Geometric Accuracy Assesment Of Orthorectification Method Based On Sensor Model Refinement In Open Source System Environment
(Case Study : Sangir Subdistrict, South Solok District, West Sumatra Province)

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Abstract. Orthorectification is one of the methods of correcting geometric condition of satellite imagery. Commonly used in high resolution satellite imagery such as IKONOS, Quickbird, and Pleiades, to reduces the effect of relief displacement. The Goal of this study is to implement the sensor model refinement procedures in orthorectification method. In this case we use orfeo toolbox (OTB) version 6.6.0 Installed in linux Mint 19. A true color Pleiades imagery of the area study in 2013, ACE2 DEM, and ground control points obtained by were used to obtain refined sensor model. This Study aimed to obtain the geometric accuracy of the output imager. The sensor model refinement process was done by access the imagery sensor model and changes its parameters using ground control points. The process of systematic orthorectification then carried out to transform the satellite imagery using modified sensor models. The geometric accuracy presented as horizontal accuracy were obtained by plotting several check points in the orthorectification output measured and calculated to obtain the horizontal accuracy. In this study we obtained that the sensor model refinement has an overall process accuracy of 1.664 meters. The model refined the imagery horizontal accuracy to 0.800 meters.

1. Introduction
Satellite imagery with spatial resolution smaller than approximately 1 meters such as Ikonos Quickbird, GeoEye, and Pleiades considered as Very High Resolution (VHR). These satellite imagery used in many applications such as base map production, Land registration, change analysis, and by its “finer” resolution, it may be used in modelling spatial phenomena with detailed characteristics such as hydrologic modelling[4]. Orthorectification is one of the methods for correcting geometric condition of a satellite imagery prior to further use[4]. There are two types of orthorectifications, systematic orthorectification where no GCP were used and using available sensor models, either Rigorous (RG) model or rational polynomial function (RPF), model and a DEM as External data[9]. Another, the rectification that taking GCPs coordinates into account where expected accuracy results were displayed, guiding the operator to correctly placed the GCP[3].

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In an orthorectification process, DEM represents the terrain condition. In some flat coastal areas\cite{1}, DEM were not required. Currently there are free DEMs such as ACE2, a combined SRTM with satellite radar altimetry\cite{8}. DEMs referenced to mean sea level (MSL) no longer relies to geometric relationship. As height difference should be vertical distance required by sensor model implementation. Thus, DEMs reference conversion from MSL to Ellipsoid are required prior to, or within the sensor model refinement stages.

The Goal of this study is to observe the sensor model refinement of an orthorectification process\cite{5}. Orfeo Toolbox (OTB) packages separate orthorectification process into sensor model refinement and (systematic) orthorectification process\cite{6}. The expected accuracy of placed GCPs were unknown since we use external application to collect pixel coordinates. Thus proper interpretation of GCPs placement are required to ensure geometric quality and become one of the major aspect of this research. As open source environment, we executed orthorectification in Linux Mint 19 Cinnamon as the operating system. We also observe some the processing sessions to collect aspects that may be useful for obtaining a good geometric output such as data condition, application features, and hardware usage, similar to the study of various orthorectification methods\cite{3}.

2. Study Area
The study area of this research located in Sangir Subdistrict, South Solok District, West Sumatra Province. This location have approximately 632,99 square kilometers with average Altitude of 453 meters since it lies in the south of Mt. Kerinci. And have 41,237 number of populations\cite{2}. Figure 1 shows the depiction of Sangir subdistrict where it lies in the border with Jambi province\cite{2}.

![Figure 1. Sangir Subdistrict Boundary, North to Mt. Kerinci and lies in the border of West Sumatra and Jambi Provinces. Source : Kecamatan Sangir In Figures 2017](image1)

3. Methodology
In this study, orthorectification are consists of preparations, GCPs collections and implementation in RPF Sensor Models refinement process. The final orthorectification process are systematic in terms no GCPs were used in the final steps. In order to obtain geometric accuracy, we use the Independent Check Points (ICPs) available in the area study. Both of GCPs and ICPs available from a total of 30 GPS surveying points. No spectral calibration process conducted since the imagery already in pan-sharpened state, results of post processing stages to any spectral processing.

![Figure 2. Monteverdi User Interface](image2)
For processing the data, a desktop PC with Intel i7-3770 with speed of 3.4 Ghz with four cores and 8 functional threads, and 16 GB DDR3. Primary software to orthorectification process are OTB version 6.6.0. via graphical user interface called mapla, and monteverdi (Figure 2), useful for displaying imagery and it’s histogram.

3.1. Preparations
The preparations of data started with image assembly where Pleiades imagery converted into OSSIM structures[6] as shown in Figure 2. We avoid global contrast stretching that may cause difficulties in imagery interpretation. The Sensor model of the imagery were stored in geom files, A single tile of ACE2 DEM With spatial resolution of 30 meters, that contain study area as shown in Figure 3, were downloaded. This local ACE2 have average height of with maximum elevation of 3774 meters and minimum elevation of 150 meters. We also prepare the EGM96 grid data to be used later in sensor refinement process to obtain ellipsoid referenced elevation.

3.2. GCPs Placement
We use QGIS 3.2.1. To plot the GCP on the satellite Imagery. GPS fields survey coordinates (x,y) in decimal degree were manually entered with fraction no less than 5 digits to match spatial resolution of the imagery pixels. In order to obtain a well interpreted locations, we preserve the imagery radiometric resolution in 16 bit that may cause some locations looks too bright or too dark. Conditional histogram stretching were used in terms of local contrast in QGIS where brightness are adjusted based on the current extent histogram rather than the entire images. Figure 4 shows the comparison of various image contrast in one location.

