Geometric Rectification Technique For High Resolution Satellite Data Imagery Using New Geocentric-Based Datum

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High Resolution Satellite Image, Geometric Correction, Geocentric Datum

ABSTRACT

Reference system is an important factor in order to verify and identify all measurement and data collection processes. The quality of the outputs is depending on how good a reference system is defined. The existing reference system is based on Rectified Skew Orthomorphic Projection (RSO), which is projected from Malayan Revised Triangulation (MRT) system. Many researches have been carried out to get a global coordinate system that suite with earth’s surface. A new datum also called geocentric datum, which is the origin referred to the origin of the earth, gives the best surface reference system for the entire world. In remote sensing applications, datum system (transformation) is important factor to gather spatial data for determination of coordinate location. By using the $\text{RSO}_{\text{geodetic}}$ datum and $\text{RSO}_{\text{geocentric}}$ datum as reference surfaces, geometry correction has been performed in terms to see the differences. The results shows that the average RMS errors is 0.2867 meter for north KL and 0.3306 meter for south KL from twelve check points that are measured. Then, the Z-test is carried out and the result shows that the errors of the checkpoints are accepted in 95 percent of confident level. From the comparison analyses between $\text{RSO}_{\text{geodetic}}$ and $\text{RSO}_{\text{geocentric}}$ coordinate datum, show that the coordinates changes happen as much as 194.0 meter to 195.0 meter.

INTRODUCTION

The development and onwards movement of the technology today has make the coordinates system been improved from time to time. Most of the coordinates systems in the world early are based on the surface that suite with the topographical surface that called geoids. But now a new datum called geocentric datum that referred to the origin of the earth, given the best surface reference system for the entire world. This is because geocentric datum capable to combine all the coordinate systems into a global coordinate system. Geocentric Datum of Australia (GDA) is one of the earliest that has been developed for local reference system and global reference system (Steed, 2000).

Datum is a surface that been used to descript the absolute and relative of the position of points on earth surface (Indiana Geographic Information Council (IGIC), 2001). This is including the framework in order to define the coordinate system based on the ellipsoid and its parameter such as semi-major (a) and flattening (f). Geocentric datum is suitable for local topography surface because all the measurement aspect for the coordinate point (x, y, z) can be more accurate. In year 2003, Department of Survey and Mapping Malaysia (JUPEM) has produced a new reference datum (geocentric) also called Geocentric Datum of Malaysia (GDM2000). The main objective to form the new datum is to get a more accurate control system and modern
positioning infrastructures with fully support from the Global Positioning System (GPS) activities.

Remote sensing data can fulfill all the application needed in terms of extracting information on earth surface such as land cover, detecting shoreline changes, forest mapping and lots more. Coordinate system is also important in remote sensing image processing (Richards, 1995). This is because all the remote sensing images need to registries in a specific coordinate system for more accurate and precious data measurement and collection.

All the raw remote sensing data, contain geometry effects that been produced by earth curve, atmospheric effects and panoramic effects. The main reason geometry correction been perform is to correct this effects so the image will be rectified in a proper way. Geometry correction is involving the changes of the original data for preprocessing by considering the position pixel and system parameter such as number of ground control points (GCP) and type of interpolation method (Jensen, 1996).

PROBLEM OF STATEMENT

The difference of the reference datum origin between RSO datum and geocentric datum will cause problem in satellite data and topography map data relationship. The accuracy of coordinate will change due to the datum that been used. Control point transformation with different reference will cause problem to the determining coordinate from satellite data and topography map data (Grant, 2000). This will be clearly effect the satellite image especially high-resolution image like IKONOS.

In datum transformation, the parameters changes for the system are complex because of the combination of several parameters in one function. Mathematical model and parameter such as semi major axis (a) and flattening (f) take important role of datum changes for each image correction. Without any model and appropriate parameters, integrating remote sensing image will be difficult.

The relationship between spatial data from satellite image and topography map in order to clarify the accuracy coordinates usually cause problem. Satellite image and topography map is hard to merge without any specific procedures because of the difference image resolution and map scale. “According to Wetch (1992), the topography relief effects still exist after the satellite image has been corrected.”

In processing spatial data for high-resolution satellite image, the processing run time will long. This is because of the number of pixel in the image is numerous and its influence the time. Extend from this, the transformation coordinate position will also be impact and there will be problem of clarify the control points.

OBJECTIVE
The main objectives for the study is:

i. Apply geometry correction technique for high resolution satellite data using new geocentric based datum.
ii. Perform data spatial accuracy comparison between the geodetic datum and geocentric datum.
iii. Perform final analysis image comparison based on RMSE value and statistical test for the rectified image on geocentric datum.

