Image-to-Image Registration Quality Assessment of IKONOS / QuickBird Imagery using Aerial Orthoimagery

D.S. Lee, M. Coan, Science Applications International Corporation/USGS EROS Data Center

Abstract

An Image-to-Image registration assessment was conducted on IKONOS Precision Master imagery and QuickBird Standard imagery of Sioux Falls, South Dakota. Independent confirmation of vendor accuracy specifications is essential for instilling customer confidence in the product for potential applications. In our case, the application in mind is providing ground control and reference imagery for geometric characterization and calibration of Landsats 5 and 7, as well as future satellite missions. In particular, we are interested in obtaining international ground control points (GCP) at least as accurate as the GCPs in our CONUS library, which are predominantly DOQ control points accurate to ~12-meters CE90 or better. Availability of control with that level of accuracy has been difficult to obtain overseas. Therefore, the primary goal of the study was to measure registration quality of the vendor's products against an orthophoto mosaic, acquired by a local aerial surveying company, and having a horizontal accuracy of ~1 ft. (0.3 meters) at its original 0.5 ft. resolution. The imagery was purchased by the city of Sioux Falls for their engineering GIS and provided to us for the purpose of this study. The Landsat 7 Image Assessment System (IAS) image-to-image characterization software was used to measure image offsets and compute error statistics. The software was developed by the USGS, and although general-purpose in nature, its traditional role is image-to-image characterization of Landsat 7's 15-meter panchromatic band. Thus, a secondary goal of the project was to evaluate the viability of using the IAS to characterize the higher spatial resolutions of the IKONOS and QuickBird panchromatic products (1-meter and 0.6-meter resolution, respectively). The IAS software uses an area-based matching algorithm based on normalized cross-correlation and correlation surface-fitting to obtain the sub-pixel location of the peak. Requirements dictate the software to be capable of correlating common features in the same bands of separate Landsat 7 images to an accuracy of 0.1 pixel at the 90% probability level. To verify the results based on this automated technique, tie-points were also selected manually and statistics based on the IAS automated matching method were compared with statistics based on the manual method.

Procedure

For visual comparison, samples of imagery taken from the city's orthomosaic, IKONOS, and QuickBird data sets are shown in Figure 1. Specifications for the three data sets are listed in Table 1. Native resolution of the orthomosaic was 0.5 ft. The city downsampled the imagery for its own use and provided us with an image at 2.0 ft resolution. IKONOS and QuickBird imagery were provided through the NASA Scientific Data Purchase Program and the Joint Agency Commercial Imagery Evaluation (JACIE) program, respectively. The first step in comparing the imagery was to resample the 2-ft. orthomosaic to resolutions matching the IKONOS and QuickBird data sets, namely, 1-meter and 0.6-meter, respectively. The 11-bit dynamic range of the satellite data sets were then rescaled to 8-bit resolution to match the orthomosaic. Each file was converted to Hierarchical Data Format (HDF) for compatibility with the IAS. A total of 86 control points were manually selected from the city's orthomosaic. The IAS optionally allows automatic selection of a regular grid of control points. Although RMSEs based on an automatically generated control point grid differed by less than a pixel compared to the hand-picked control points, the grid positioned several points on rooftops, trees, or in uniform areas with no distinctive markings. For these reasons, results based on the hand-picked control points were judged more reliable and, therefore, are the results reported in this study. Given the set of control points, the IAS was used to automatically search for matching points in the IKONOS and QuickBird imagery, and to compute the registration statistics. After eliminating outliers based on a 95% probability threshold, 24 GCPs were correlated on the IKONOS image and 31 GCPs were correlated on the QuickBird image. Figure 2 shows examples of tie-points accepted, as well as rejected, by the IAS software. Based on a visual inspection of the correlated points, a template window size of 128x128 was found to be optimal for the QuickBird data, while a 64x64 window size worked best for IKONOS. Results based on automated tie-point selection using the IAS are listed in Table 2, while for comparison, registration results based on manual tie-point selection are listed in Table 3.

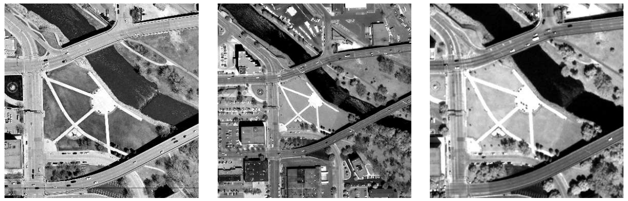

Figure 1. From left to right, samples of imagery from Orthophoto Mosaic, IKONOS, and QuickBird data sets used in the study. Orthomosaic and QuickBird are displayed at 0.6-meter resolution, while IKONOS is displayed at 1-meter resolution. Area shown is near downtown Sioux Falls, South Dakota.

