QuickBird – Geometric Correction, Data Fusion, and Automatic DEM Extraction

Philip Cheng
PCI Geomatics
50 West Wilmot St
Richmond Hill, Ont
Canada L4B 1X3
cheng@pcigeomatics.com

Thierry Toutin
Canada Centre for Remote Sensing
588 Booth St
Ottawa, Ont
Canada K1A 0Y7
thierry.toutin@ccrs.nrcan.gc.ca

Yun Zhang
University of New Brunswick
Dept. of Geomatics Engineering
Fredericton, NB
Canada E3B 5A3
yunzhang@unb.ca

Abstract: QuickBird satellite is quickly becoming the best choice for high-resolution mapping using satellite images. In this paper, we will describe the followings: (1) how to correct QuickBird data using different geometric correction methods, (2) data fusion using QuickBird panchromatic and multispectral data, and (3) automatic DEM extraction using QuickBird stereo data.

Keywords: QuickBird, Geometric Correction, DEM, data fusion,

1. Introduction

Since the successful launch of DigitalGlobe's QuickBird satellite and the availability of the data, QuickBird Imagery has quickly become a popular choice for large-scale mapping using high-resolution satellites. First, the 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 a good stereo geometry and a high 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.

In this paper, we will describe the followings: (1) how to correct QuickBird data using different geometric correction methods, (2) data fusion using QuickBird panchromatic and multispectral data, and (3) automatic DEM extraction using QuickBird stereo data.

2. Geometric Correction

Several 3D geometric correction methods can be used to correct the data, i.e. (1) the 3D rational polynomial function computed from the user's GCPs, (2) the 3D rational polynomial function supplied with the data, and (3) the 3D rigorous (physical) method.

The first method is to compute the unknowns of a rational polynomial function using GCPs. Results published by Toutin and Cheng [1] showed that this method is not stable enough in operational environments and hence not recommended. The accuracy depends on the number, location, and accuracy of GCPs. More details can be found in [1].

The second method provides an empirical non-physical model, which is an approximation of a 3D rigorous physical model, without releasing satellite-sensor information. This method has been getting a lot of attention recently due to the release of the IKONOS satellite, which only provides the rational polynomial function without releasing the satellite information. The method was initially designed to provide images to the user for performing their own geometric correction without GCPs, but with a DEM. Although this method does not have a very high degree of accuracy, it is still useful for areas when GCPs are unavailable. Recently, Space Imaging proposed a Block Adjustment method [2] to improve the accuracy by using GCPs. By collecting a few GCPs, a complementary polynomial adjustment (first or second order) is then computed to improve the final positioning accuracy. Several papers and articles claiming high accuracy results were published using this method together with GCPs and the IKONOS data. Some even suggested that the Block Adjustment Model with rational functions could be used to approximate the rigorous method.

The third method is the traditional approach to image geometry mathematical models, which separately model most of the physical elements of the image sensor and its environment. Such an image geometry model is often called a 3D "rigorous" or "physical" model. It has always been considered as the best method to correct image data, especially raw image data without any geometric correction, because it fully reflects the geometry of viewing. In fact, this method has the advantage of a high modeling accuracy (approximately one pixel or better), a great robustness in operational enviroments, and consistent results over the full image, with only a few GCPs.

In order to compare the results using different geometric correction methods, a stereo pair of along-track QuickBird Basic imagery of Spokane, WA, U.S.A. was used. The images have in-track viewing angles of –27.24 and 26.35 degrees, respectively. Since 1st method is not a stable method, only 2nd and 3rd methods were used for the comparisons. The PCI OrthoEngine software, developed by PCI Geomatics, was used. It supports the use of RPC model and a rigorous model developed by Dr. Thierry Toutin at Canada Centre for Remote Sensing and adapted to high resolution data [1,3,4,5]. Based upon well-defined and good quality GCPs, the accuracy of the Toutin's model was proven to be within one-third of a pixel for medium resolution VIR images, one pixel or better for HR images, and within one resolution cell for SAR images.

Seven DGPS stereo ground control points (GCPs) and twenty-nine stereo independent check points (ICPs) were collected from the images. Table 1 and 2 show a comparison of results of the fore and aft looking images, respectively. For the RPC method the errors are consistent regardless of the number of GCPs used. However, these RMS/maximum errors are about 2 to 5 times higher than the RMS/maximum errors from the rigorous model. The finding of this comparison clearly indicates that the rigorous model should be employed as a primary choice. The RPCs model is still a viable alternative when the accuracy requirement is not a high priority or when the number of GCPs is very limited.

3. Data Fusion

Table 1. Comparison of the fore-looking results using rigorous and RPC models. All units are in metres.

Model	No. of GCPs	No. of ICPs	ICP RMS		Max Error	
			X	Y	X	Y
Rigorous	7	29	0.8	0.7	1.5	1.4
RPCs	7	29	1.2	0.8	2.2	1.5
	6	30	1.2	0.7	2.6	2.3
	5	31	1.6	0.8	4.0	1.5
	4	32	1.5	0.8	3.8	1.6
	3	33	1.3	0.7	3.4	1.3
	2	34	1.4	0.9	2.6	1.9
	1	35	1.9	2.0	3.2	3.2
	0	36	8.4	13.0	10.2	14.3

Table 2. Comparison of the aft-looking results using rigorous and RPC models. All units are in metres.