SCOPE OF STUDY

The scope of study that need to be fulfil is:

IKONOS satellite data with 1 meter and 4 meter resolution for the Klang Valley area has been used.
GPS Rapid Static method has been apply for ground control point’s observation.
For the RMSE ground control points network accuracy analysis, Z test been used in order to evaluate the analysis.

SIGNIFICANT OF STUDY

The important of the study is to evaluate the accuracy of the output data (result) that can be produce from the high-resolution satellite image rectification by using the new RSO geocentric datum compared to the existing RSO geodetic datum. This is important to evaluate which of the both datum giving the more accurate image rectification and the position of the points in the image. The result will conclude whether the new datum is capable of producing more accurate coordinate position through out the country.

Coordinate transformation can easily perform to the satellite image and topography map if JUPEM would like to use GDM2000 as reference datum. With this study, the effects of geocentric datum to the satellite image can be detected. The changes will show how much the different relief that happen to the satellite image compared to the topography map. This is important to view whether the satellite image is displacement exactly as same as the topography map. Beside that, with this study the procedure how to implement the geocentric datum to the satellite image can be identify. Actually, this will help in terms of knowing the geocentric datum implementation process. Each of processing steps can be carried out for the future needed.

The result of the study can become as the prototype rectified image for other satellite images. This will help to verify the GCP in order to improve the satellite image and the correlation in model order to gain the accuracy and precious of the data. With this, datum transformation is implement easily for determining the effectiveness of the new geocentric based datum in satellite image geometry correction.
Klang Valley has been choosing as the study area because of the compact area network that has been used as the main reference in the country. The relationships between the reference datum with the area lots network can be studied for the changes coordinates. Information regarding the boundary of the area needs to be identified for the national mapping. A total study in terms of determines the changes that will happen if the geocentric datum has been implemented need to been done. Figure 1, Figure 1a and Figure 1b shows the study area.

Figure 1: Study Area (Kuala Lumpur)

Figure 1a: North Kuala Lumpur

Figure 1b: South Kuala Lumpur

Figure 1: Study Area (Kuala Lumpur)

METHOD
At the beginning the high-resolution satellite image will be subset into the interest of study area only. This area is containing all the distribution of the control point that been collected by the GPS observation. The coordinate then been converted from WGS84 coordinate system into the geocentric coordinate system by transformation coordinate program. Then, the entire coordinate will be applied to the satellite image for image geometry correction processing. The Bi-linear interpolation with second-degree polynomial resampling method has been used. This is because Bi-linear interpolation can predict big control point network as same as real world (Richards, 1995). From the result, accuracy analysis will be evaluating the RMSE value and Z-test in order to clarify the accuracy of the image geometry correction. Figure 2 shows the there flowchart for this study. Table 1 shows the parameter that been used for geometry correction process.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Type/No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Resolution Satellite Image</td>
<td></td>
</tr>
<tr>
<td>Datum Parameter Changes</td>
<td></td>
</tr>
<tr>
<td>Datum Transformation</td>
<td>RSO – WGS84</td>
</tr>
<tr>
<td>Registration</td>
<td></td>
</tr>
<tr>
<td>Registration Image to Map</td>
<td></td>
</tr>
<tr>
<td>Processing</td>
<td></td>
</tr>
<tr>
<td>Resampling</td>
<td></td>
</tr>
<tr>
<td>Analysis</td>
<td></td>
</tr>
<tr>
<td>Accuracy Analysis</td>
<td></td>
</tr>
<tr>
<td>Accuracy Test</td>
<td></td>
</tr>
<tr>
<td>RMSE value</td>
<td></td>
</tr>
<tr>
<td>Z test</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2: Flowchart of study

Table 1: Geometry Correction Parameter
The rectification accuracy of scene for north KL is 0.30 pixels (x direction) and 0.28 pixels (y direction) and scene for south KL is 0.39 pixels (x direction) and 0.30 pixels (y direction) using all 53 GCPs based on new geocentric datum. Table 2 and 3 show the results of RMSE of GCPs and checkpoints. The accuracy is almost constant for the geocentric datum compared to geodetic datum. The RMSE value for geocentric datum is smaller than the RMSE value for geodetic datum. There is several factors that contribute for the result which is the different type of datum that been used, the data input quality for control points and placing the control points in the image.

