Evaluation of the Geopositioning Accuracy of QuickBird Imagery

Xutong Niu, Jue Wang, Kaichang Di, Jin-Duk Lee, Ron Li
Mapping and GIS Laboratory, The Ohio State University
Email: li.282@osu.edu

QuickBird satellite imagery, provided by DigitalGlobe Inc., has the highest resolution, among the satellite imaging systems that are commercially available. The QuickBird imaging system simultaneously collects 67-72 centimeter resolution stereo panchromatic and 2.44-2.88 meter resolution multispectral images. In this research, a QuickBird stereo pair of basic imagery product that was taken over Tampa Bay, FL, was acquired and its geopositioning accuracy evaluated based on Rational Function (RF) models.

Rational Functions (RFs) are described in detail in Tao and Hu (2001) and Grodecki and Dial (2003). RFs perform a transformation between an image point (i, j) and its point in the object space (X, Y, Z) through a ratio of two third-order polynomials. The ground coordinates derived from such Rational Function Coordinates (RFCs) typically have an accuracy of about 14 meters, which is that of DigitalGlobe's basic imagery product. If quality ground control points (GCPs) are available, there is the potential of using them for enhancing ground accuracy through an image or ground based adjustment (Di et al. 2003a).

The GCPs and check points (CKPs) used in this experiment were obtained from GPS surveying conducted in Tampa Bay, FL, in November 2002. There are totally seven GPS points. CKPs are those GPS points not used for estimating the transformation parameters in the adjustment. Image coordinates of these GPS points were measured manually. Ground coordinates were calculated using the RFCs supplied with the data. After registering both sets of ground coordinates (GPS-surveyed and RF-derived) within the same reference system (State Plane, NAD83, Florida West), the differences between both coordinate sets were calculated. Errors observed are systematic and exist mainly in the north-east direction. The maximum distance between the GPS-surveyed and RF-derived coordinates for the control points was 12.86 meters.

There are two main methods for improvement of the accuracy of RF ground coordinates (Di et al., 2003a; Li et al., 2003). The first method is to refine the RF coefficients based on a large number of GCPs. The second approach refines the ground coordinates calculated from the RFs using a polynomial correction in either image space or object space. The second method requires significantly fewer GCPs than the first approach. A number of publications have reported on results of this approach (with some variation), including Grodecki and Dial (2003) and Di et al. (2003b).

In this research, the second method is applied. Four improvement models (translation, scale-and-translation, affine, and second-order polynomial) are used in both object space and image space. In both object and image spaces, the translation model adds a translation to the ground coordinates computed from the RFCs to achieve improved ground coordinates. The scale-and-translation model uses three additional scale factors to correct inhomogeneous scale distortions. Affine transformation and second-order polynomial transformation are also applied. Using all available GCPs (usually more than the minimum number required in the models), over-determined equation systems can be set up to compute the optimal estimates of the transformation parameters by a least-squares adjustment. The transformation parameters can then be used to compute improved coordinates for other points. In order to assess the appropriateness of the models, CKPs are used. The root-mean-square error (RMSE) of each model is calculated based on differences between calculated and known coordinates of the CKPs.

All four methods were conducted in image space. The translation model offers a simple way to improve accuracy, with RMSEs less than 1 m in the horizontal direction and 1.2 m in the vertical direction. The level of accuracy has no apparent relationship with the location of the GCPs used. The scale-and-

translation model has additional scaling factors in the coordinate axis directions. Two GCPs are necessary for this model. In both object and image spaces, the RMSEs calculated show similar results of less than 71 cm in the horizontal direction and 65 cm in the vertical direction. The affine model offers the capability of considering affinity. In object space, the additional affine parameters and GCPs do not generate any improvement over the result of the scale-and-translation model. But in image space, a comparable result is obtained by using six GCPs (less than 90 cm in the horizontal and 52 cm in the vertical). Because the second-order polynomial model in object space requires at least ten GCPs, this model is only applied to image space. In image space, using six GCPs, the obtained result from the second-order polynomial model is not significantly improved compared with the other three methods. Higher-order polynomials are generally very sensitive, requiring both a large number of GCPs and good GCP distribution. Their use does not exhibit convincing advantages over other methods.

It is important to note that this experiment is not focused on high-precision subpixel object identification using QuickBird images, in which special image features (for example circles, sharp corners of large structures, and symmetric man-made objects) can be mathematically modeled and determined. The objects chosen in this study are general image features such as road intersections, building corners, and other objects distinguished in the coastal area. The precision of the image point measurement is about one-half to one pixel. The accuracy thus achieved can be repeated without any additional requirements.

In general, there are no significant differences in results from using these models in either object or image space, although the affine and second-order polynomial models in image space require fewer GCPs. The scale-and-translation model and the affine model seem to be most practical in application, as four to six well-distributed GCPs can be used to achieve improved accuracy (to about 90 cm in the horizontal and 65 m in the vertical). Thus their use is recommended for accuracy improvement.

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