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A GEOMETRIC CONSISTENCY EVALUATION OF NCU SPOT LEVEL 10 PRODUCTS BY THE AUTOMATED IMAGE MATCHINGTECHNIQUE

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ABSTRACT

The Center for Space and Remote Sensing Research, the National Central University, provides level 10 products for both SPOT Pan and XS images. These images are differentially rectified with the digital elevation model. In other words, these images are truly orthogonal projections with both the tilt and relief displacements removed. In this study, the geometric consistency of the level 10 product is evaluated. Five scenes of the same area, the ToaCheng watershed, are used for numerical assessment.

The least squares matching method is applied to locate common points between each scene. Then, the coordinates are compared. The coordinates are also evaluated with a two-dimensional perspective transformation. Both blunder and systematic error detection schemes are implemented.

INTRODUCTION

Remotely sensed imagery carries immense amounts of information. Due to the characteristics of imaging geometry, there are differences between the sensed imagery and the orthogonal projection used for the map production. In order to suit the needs of a variety of applications, the image providers offer a line of products. For example, based on the level of pre-processing, SPOT Image offers products of five levels, namely, 1A, 1B, 1AP, 2A, 2B and ortho. The positional accuracy of Level-Ortho relies on the quality of the DEM and map, which can range from 10 to 30m (SPOT, 2001). ACRES (Australian Center for Remote Sensing), which is a business unit of the Australian Surveying and Land Information Group (AUSLIG), Department of Industry, Science and Resources, provides Landsat and SPOT imagery in two different geometric levels. Depending on the sensor, level of processing, DEM, spatial resolution and source of GCP's, the positional accuracy is different. Assuming usage of the AUSLIG 9" DEM (Orthocorrected Image Products only) and 1:100 000 scale maps as the source of GCP's, the following specification is given (ACRES, 2001).

Landsat 7 ETM+ - Path and Map Oriented Image Products: +/- 1 km

Landsat 7 ETM+ - Orthocorrected Image Products: +/- 60 m

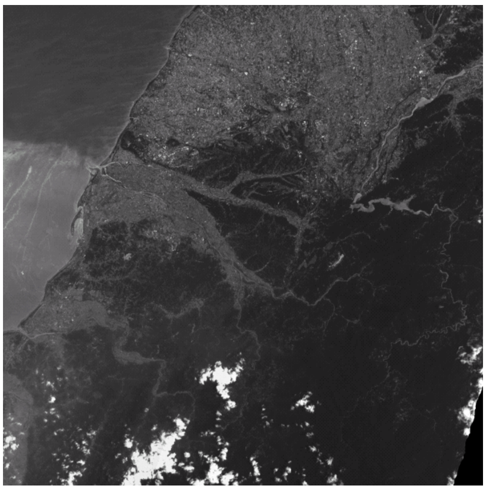
SPOT XS, Pan and Mono - Raw, Path and Map Oriented Image Products: +/- 3 km

SPOT XS, Xi, Pan and Mono – Orthocorrected Image Products: +/- 60 m

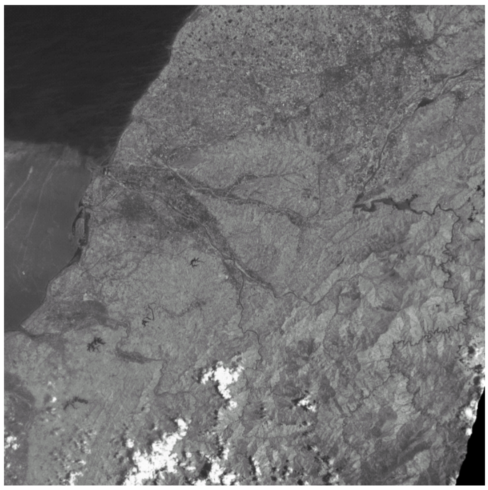
The Center for Space and Remote Sensing Research (CSRSR), National Central University, operates a receiving station in Taiwan. CSRSR provides a level 10 product for both SPOT Pan and XS images. This product is ortho-rectified with the 40 meter horizontal resolution DEM and the control points taken from 1/5000 or 1/10000 ortho photo maps. , The ground resolution is 12.5 m for the SPOT XS, and 6.25 m for PAN. Because the quality of the DEM has not been validated, the positional accuracy of the level 10 product is not specified. In this study, five scenes of the ToaCheng watershed area are studied. The least squares method matching is applied to locate common points between each scene. Then, the coordinates are compared.

THE DATA SET

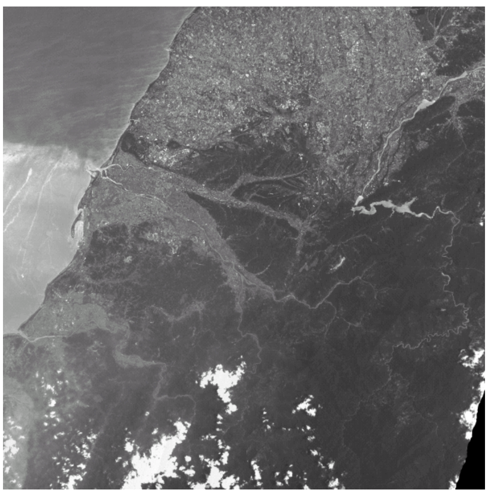
Five scenes of the ToaCheng watershed area as listed in Table 1, are used for numerical assessment. Although the coordinates of the corners of each frame are the same due to geometric registration, the coverage of each image may be different, as shown in Figure 1. While the radiometric characteristics of different bands are different, the same band of a different date may have different semantic contents. For example, the features in the ocean area of the XS-1 band vary between the scene in 1999 and that in 2000.



