Mapping of QuickBird Images Using the RPC Method

Improvement in Accuracy Since Release of First QuickBird Data

DigitalGlobe’s QuickBird satellite and the availability of these data, QuickBird imagery has become a popular choice for large-scale mapping using high-resolution satellites. This article is about the geometrical correction of QuickBird images. Two blocks of QuickBird images are used and the accuracy of geometric correction using the RPC method is examined.

Introduction

The QuickBird satellite has panchromatic and multispectral sensors with resolutions of 61-72cm and 2.44-2.88m, respectively, depending upon the off-nadir viewing angle (0-25 degrees). The sensor therefore has a coverage of 16.5-19km in the across-track direction. In addition, the along-track and across-track capabilities provide stereo geometry and a revisit frequency of 1-3.5 days. Finally, the data is available in different formats, including the raw data format (Basic Imagery), which preserves the satellite geometry and is preferred by the photogrammetry and mapping community to achieve high accuracy geometric correction and geospatial products.

Correcting QuickBird Images

In order to leverage the QuickBird images for applications such as GIS it is necessary to correct the images geometrically. Two methods can be used: the rigorous method and the rational polynomial coefficient (RPC) method (http://www.pciglobe.com/newswm_quickbird_2003.pdf). Over the past few years, the RPC method of correcting high resolution images has become more popular, mainly because it requires a small number of ground control points (GCPs), and in some cases, no GCPs at all. However, the accuracy of geometric correction using the RPC method for QuickBird images is still unknown to many users, especially when the method is applied to a large block of images.

The RPC method uses an empirical/statistical model developed by DigitalGlobe, which approximates the 3D physical sensor model of QuickBird. Occasionally used during the 1980s, this method received a great deal of renewed attention with the launch of Space Imaging’s IKONOS satellite, because its sensor and orbit parameters are not included in the image metadata. The RPC method could be a useful method to avoid the development of 3D physical models because it enables users, having little familiarity with the QuickBird sensor, to perform a geometric correction without GCPs. Only a digital elevation model (DEM) is required. Since biases or errors still exist after applying the RPCs, the results can be post-processed with a translation and several precise GCPs. Alternatively, the original RPC parameters can be refined with linear equations and RPC parameters. Several recent articles and papers addressing IKONOS data showed good results by using RPCs together with a few GCPs to apply a complementary first order polynomial adjustment to the data.

The accuracy improves after several refinements applied by the satellite data vendors. This is true for QuickBird images—the accuracy of their RPC data has significantly improved recently.

OrthoEngine Software

The latest version of PCI Geomatics’ OrthoEngine software was used for this testing. This software supports reading of the data, manual or automatic GCP (tie point) collection, geometric modeling of different satellites using Toutin’s rigorous model or the RPC method, automatic DEM generation and editing, ortho rectification, and either manual or automatic mosaicking. OrthoEngine’s RPC method is based on the...
block adjustment method developed by Grodecki and Dial and was certified by Space Imaging (http://www.pcigeomatics.com/support_center/tech_papers/rfcpci_cert.pdf). The method computes the polynomial adjustment math model, see below, for each image. Where $A_0, A_s, A_L, A_{SL} \ldots$ and $B_0, B_s, B_L, B_{SL} \ldots$ are the image adjustment parameters, Line and Sample are the line and sample coordinates of an image, and $\Delta P$ and $\Delta R$ are the adjustable functions expressing the differences between the measured and the nominal line and sample coordinates. For IKONOS images a zero order polynomial adjustment ($A_0$ and $B_0$) is adequate for most cases. For QuickBird images a first order polynomial adjustment is required to achieve the best results. The OrthoEngine software supports both zero and first order RPC polynomial adjustments.

Although the RPC method only requires a small number of GCPs and TPs, high accuracy may not be achieved if the GCPs are not well distributed within the block. To improve the accuracy, a DEM is used. During each bundle adjustment iteration, the computed elevation of each tie point can be replaced by the elevation at the computed TP X and Y coordinates from the DEM, similar to the results of changing the planimetric TPs into altimetric points. This method also helps to improve the relative accuracies between the ortho images, which helps to minimize differences during the mosaicking process. This option is available inside the OrthoEngine software.

