THE APPLICATION OF GEOEYE-1 STEREO PAIR IMAGES TO REGIONAL GRAVIMETRIC TERRAIN CORRECTIONS

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ABSTRACT

The accuracy of the gravity corrections is limited by the ability to survey the near-station topography. By now, regional gravity terrain corrections still rely on traditional high field survey, which is inefficient and expensive. In this paper, we explored an alternative way by using high resolution satellite stereo-photogrammetry for gravimetric terrain corrections. In the proposed approach, geoeye-1 stereo pair images with rational function model were used to obtain high precision and density digital terrain models near gravimetric points. Meanwhile, a differential equation was put forwards to compute the gravity terrain effect. Compared with field gravity surveying data, results illustrated that our model is effective for middle zone terrain correction, and has a good prospect for inner zone terrain correction.

Key words: Gravimetric Terrain Correction, Geoeye-1, Rational Polynomial Coefficient, Digital Elevation Model

Digital terrain models are widely available [4][5][6], but they may not be sampled finely enough for computing what are referred to as the near or inner zone terrain corrections in areas of topographic relief or where high-resolution gravity observations are required [7]. Therefore, for the last decades, various efforts such as global positioning systems (GPS) and reflectorless laser scanners have been applied into obtaining clouds of points DEMs for increasing gravity surveying efficiency [1].

With the development of earth observation, high resolution satellite imagery have been increasingly employed for large-scale topographic mapping, and especially for digital terrain models updating. As one of the World’s highest resolution commercial earth imaging satellites, GeoEye-1 has exhibited unsurpassed georeferencing accuracy [8][9]. Thus, in this paper, we explored the method of geoeye-1 stereo pair images surveying with rational function model for regional gravity terrain corrections, especial for high precision near zone.

1. INTRODUCTION

Bouguer gravity anomalies are ideal for geophysics because they show the effects of different rock densities in the subsurface, and play important roles for finding oil field basin, metallic deposits or caves in urban engineering studies. To obtain Bouguer anomaly it is necessary to apply a terrain correction. This processing step is a critical concern in rugged topography, because the magnitude of the corrections may be large with respect to the anomalies of interest [1].

In general, the accuracy of the anomalies is limited by the ability to estimate the near zone topography. For example, elevation variations of as little as two feet located less than 55 ft from the observing station can produce Terrain Corrections as large as 0.04 mGals [2][3]. For a very rough topography the classical field survey method suffers from the disadvantage that it is very expensive, but it is still frequently adopted in the regional gravity surveying routines.

2. THE PROPOSED METHOD

Our main process can be summarized in three parts: data preparation, digital elevation model extracted from GeoEye-1 and gravity terrain correction.

2.1 Data Preparation

Firstly, a test field was set up in the north of Changping County for gravity corrections by using classical topographic surveying, geoeye-1 stereo pair images surveying, laser scanners and so on. The study area is located in between the latitude 40°15’-40°25’ and longitude 116°10’ and 116°15’, and includes two parts: the northern valleys and the southern plains.

The geoeye-1 Basic stereo images were collected on January 9th, 2011. And we collected 9 ground control points by using differential GPS for absolute orientation of photogrammetry. By the way, for difficult to receive GPS
signs in the gorge between precipices with elevation ranging from 220 to 530 meters, we only obtain two check points in the northern part.

### 2.2 DEM Extraction from GeoEye-1 Stereo Images

Rational functions models (RFM) provide an opportunity for photogrammetric processing for high resolution stereo pairs. A sensor model relates 3D object point positions to their corresponding image positions through the collinearity condition equations. The RFM relates object space coordinates to the image space coordinates. The image pixel coordinates are expressed as ratios of third order polynomials of ground coordinates. In the study, we applied a standard methodology for the generation of DEMs by Rational Polynomial Coefficients (RPCs) with ground control points (figure 1).

Due to rugged terrain, local image enhancement has to be applied to reduce the effect of mountain shadow. And 74 tie points were selected by human-machine interaction for comparing the similarity of left and right images and generating epipolar images.