**Table 2: RMSE of rectification for north KL**

<table>
<thead>
<tr>
<th>Datum</th>
<th>No. Of CPs</th>
<th>Ground Control Points</th>
<th>Check points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>RMSE</td>
<td>RMSE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X</td>
<td>Y</td>
</tr>
<tr>
<td>Geocentric</td>
<td>28</td>
<td>0.3038</td>
<td>0.2782</td>
</tr>
<tr>
<td>Geodetic</td>
<td>28</td>
<td>0.3678</td>
<td>0.2738</td>
</tr>
</tbody>
</table>

**Table 3: RMSE of rectification for south KL**

<table>
<thead>
<tr>
<th>Datum</th>
<th>No. Of CPs</th>
<th>Ground Control Points</th>
<th>Check points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>RMSE</td>
<td>RMSE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X</td>
<td>Y</td>
</tr>
<tr>
<td>Geocentric</td>
<td>28</td>
<td>0.3867</td>
<td>0.2020</td>
</tr>
<tr>
<td>Geodetic</td>
<td>28</td>
<td>0.4482</td>
<td>0.6133</td>
</tr>
</tbody>
</table>

**ACCURACY ANALYSIS**
Statistical Analysis

From the RMSE value results for geocentric datum, statistical analyses using the Z-test need to be carrying out in terms of evaluating the quality of the RMSE value. This is to ensure whether the RSME total value can be accepted or not for the observation points that been tested. Hypothesis Null has set up the RSME value for north KL is 0.2867 meter and for south KL is 0.3306 meter can be accepted if the Z value is lower than 1.96 in 95 percent of confident level. Based on the Z-test, the RMSE values for the both scene is accepted. This shows that the RMSE value for the image accuracy is valid. Table 4 shows the RMSE values for both scene and the result the Z-test value.

<table>
<thead>
<tr>
<th>Area</th>
<th>RMSE</th>
<th>Z-Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>North KL</td>
<td>0.2867</td>
<td>0.6399</td>
</tr>
<tr>
<td>South KL</td>
<td>0.3306</td>
<td>0.5423</td>
</tr>
</tbody>
</table>

RSO Geodetic and RSO Geocentric Coordinate Comparison Analysis

From the final result, there is a different between this two datum. The results shows that rectified image using RSO geocentric datum has been displacement as much as –5.703 meter (northing) and 194.927 meter (easting) for north KL meanwhile for south KL is –5.694 meter (northing) and 194.873 meter (easting) averagely. Table 5 shows the different of the both datum.

<table>
<thead>
<tr>
<th>Area</th>
<th>North KL (Geocentric Datum)</th>
<th>South KL (Geocentric Datum)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>∆E (m)</td>
<td>∆N (m)</td>
</tr>
<tr>
<td>Min</td>
<td>-5.7030</td>
<td>194.927</td>
</tr>
<tr>
<td>Maximum</td>
<td>-5.6593</td>
<td>194.962</td>
</tr>
<tr>
<td>Minimum</td>
<td>-5.7402</td>
<td>194.899</td>
</tr>
<tr>
<td>Total</td>
<td>-159.682</td>
<td>5457.960</td>
</tr>
</tbody>
</table>
The coordinates change has been shown in vector direction in Figure 3 and Figure 4. Totally, the coordinates change is uniform into one direction, which is the earth origin. Based on this, the geocentric datum will synchronize the coordinate into a specific origin so then the coordinates system can be used globally. Figure 5 shows the changes for the road line between both datum.
Figure 5: Vector Line Changes Between RSO Geodetic and RSO Geocentric

Figure 6: North KL Satellite Image Changes
Figure 7: South KL Satellite Image Changes

From the satellite image that has been overlaid between RSO geodetic datum and RSO geocentric datum shows that there is different between this both datum. Figure 6 and Figure 7 shows the result for the overlaid image that has been rectified for north KL and south KL. The displacement image is almost about 200.0 meter. The result is similar to the topography map that has been changed the projection into RSO geocentric (JUPEM, 2003). Clearly seen that the changes of the ear reference system will affected the coordinate system for the satellite image.

CONCLUSION

Briefly, the using of geocentric datum on high-resolution satellite image will effects the system of coordinates transformation. The changing reference system from Modified Everest
(Kertau 1948) to GRS80 will allows coordinates transformation take place easily. In future, a universal coordinate system can be produce for integrating the local coordinate system with international. The results for the geometry correction for north KL are 0.4120 pixels and for south KL is 0.4120 pixels based on geocentric datum. The coordinates changes from RSO geodetic to RSO geocentric are almost about 200.0 meter for each coordinate.

As a conclusion, the result from the analysis shows that it is possible to used the new reference system (RSO geocentric) due to replace the old datum (RSO geodetic). The effectiveness using the RSO geocentric datum on IKONOS satellite image is easy to combine with topography map if JUPEM going to implement the RSO geocentric datum as new national reference surface.

RECOMMENDATION

Further study can be done for geocentric datum by studying the 3D surface (height value). The 3D surface of geocentric datum can displayed the earth surface compared to geodetic datum and the changes of the datum can be evaluated. In fact, analysis between topography map and remote sensing image can also been done in terms of evaluating the changes. The clarify accuracy can be produced for satellite image compared to topography map which is both are based on geocentric datum. For advance study, geocentric datum can be applied to variety level of resolution images to see the differences and the effects of the multi resolution images. This because each image has it own resolution and accuracy analysis result due to the changes of the reference datum.

REFERENCE