Table 1 shows a summary of the results. In the first case, all the points were used as independent check points (ICPs). The ICPs have a root mean square (RMS) error of 6.1m in X and 11.9m in Y. These results are much better than the results when the first QuickBird image was released (2002), where the average error was about 65m in X and 12.5m in Y for the Basic product (http://www.eomonline.com/Current/products/Apron/eng.html). In the second case, all the points were used as GCPs. The RMS residuals were 0.7m in X and 1.7m in Y. In the third case, all the surveyed check points were used as ICPs. A total number of 6 ICPs were identified from all the images. The GCP RMS residuals did not change significantly but the ICP RMS errors were about 1.7m in X and 2.5m in Y. To meet the 1:4800 National Map Accuracy Standard (NMAS), the RMS error should be within 1.9m. The ICP RMS error is slightly above the minimum requirement in the Y direction in this case.

First Block Results

The first block consists of seven QuickBird Basic 3B panchromatic images. It is located in the Colorado Front Range, Denver, CO. The total coverage is about 40km by 42km, with an elevation range of 1500m to 2500m. 8 surveyed control points and 5 surveyed check points were available. A total number of 22 control points and 46 TPs were collected at ground level on all the images due to the overlap coverage. A USGS 7.5-minute DEM (grid spacing at 30 meters) was used during the bundle adjustment iteration to improve the accuracy of the model.

Time Consuming Process

Mosaicking and color balancing of the orthorectified images are extremely time consuming processes. The OrthoEngine automatic cutline searching, mosaicking and color balance tools were used to process these images. Figures 2a and 2b show a mosaicked panchromatic image (9 Gigabytes) without color balance and with color balance, respectively. No human intervention was required during the process. Similarly, figures 3a and 3b show a mosaicked multispectral image.
The accuracy of geometric correction using the RPC method for QuickBird images is still unknown to many users, especially when the method is applied to a large block of images.

(3 Gigabytes) without color balance and with color balance, respectively.
The combination of the 61cm panchromatic and 2.44m multispectral images provides the opportunity to create an effective 61cm pan-sharpened image by using a fusion technique developed by Dr. Yun Zhang at the University of New Brunswick, New Brunswick, Canada (http://www.pcigeomatics.com/press-news/2003pansharp.html). This technique solves the two major problems in image fusion – color distortion and operator dependency. A method based on least squares was employed for a best approximation of the grey level value relationship between the original multispectral, panchromatic, and fused image bands for a best color representation. Statistical approaches were applied to the fusion for standardizing and automating the fusion process. Figures 3a, 3b and 3c show full resolution examples of panchromatic, multispectral, and pan-sharpened images of the same area, respectively.

Second Block Results

The second block consists of six QuickBird Basic 1B panchromatic images. It is located in Brasília, Brazil. The block has a coverage of about 41km by 39km. 6 surveyed control points and 3 surveyed check points were available. A total of 15 control points were collected from all the images. In addition, 110 TPs were collected automatically and 15 TPs were collected manually using the OrthoEngine software. All TPs were collected at the ground level, so that they can be used together with the SRIT 90m DEM provided during the bundle adjustment iteration. Table 2 shows a summary of the results. In the first case, all the points were used as ICPs. The ICPs have RMS errors of 23.2m in X and 5.8m in Y. In the second case, all the points were used as GCPs. The RMS residuals were 1.7m in X and 1.6m in Y. In the third case, all the surveyed check points were used as ICPs. A total number of 6 ICPs were collected from all images. The GCP RMS residuals were 2.1m in X and 2.0m in Y, and the ICP RMS errors were 1.3m in X and 1.0m in Y. The ICP RMS errors are within the NMAS 1:4800 accuracy requirement.

The results were mosaicked together using the OrthoEngine software. Figures 4a and 4b show the mosaicked results of the panchromatic and multispectral images using automatic mosaicking and color balance, respectively.

Conclusions

The two examples show that it is now possible to correct a QuickBird Basic 1B image block using the RPC method in PCI Geomatics’ OrthoEngine with accuracy close to the NMAS 1:4800 requirement. The accuracy of the QuickBird’s RPC has significantly improved since the release of the first QuickBird data in 2002. It is also possible to mosaic the image block automatically using OrthoEngine’s automatic mosaicking and color balance tools.

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<table>
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Table 2: Comparison of RMS results in meter for different number of GCPs and ICPs of the second QuickBird image block.