Table 1. Data Set Specifications

	Sioux Falls Orthophoto	IKONOS	QuickBird
Product	Aerial Orthophoto	Precision Master	Standard
Band Tested	Red	Panchromatic	Panchromatic
Pixel Size	0.5 feet (original)	1 meter	0.6 meter
Orthorectified	Yes	Yes	No
Stated Horiz Accuracy	n/a	2 meters CE90	23 meters CE90
Sensor Elevation Angle	n/a	81.8°	70.7°
Sun Elevation Angle	n/a	64.6°	65.5°
Acquisition Date	5/28/2002	5/20/2002	6/27/2002

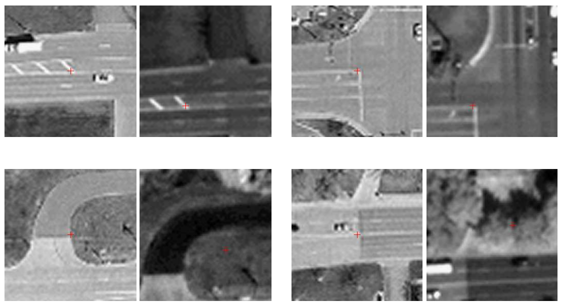

Figure 2. Top: Examples of matching points found and accepted by the IAS image-to-image characterization algorithm. **Bottom:** Examples of points that were rejected based on outlier determination logic. For each pair, image chip on left is from city's orthophoto mosaic, while chip on right is from QuickBird.

Table 2. Registration results based on IAS software (automated approach)

	Mean (m)		Std Deviation (m)		RMSE (m)		RMSE (m)	Horizontal
Image Type	**Line**	**Sample**	**Line**	**Sample**	**Line**	**Sample**	**Radial**	**CE90 (m)**
IKONOS Prec. Master	-0.17	-0.36	0.72	0.45	0.72	0.57	0.92	1.38
QuickBird Standard	12.50	5.88	2.11	1.58	12.67	6.08	14.05	n/a

Table 3. Registration results based on manual tie-point selection

	Mean (m)		Std Deviation (m)		RMSE (m)		RMSE (m)	Horizontal
Image Type	**Line**	**Sample**	**Line**	**Sample**	**Line**	**Sample**	**Radial**	**CE90 (m)**
IKONOS Prec. Master	0.64	-0.55	0.57	0.53	0.86	0.77	1.15	1.74
QuickBird Standard	12.68	5.57	2.50	1.55	12.92	5.78	14.15	n/a

Discussion of Results

A comparison of Tables 2 and 3 shows that results from automated and manual methods were in close agreement. Radial RMSE differed by 0.23 meters for IKONOS and 0.10 meters for QuickBird, confirming that the IAS is a viable tool for measuring high-resolution data sets. For the terrain-corrected IKONOS image, horizontal accuracy was measured as 1.38 and 1.74 meters CE90, using the IAS and manual methods, respectively. These values exceed Space Imaging's accuracy specification of 2-meters CE90 for their Precision Master product. Figure 3 shows residual vector plots based on the manual and automated approaches. The QuickBird residuals appear to have a systematic shift to the northeast. RMSE in the line direction was roughly twice that in the sample direction. The shift could be due to ephemeris error, since the residual vectors appear to be aligned with the along-track azimuth (15.53°) of the satellite. Conversely, the IKONOS residuals exhibit a random pattern, as a result of having systematic error removed. Circular error for IKONOS was calculated based on the Federal Geographic Data Committee standard (FGDC-STD-007.3-1998). Circular error for the QuickBird image could not be calculated using the FGDC standard, since it provides no formula for cases when the ratio of minimum to maximum RMSE is smaller than 0.6. In order to have a means of comparing our results with Digital Globe's published specification, MIL-STD-600001 was used to compute a horizontal accuracy approximation of 16.7 meters CE90. This exceeds Digital Globe's accuracy specification of 23-meters CE90 for their Standard product.

In summary, it was shown that both products met their published accuracy requirements, as measured against an aerial orthophoto mosaic. Registration was carried out using the USGS Image Assessment System, which automatically extracted tie-points and computed the relevant statistics. Results from this automated approach were confirmed using manually selected tie-points. If the imagery tested in this study is typical of acquisitions over other locales, times, and conditions, then imagery from these vendors could serve the purpose of providing ground control and reference imagery for Landsat calibration. As it stands, the IKONOS Precision Master product is accurate enough for the task. The QuickBird Standard product, however, would first require removal of systematic errors (e.g., from ephemeris, attitude, terrain) in order to achieve the level of horizontal accuracy required for Landsat calibration.

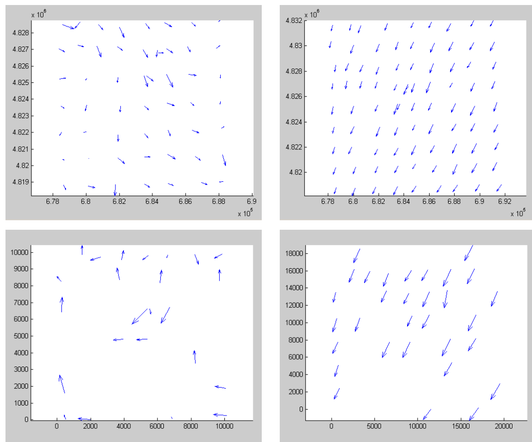

Figure 3. Top: Residual vectors based on manual tie-point selection. **Bottom:** Residual vectors based on automatic tie-point extraction using the IAS. IKONOS residuals are on the left, QuickBird residuals on the right. The QuickBird points exhibit a systematic shift to the northeast, requiring a southwest correction vector. Vectors are scaled for easier visibility. In reality, IKONOS residuals are approximately 14 times smaller than the QuickBird residuals.