Analysis of deriving control points from LiDAR intensity image for orthophoto production

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Abstract. In aerial photogrammetry need control points and has a reference to the land coordinates where the measurement location is carried out. This control point would be used in aerial photo georeferenced. But in practice it often finds severe field conditions that can affect the process of measuring control points, such as a forest, mountains area and even conflict areas, which could make the process of measurement at that location impossible. LiDAR Intensity Image is one product of processing LiDAR data that can be used to produce coordinates of ground control points. So that it can reduce or eliminate the use of coordinates from GCP point measurements in the field of georeferenced in aerial photographs. This research is calculating the accuracy orthophoto produced of control points from LiDAR Intensity Image. The data used are LiDAR data and aerial photography using the Bundle Block Adjustment method. The result is orthophoto which tested for accuracy based on PERKA BIG No. 15 of 2014. The results from the CE90 and LE90 tests for orthophoto that use control points from the Premark Intensity Image are 0.433 m and 0.479 m which means fulfilling the scale 1:2500 class 1 for horizontal and vertical accuracy. For the CE90 and LE90 tests that use control points from a combination of intensity image and GCP points from GPS measurements, produce better accuracy of 0.314 m and 0.301 m so that fulfilling the scale 1:2500 class 1 for horizontal and vertical accuracy.

1. Introduction
Photogrammetry is a survey and mapping method that can take photos of a wide area from a specified distance and great accuracy in just a short time. In taking aerial photographs, it takes known points and has a reference to the coordinates of the land where the measurement location is carried out. This control point will later be used in aerial photo georeferenced. Orthophoto is an aerial photograph that has been rectified (orthorectification) to produce an image with an upright object, free from geometric errors due to central projection and relief displacement. The object is tilted because the angle of shooting will be corrected so that the photo becomes upright [1]. To produce accuracy that matches tolerance, the number of control points and its even distribution influences the accuracy produced. This control point will later be used in aerial photo georeferenced. But in practice it often finds severe field conditions that can affect the process of measuring control points, such as untouched forests, mountainous areas and even conflict areas, which can make the process of measurement at that location impossible. LiDAR Intensity Image is defined generally as the power backscattered for each measured point or can be simplified as the ratio of laser energy transmitted and received back by the receiver [2]. LiDAR Intensity Image is a product of processing LiDAR data that can be used to produce coordinates of ground control points (GCP) so that
it can reduce or eliminate the use of coordinates from GCP point measurements in the field in the georeferenced process on aerial photographs. This research examined the accuracy of orthophoto resulting from the use of control points derived from LiDAR Intensity Image. The data used are LiDAR data and aerial photography using the Bundle Block Adjustment (BBA) method. Processing is carried out with 2 different control point samples, for sample 1 using control points taken from Premark coordinates at the intensity image consisting of 11 GCP points and for sample 2 using control points taken from a combination of premark intensity image coordinates and GCP coordinates GPS measurement which consists of 11 GCP points. The result is orthophoto which is then tested for accuracy based on PERKA BIG No. 15 of 2014. This research was conducted in the area of Palangka Raya, Central Kalimantan. It is expected that this research can determine the accuracy of orthophoto produced from the point of GCP LiDAR Intensity Image and can be a recommendation for making maps orthophoto by utilizing data based on PERKA BIG No. 15 of 2014 concerning technical guidelines for the accuracy of the basic maps of CE 90 and LE 90 [3].

2. Method

2.1. Research sites
The research location is on City of Palangka Raya its geographical located at 113°30’16”- 114°07’18” East and 1°35’16”- 2°24’21” South, with a broad area is 267,851 ha with topography consisting of flat and hilly land with a slope of less than 40%.