Model	No. of GCPs	No. of ICPs	ICP RMS		Max Error	
			X	Y	X	Y
Rigorous	7	29	0.8	0.8	1.2	1.5
RPCs	7	29	2.1	0.9	5.6	2.2
	6	30	2.1	0.9	5.7	1.8
	5	31	2.5	0.9	6.6	2.4
	4	32	2.4	0.9	6.4	1.6
	3	33	2.2	1.0	5.8	2.5
	2	34	2.7	1.7	5.3	3.4
	1	35	2.5	1.2	6.3	2.7
	0	36	2.4	3.8	6.1	5.8

The availability of a 0.6m panchromatic band, in conjunction with 2.4m VIR bands, affords the opportunity to fuse panchromatic and VIR data to create an effective 0.6m VIR pan-sharpened image. Image fusion is an important technique for a variety of remote sensing applications. Most earth resource satellites, such as the SPOT, IRS, Landsat 7, IKONOS, QuickBird and Orbview provide both multispectral images at a lower spatial resolution and panchromatic images at a higher spatial resolution. However, existing techniques can hardly satisfy the fusion of multispectral and panchromatic images from the new satellites such as IKONOS, QuickBird, and Landsat 7 and Orbview.

Based on thorough studies and analyses of existing fusion algorithms and their fusion effects, a new automatic fusion approach has been developed by the Dr. Yun Zhang [6] at the University of New Brunswick, Canada. This new technique solved the two major problems in image fusion – colour distortion and operator dependency. A method based on least squares was employed for a best approximation of the grey value relationship between the original multispectral, panchromatic and the fused image bands for a best colour representation. Statistic approaches were applied to the fusion for standardizing and automating the fusion process.

The new fusion approach has been extensively applied to the fusion of different IKONOS, QuickBird and Landsat 7 multispectral and panchromatic image bands. All the multispectral bands of a satellite can be fused with the corresponding panchromatic band at one time, resulting in optimal fusion result with minimized colour distortion, maximized feature detail, and natural integration of colour and spatial feature from multispectral and panchromatic bands. The algorithm is now included in the PCI Geomatics software.

To demonstrate the fusion technique, small sub-scenes were extracted from the QuickBird images. Figure 1 show the original panchromatic, multispectral and the pan-sharpened fused images of a residential area. It can be seen from the fused image all features, such as roofs, driveways, from the original panchromatic image were extracted together with the color from the multispectral image.

4. Automatic DEM Extraction

It is possible to extract DEM automatically from the stereo pair. PCI OrthoEngine software was used to extract the DEM automatically. The DEM generation includes quasi-epipolar image generation, image matching and filtering, and geocoding. In comparing the extracted DEM with the 29 ICP elevations, the maximum difference was 2.2m. In addition, the extracted DEM was also compared with an USGS 7.5-min DEM (grid spacing at 30m) obtained from the USGS. Most of the USGS 7.5-min DEMs have a RMS error of 7.5m. The accuracy of this USGS DEM was not available during the study. A total of 330000 elevation points were used to compare the results. Table 3 shows a summary of the differences between the USGS DEM and the stereo-extracted QuickBird DEM. In general the USGS DEM has an accuracy of ±10m, a large part of the USGS DEM error is included in Table 3 results. The internal accuracy of the stereo-extracted QuickBird DEM should be much better (1-2 resolution).

Table 3. Differences between USGS DEM and the stereo-extracted QuickBird DEM

Within 5m	Within 10m	Mean Diff	Max Diff	Standard Deviation
77%	95%	2.4m	45m	5.8m

5. Conclusions

To achieve high geometric accuracy, the QuickBird Basic Imagery together with the Toutin's rigorous model can be used effectively. If high accuracy is not a high priority, or if the number of GCPs is limited, the RPCs method can be a useful alternative choice.

If both panchromatic and multispectral images are available, the fusion of panchromatic and multispectral images can be performed using a new fusion technique developed by Dr. Zhang at the University of New Brunswick, Canada. The resulting fused image displays sharp features from the panchromatic image while preserving the colour from the multispectral image.

DEM can also be extracted from the QuickBird stereo images. Ninety-five percent of the extracted data were within 10m differences when comparing with the USGS DEM using a QuickBird stereo pair.

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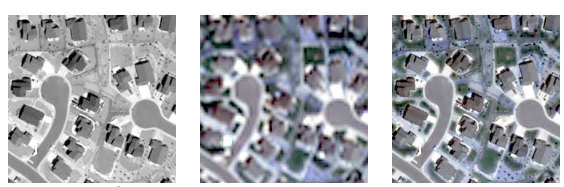

Figure 1: QuickBird panrhcomatic, multispectral and pan-sharpened images.