from this study are:

- Based on the results of rectification, the most optimal distribution of GCP from each polynomial order used is, order 1 with 5 GCP produces RMSE of 0.487 m, order 2 with 8 GCP produces RMSE of 0.397 m, and order 3 with 12 GCP produces RMSE of 0.326 m. Of the three polynomial orders, the distribution pattern of GCP is located in the outermost region of the image or near the sub-district boundary and the image overlay area.

- In this study, the polynomial rectification method of order 1, 2, and 3 is suitable for making a 1:1,000 scale base map in class 3. For practical purposes in making basic maps in this study area, polynomial rectification methods can be used order 1 with 5 GCP which has an average distance between points of 5.603 km.

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