2.2. Data and equipment
The data used in this research is LiDAR data from Orion Optech H-300 and aerial photography data of Palangka Raya City, Central Kalimantan in the calibration area with a total of 2563 photos with GSD 10 cm from Phase One IXA cameras R-180 with a sensor resolution of 10328 (X_axis) x 7760 (Y_axis) or 80 Mega Pixels with a spatial resolution of 25 cm. Data of Ground Control Point (GCP) and Independent Check Point (ICP) used are data generated through terrestrial measurements using a geodetic GPS measuring device with a total number of binding points of 11 GCP and 10 ICP.

![Figure 1. (a) Orion Optech H-300  (b) Phase One IXA](image)

2.3. The steps of processing
The steps of processing that are carried out are first to do the automatic and manual classification process then eliminate noise and spike on LiDAR data. Then make the LiDAR Intensity Image which later the coordinates of the LiDAR Intensity Image are used for the process georeferenced. After the LiDAR Intensity Image is produced, then the detection and extraction of objects will be used as control points (GCP) to produce coordinates (x, y, z) that are used for the process of georeferenced aerial photographs. Aerial triangulation is a method of determining control points by measuring photo coordinates or model coordinates, using Bundle Adjustment method. The results of this processing of the sigma naught must be less than 5 microns if it is not necessary to repeat the processing process starting from the detection
and extraction of control points to LiDAR Intensity Image. Then the process carried out Orthophoto and mosaicking are, namely combining aerial photos together to form Orthophoto. Then a horizontal and vertical precision test of orthophoto was carried out, in this research following the calculation set forth in PERKA BIG No. 15 of 2014 calculation of CE90 and LE90.

2.4. Mathematics model

The aerial triangulation is a method of determining control points by measuring photo coordinates or model coordinates which are then processed by leveling calculations, so that coordinates and elevation can be obtained with precision that meets the technical requirements for photogrammetric mapping. Based on the measured coordinate data, air triangulation can be done with the Bundle Block Adjustment, in this leveling method derived from photographic pieces or blocks with at least 60% overlap and 20% sidelap [4]. The Bundle Block Adjustment is to directly connect the photo coordinate system to a map or ground coordinate system without going through the relative and absolute orientation stages. Mathematically the bundle equation adjustment block can be expressed as the equation of a three-dimensional conformation transformation, namely:

\[
\left( \begin{array}{c} X_p \\ Y_p \\ Z_p \end{array} \right)_{Ground} = \left( \begin{array}{c} X_o \\ Y_o \\ Z_o \end{array} \right) + \lambda R \left( \begin{array}{c} x_p \\ y_p \\ z_p \end{array} \right)_{Photo} \tag{1}
\]

- \(X_p, Y_p, Z_p\): The position of the point in the coordinate system
- \(X_o, Y_o, Z_o\): The position of the center of the projection camera
- \(x_p, y_p, z_p\): The position of the p point in the photo coordinate system
- \(\lambda\): Scale factor
- \(R\): Scale rotation

3. Results

3.1. LiDAR intensity image results

After the noise selection and classification have been done, the next step is the formation of Intensity Image. Intensity Image produced grey scale by forming objects in the field. The results of the Intensity Image can be seen in the picture below.

![Figure 2](image.png)

**Figure 2.** (a) Intensity Image (b) Premark GCP Points from Intensity Image (c) Premark GCP Points from Orthophoto

From these images can be seen objects Premark from CP 021 points beside the road highway objects premark can be seen in the image intensity image caused by brightly coloured premark and its installation from the ground not directly attached to the ground so that when the LiDAR acquisition process can be formed point clouds from the object so that it can be identified on the intensity image.
The results of this Intensity Image are then used to look for Premark GCP point images which are then taken coordinates to be carried out by aerial photo processing. Accuracy of Intensity Image produced is below 0.5 m, this is also in line with the research conducted by Hsu, that the accuracy of the LiDAR Intensity Image produced <0.500 m [5].