The terrain correction calculates the irregularities of the surface around the station. For high precious Bouguer anomalies, digital terrain models near gravimetric points in the near zone with distance from 0 to 20 meters, and in the middle zone from 20 to 500 meters were automatically extracted with resolution of 0.5 meter, respectively (figure 2).

$$\Delta g_n = f \sigma \int \int \int \frac{z}{(x^2+y^2+z^2)^2} \, dx \, dy \, dz$$

(1)

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(a) The DEM derived from Geoeye–1 image in the south part.

(b) The DEM derived from Geoeye –1 image in the north part.

Figure 2: The DEM extracted from proposed method for the test field.

### 2.3 Gravity Terrain Correction

The calculation of terrain correction is one of the central issues in physical geodesy, and one of the most time-consuming operations in gravity field modeling as well. There are some models such as tesseroid, prism and point-mass approaches for mass reductions have been put forward for terrain corrections \(^3\).

The normal computation of the gravity effect has been done by numerical integration. In this paper, the gravity effect \(\Delta g_n\) due to zonal compartments is represented as a triple integral on homogeneous volume elements, where each data point in the digital terrain models represents a solid vertical rectangular prism of finite size.
where \( \sigma \) is the density and \( f \) is gravitational constant. Applying the fubini's theorem to triple integral, we can reduce the above triple integrals to double integrals:

\[
\Delta g_n = f \sigma \int \int \left( 1 - \frac{\sqrt{x^2 + y^2}}{\sqrt{x^2 + y^2 + h^2}} \right) \frac{1}{(x^2 + y^2)^{1/2}} dx
\]

At last, the differential equation for gravity terrain effect for digital terrain models is computed as follows:

\[
\Delta g_n = f \sigma \Delta y \Delta x \sum_{i=1}^{n} \sum_{j=1}^{m} C_{ij} \left( \frac{1}{r_{ij}} - \frac{1}{\sqrt{r_{ij}^2 - h_{ij}^2}} \right)
\]

where \( \Delta x, \Delta y \) are the interval along \( x \) and \( y \)-axis, respectively. The \( r_{ij} \) is the distance from the point\((i,j)\) to the center, and \( h_{ij} \) is the difference between point\((i,j)\) and the center. \( C_{ij} \) is coefficient of point\((i,j)\).

3. RESULT ANALYSIS

At first, we analyzed the planimetric and elevation accuracies of the DEM extracted from GeoEye-1 stereo data. After comparing with 62 check points in the study area provided by Development Research Center of Geological Survey, RMS errors of georeference accuracy are computed and shown in Table 1.

<table>
<thead>
<tr>
<th>Number of checkpoints</th>
<th>RMSE Easting (m)</th>
<th>RMSE Northing (m)</th>
<th>RMSE Height (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>62</td>
<td>0.736</td>
<td>0.819</td>
<td>0.846</td>
</tr>
</tbody>
</table>

Meanwhile, in order to test the precision of our method, 23 gravity surveying points were used to assess terrain corrections accuracy with classical field surveying by Development Research Center of Geological Survey. In the near zone from 0 to 20 meters, there are 8 check points which error rate are more than 10%.

Obviously, main errors come from seriously interfere by vegetation near gravity surveying point. Brush, high grass, trees and builds near the gravity surveying point have a significant effect on terrain correction accuracy, for it is very difficult to automatically delineate vegetation crowns and reduce vertical elevation shifts in the satellite photogrammetry. The influence of topography is greatest close to the station and this influence decreases with distance from the station.

In the middle zone from 20 to 500 meters, error rate of all are less than 8.3%, for with distance away from the survey point, the effect of vegetation will decrease.

4. CONCLUSIONS

In this paper, we developed a new application of Geoeye-1 stereo surveying for high precision gravimetric terrain corrections. The results show that our model is effective for middle zone terrain correction, meanwhile suitable for inner zone terrain correction in the bare land. This method has been used as an important alternative to regional gravity terrain corrections for geological survey in China.

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REFERENCES