OSSIM georeferences were unreadable in QGIS. We perform an initial systematic orthorectification to guide GCPs placement. By using the list of GCP Observed coordinates, we create x,y plot and overlaid them to the image to obtain a rough locations of GCPs. Field Photos that have scenery orientation of The GPS were used to refine GCP locations. From this step, we obtained a distribution of 12 GCPs shown in Figure 5. Some of them listed in Table 1. Notice that the pixel coordinate columns are shown in negative number, as it origins started from upper left while the image pixel coordinates arrangement increased to maximum at the lower right.
### Table 1: Examples of Collected GCP

| Points   | row  | column | Longitude | Latitude  |
|----------|------|--------|-----------|-----------|
| GCP 5    | 20772| -6857  | 101.3070746| -1.5381736|
| GCP 7    | 14553| -8051  | 101.2784824| -1.544231381|
| G_ICP 12 | 4126 | -15351 | 101.2306653| -1.579112036|
| G_ICP 9  | 14996| -14386 | 101.2805192| -1.574076947|
| GCP 13   | 1371 | -16946 | 101.2180514| -1.586787769|
| GCP 14   | 6733 | -20313 | 101.2425404| -1.602589778|
| GCP 15   | 14249| -20975 | 101.2770069| -1.605367303|

Note that some of the GCP were ICP, since the accuracy of GPS survey were equal, the role changes of points are acceptable.

### 3.3. Orthorectification Procedures

After GCPs were collected and stored in text document, we use OTB’s refine sensor model tool to modify the coefficients of RPF models. The key to this process is the affine transformation to the models, as shown in equation (1), where $rpf_{r}(\lambda,\phi,h)$ and $rpf_{c}(\lambda,\phi,h)$ are the original RPF, while set of coefficients $a$ and $b$ are the six estimated affine transformation parameter [3]. In refining the sensor models, we use geom file that need to be refined, a GCP list to refine the sensor model, ACE2 DEM, and EGM96. The output of the process is another geom file that contain refined sensor model, while the achieved accuracies shown in Table 2.

$$r_{\text{refined}} = a_0 + a_1 \cdot rpf_{r}(\lambda,\phi,h) + a_2 \cdot rpf_{c}(\lambda,\phi,h)$$

$$c_{\text{refined}} = b_0 + b_1 \cdot rpf_{c}(\lambda,\phi,h) + b_2 \cdot rpf_{r}(\lambda,\phi,h)$$

source: Hoja, D., Schneider, M., Müller, R., Lehner, M., Reinartz, P., 2008

### Table 2: Estimation of refined Sensor Model final accuracy

| Accuracies             | Values (meters) |
|------------------------|-----------------|
| Overall Root Mean Square Error | 1.63432         |
| X Mean Error           | -0.00427        |
| X standard deviation   | 1.10246         |
| X Root Mean Square Error| 1.10247         |
| Y Mean Error           | 0.013312        |
| Y standard deviation   | 1.20639         |
| Y Root Mean Square Error| 1.20647         |

Next, we replace the original geom file with refined one in the OTB’s systematic orthorectification process, the Pleiades then corrected with the refined sensor model. We change the default RAM size which is 128 MB to 8096 MB (8GB) to improve performance. The orthorectifications process were
utilized most threads up to their maximum load as shown in Figure 6. Only thread 2 and 6 are fully. The output of rectification process are converted to UTM Zone 47 S in to be able to obtain geometric accuracies in metric units.

3.4. Accuracy Assessments
To obtain the geometric accuracy presented as horizontal accuracy in the form of horizontal Accuracy. As the Imagery geometric coordinate are now available, we can now use QGIS to locate ICP locations directly. From the ICP Placement, we obtain 11 Check points shown in Figure 7 where some of them are also points that planned to be GCP.

4. Results And Discussion
The topography of the area study are considered high since it is near the Mt. Kerinci with height range of 3672 meters. Thus relief displacement may occur and need to be corrected with DEMs. DEMS used in this study is referenced to MSL. There is no explicit undulation for the EGM 1996 so we let the OTB calculate the correct geometric height within the refinement process.

Not all GPS survey results were used since no identifiable placement after modifying the imagery contrast. Some points also have a vague photograph orientation where its properly oriented. The accuracy of refined sensor model are presented in standard deviation of 1.634 meters by using collected GCPs from its original 1.664 meters. From the ICPs collection stages, we obtain the RMSE of 0.800 meters as the geometric accuracy of Pleiades Imagery.

5. Conclusion
The orthorectification of Pleiades in an open source environment opens the possibility of obtaining high accuracy imagery in reduced cost since no licensed softwares. On the other hand, there still a little documentation available that explain the proper OTB’s functions such as creating GCP list in a correct structures to be correctly read by OTB’s sensor refinement process. The use of tab delimiter show correct reading, but the process of correctly delimit the GCP list still need to be observed.

Although the usage of ACE2 DEM resulting good accuracy, the availability of local DEM such As recently published DEMNAS opens the possibility of obtaining more accurate result for the Pleiades imagery. The availability of undulation of the EGM 2008 in DEMNAS made the change of DEMs elevation reference to ellipsoid prior the sensor model refinement possible.
The usage of CPU’s most thread indicates that OTB are optimized in multi-threaded system. Thus, increasing available thread may improve the process performance. Additional memory size, may improve the orthorectification process, however, change of default RAM size can only be done in the application compilation. Thus, knowledge of compiling the OTB is also required

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