3.2. Results of GCP coordinates and ICP from intensity image

After Intensity is produced, the coordinates of GCP and ICP taken to provide the marker at the point Intensity Image. These coordinate points will be used in the aerial triangulation process with the method bundle block adjustment on aerial photography. In this research 2 samples of different control points were used, for sample 1 using control points taken from Premark coordinates at the intensity image consisting of 11 GCP points and for sample 2 using control points taken from a combination of premark intensity image coordinates and GCP coordinate measurements GPS which consists of 11 GCP points. The following are the results of the coordinates of the samples 2.

| Point No | Easting (m) | Northing (m) | Elevasi (m) |
|----------|-------------|--------------|-------------|
| GNM008   | 789,552,338 | 9,823,585,738| 35,527      |
| PKY003   | 796,391,460 | 9,824,776,285| 32,050      |
| PKY004   | 789,821,095 | 9,821,233,384| 48,083      |
| PKY005   | 790,706,613 | 9,815,214,241| 44,922      |
| PKY006   | 794,829,993 | 9,817,518,118| 24,646      |
| PKY007   | 799,890,518 | 9,821,915,163| 43,839      |
| PKY012   | 795,908,623 | 9,813,213,189| 25,403      |
| PKY013   | 792,006,223 | 9,809,772,527| 36,860      |
| PKY021   | 795,352,443 | 9,807,818,547| 34,950      |
| PKY042   | 794,050,648 | 9,824,862,658| 15,191      |
| PKY044   | 797,987,390 | 9,810,910,971| 12,483      |
| CP001    | 791,500,875 | 9,824,693,797| 23,273      |
| CP002    | 793,648,843 | 9,822,761,198| 16,634      |
| CP003    | 796,708,515 | 9,817,711,094| 18,241      |
| CP005    | 793,720,438 | 9,815,139,200| 41,891      |
| CP006    | 792,885,106 | 9,819,433,813| 29,303      |
| CP011    | 797,865,339 | 9,814,966,330| 17,326      |
| CP012    | 791,010,001 | 9,811,505,699| 30,515      |
| CP013    | 793,144,049 | 9,807,866,078| 38,959      |
| CP014    | 796,694,393 | 9,809,858,791| 26,595      |
| CP021    | 794,575,469 | 9,810,914,157| 38,824      |

The tables above is a sample 1 taken from the coordinates Premark which is seen in the intensity image consisting of 11 GCP points and 10 ICP points, then the GCP point is used in the process georeferenced aerial photo and the ICP point will be used in the process of testing the accuracy of maps orthophoto the resulting.
Table 2. Coordinate of GCP and ICP Samples 2.

| Point No | Easting (m) | Northing (m) | Elevasi (m) |
|----------|-------------|--------------|-------------|
| GNM008   | 789,552,461 | 9,823,585,328| 36,020      |
| PKY003   | 796,391,375 | 9,824,776,368| 32,183      |
| PKY004   | 789,821,095 | 9,821,233,384| 48,667      |
| PKY005   | 790,706,408 | 9,815,214,548| 45,559      |
| PKY006   | 794,829,993 | 9,817,518,118| 25,389      |
| PKY007   | 799,890,518 | 9,821,915,163| 44,162      |
| PKY012   | 795,908,295 | 9,813,212,986| 25,523      |
| PKY013   | 792,006,223 | 9,809,772,527| 36,860      |
| PKY021   | 795,352,443 | 9,807,818,547| 34,950      |
| PKY042   | 794,050,648 | 9,824,862,658| 15,191      |
| PKY044   | 797,987,390 | 9,810,910,971| 12,483      |
| CP001    | 791,500,875 | 9,824,693,797| 23,273      |
| CP002    | 793,648,843 | 9,822,761,198| 16,634      |
| CP003    | 796,708,515 | 9,817,711,094| 18,241      |
| CP005    | 793,720,438 | 9,815,139,200| 41,891      |
| CP006    | 792,885,106 | 9,819,433,813| 29,303      |
| CP011    | 797,865,339 | 9,814,966,330| 17,326      |
| CP012    | 791,010,001 | 9,811,505,699| 30,955      |
| CP013    | 793,144,345 | 9,807,865,773| 39,479      |
| CP014    | 796,694,393 | 9,809,858,791| 27,374      |
| CP021    | 794,575,469 | 9,810,914,157| 39,270      |

The table above is sample 2 taken from a combination of coordinates Premark is seen in the intensity image and coordinates of GCP and ICP Measurement GP S which consists of 11 GCP points and 10 ICP points, which then the GCP point is used in the process georeferenced aerial photo and the ICP point will be used in the test process for the accuracy of maps orthophoto the resulting

3.3. The orthophoto
The results of orthophoto produced can be seen in Figure 3. This orthophoto is good because the photos produced are not split and there is no shift. These results are influenced by sigma naught which results in both samples in the aerial triangulation process already below 5 microns, from the provisions regulated by the Indonesia Geospatial Information Agency (BIG) that sigma naught the resulting must be below 5 microns.
The sigma naught is a value that states the overall level of processing accuracy value sigma naught resulting from process bundle block adjustment in the processing of aerial photographs for sample 1 was 1.1 microns with a GSD by 15 cm and has a total tie point as much as 609491 points. Whereas for sample 2 produces sigma naught of 1.2 microns with GSD of 15 cm and has a total tie point of 609491 points. Can be seen for sample 2 producing sigma naught which is slightly larger but still below 5 microns according to the provisions regulated by PERKA BIG. This can happen because sample 2 is a combination of control points generated from Intensity image and from geodetic GPS measurements to produce sigma naught which is greater than sample 1.

3.4. The error total georeferencing point of GCP

From the georeferencing results on the model shown in the graph, it shows that the RMSE control points in samples 1 and 2 of the results are varied. For the largest RMSE the control point in sample 1 is PKY 012 of 0.239 m while the RMSE is the smallest control point that is at PKY 006 of 0.022 m. Whereas the largest sample of 2 RMS errors in PKY 042 was 0.359 m while the smallest RMSE control point was PKY 003 of 0.028 m. The RMSE value not only shows the error at which point needs to be corrected but can also describe which points are poor accuracy and know whether the processing results are in accordance with the ground control point system or not.
3.5. Horizontal and vertical accuracy tests

The accuracy of horizontal and vertical geometry uses a reference to the PERKA BIG No. 15 of 2014. Accuracy testing in this research was carried out on horizontal coordinates (X, Y) and vertical Z. Calculations were taken from RMSE ICP points. The ICP point in the field will be compared with the ICP point in orthophoto. The rules of PERKA BIG No. 15 of 2014 use the calculation of Circular Error 90% (CE90) [4]. A measure of horizontal geometric precision defined as a radius of a circle that shows 90% of the error or difference in the horizontal position of an object on a map with a position that is assumed to be not greater than that radius. Whereas LE90 is a measure of vertical geometric accuracy, namely the value of distance which indicates that 90% of errors or differences in object height values on maps with actual altitude values are not greater than the distance values. The RMSE value is formulated as follows:

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

\[
\text{LE90} = 1.6499 \times \text{RMSE}_z
\]

With:
RMSE_r = Root Mean Square Error on x,y (horizontal)
RMSE_z = Root Mean Square Error on z (vertical)

With observations its Independent Check Point scattered (ICP) can be used to determine the accuracy of the results of processing orthophoto. These ICP points were not previously included in the aerial triangulation process, the ICP Model coordinates were obtained after the process georeferencing. The free check point/ICP aims to test the accuracy of ground control points (GCP). The model ICP coordinates of the model obtained were used for Horizontal and Vertical accuracy tests based on PERKA BIG No. 15 of 2014.

Table 3. Difference in ICP coordinate model and field sample 1.

| Titik | ∆X (m) | ∆Y (m) | ∆Z (m) |
|-------|--------|--------|--------|
| CP001 | 0.185  | -0.166 | -0.265 |
| CP002 | 0.123  | -0.051 | -0.333 |
| CP003 | 0.437  | -0.288 | 0.081  |
| CP005 | 0.069  | -0.047 | -0.437 |
| CP006 | 0.057  | 0.015  | -0.300 |
| CP011 | 0.064  | 0.354  | -0.083 |
| CP012 | 0.110  | -0.069 | -0.396 |
| CP013 | 0.400  | -0.303 | -0.257 |
| CP014 | 0.102  | 0.132  | -0.214 |
| CP021 | 0.156  | 0.022  | -0.313 |

From the model coordinate table and sample 1 above it can be seen that the biggest difference between the ICP coordinates of the model and the field for the X coordinate, namely in CP 003 of 0.437 m, for the Y coordinates on the CP 011 of 0.354 m and for the Z coordinates of the CP 005 at -0.437 m.
### Table 4. Difference in ICP coordinate model and field sample 2.

| Point No | (m)  | (m)  | (m)  |
|----------|------|------|------|
| CP001    | 0.052| -0.180| -0.098|
| CP002    | 0.075| -0.038| -0.025|
| CP003    | 0.420| -0.268| 0.408|
| CP005    | 0.011| -0.099| -0.162|
| CP006    | 0.028| 0.023| -0.084|
| CP011    | 0.050| 0.317| -0.081|
| CP012    | -0.023| -0.108| -0.447|
| CP013    | -0.069| -0.039| -0.469|
| CP014    | 0.010| 0.026| -0.329|
| CP021    | 0.041| -0.044| -0.401|

From the model coordinate table and sample 1 above it can be seen that the biggest difference between the ICP coordinates of the model and the field for the X coordinate, namely in CP 003 of 0.420 m, for the Y coordinates on the CP 011 of 0.317 m and for the Z coordinates of CP 013 at -0.469 m.

### 3.6 The following are the results of the calculation of horizontal accuracy / vertical ICP coordinate model

![Figure 5. Horizontal and vertical accuracy test graphs.](image)

From the results of the CE 90 and LE 90 tests on the model shown in the graph, show that accuracy with the smallest map scale is in sample 1 with results CE90 and LE90 in sample 1 amounted to 0.433 m and 0.479 m entered into a scale of 1: 2500 class 1. The control point of sample (1) was taken from the coordinates seen in the intensity image which produces the largest sigma naught which is 1.1 microns so that it affects the test results ICP carried out with CE 90 and LE 90 based on PERKA BIG No. 15 of 2014. While the results of the CE 90 and LE 90 tests with the largest map scale are in sample 2 with results of 0.314 m and 0.301 m entered on a 1: 2500 class scale 1. This sample uses a combination of coordinate points derived from geodetic GPS measurements and Intensity Image so that it produces a small RMSE and produces the smallest sigma naught which is 1.1 microns. From the graph the accuracy of orthophoto produced from the control points of the LiDAR Intensity Image can meet the requirements of a 2500 scale map.
4. Discussion and Conclusion
In a research in this study area it produced orthophoto a 1: 2500 scale using control points from LiDAR Intensity Image with area coverage Palangkaraya City, Central Kalimantan. The mapping area has an area of 15,000 hectares with a flying height of an average of 750 meters. The total photos obtained were 2,563 photos and processed using the algorithm BBA. From the horizontal and vertical accuracy test, the results of mapping aerial photographs at the location of the study obtained CE90 and LE90 results in sample 1 of 0.433 m and 0.479 m in class 1: 2500 scale. For sample 2, the smallest result is 0.314 m and 0.301 m, which means that the horizontal accuracy test accuracy of the map meets for a scale of 1: 2500 which is entered into class 1 order with a minimum accuracy of 0.5 m from sample 2 using control points from Premark Intensity + GCP GPS measurements.

5. References
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