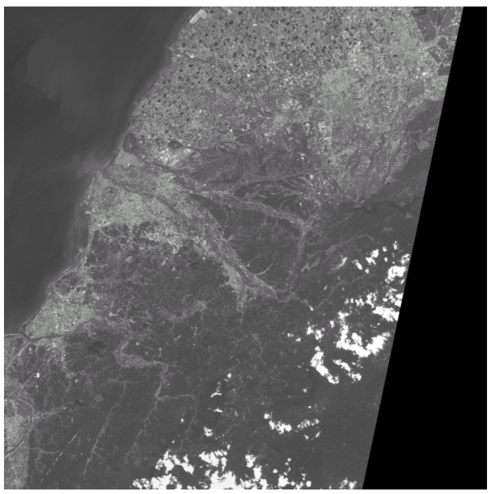
99_R



99_IR



99_G



00_G

Figure 1: Sample SPOT Level 10 Images

Table 1: Basic Data of the Images

Date of Imaging	Satellite	Sun Elevation	Sun Azimuth	Cloud %
July 25, 2000	SPOT 1	68.200226°	98.4660645°	20
July 24, 1999	SPOT 2	75.389100°	104.8262253°	18
Sept. 11, 1997	SPOT 2	66.1099777°	143.5577698°	17
July 29, 1995	SPOT 2	74.3176880°	107.1865005°	27
July 17, 1993	SPOT 2	68.7474670°	94.3859711°	17

THE MATCHING SCHEME

The automated matching scheme applied in this study integrates both the interest operator and the least square matching method. Among several different interest operators, TDGO (Lee, 1990) is selected for implementation. After points are selected by the interest operator, NCC (Normalized Cross Correlation) is applied to acquire the corresponding points in the other image. Then, the least square matching algorithm (Ackermann, 1984) is applied for sub-pixel matching. Starting with four points in each quadrant of the image, the system gradually adds more points for matching.

According to Ackermann [1984], the least square matching principle is as follows. Let $G_T(X_i, Y_i)$ be the grayscale value in the target window, $G_S(x_i, y_i)$ be the grayscale value in the search window, an affine transformation model accommodate the geometric difference between two images. The parameters, h_1, h_2 are to be used for the radiometric difference modeling.

$$G_T(X_i, Y_i) = h_1 + h_2 \cdot G_S\left(\begin{bmatrix} a_1 & a_2 & a_3 \\ a_4 & a_5 & a_6 \end{bmatrix}\begin{bmatrix} 1 \\ x_i \\ y_i \end{bmatrix}\right)^T = h_1 + h_2 \cdot G_S(x_i, y_i; A) \quad (1)$$

Where

$$A = \begin{bmatrix} a_1 & a_2 & a_3 \\ a_4 & a_5 & a_6 \end{bmatrix}$$

For the blunder detection, the Tau test is applied to the residual coordinates. As systematic errors, three statistical tests, Ajne's, Moore's, and Spearmans, are implemented to test the existence (Hung, 1999).

RESULTS

As shown in Table 2-5, not all image matching resulted point pairs are matched correctly. However, for those channel pairs matched successfully, the RMSE are about 1.2 pixels. An example of a good fit is plotted in Figure 2.

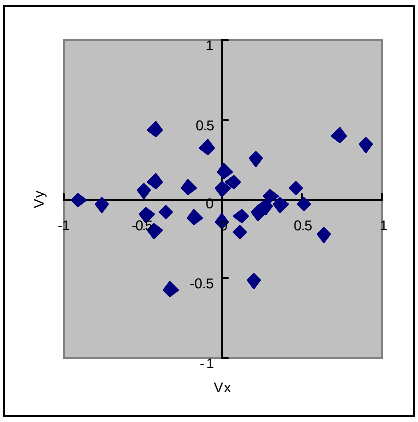


Figure 2: The Coordinate Discrepancies between the 2000 and 1999 XS2

Table 2: Cross-Band Registration, From the Matching

	# of Points	m_{dx}	s_{dx}	$m_{\|dx\|}$	95% error-x	m_{dy}	s_{dy}	$m_{\|dy\|}$	95% error-y
99G-99R	50	0.0789	0.2146	0.4197	0.4478	-0.1044	0.2728	0.4892	0.3488
99G-99IR	35	0.8994	3.1783	1.3043	8.4309	0.9304	3.0606	1.3017	6.3616
99R-99IR	46	0.9366	2.4997	1.1637	6.6451	0.2465	1.2579	0.9129	1.8185
00G-00R	50	-0.2546	0.3186	0.5644	0.2956	-0.3345	0.3455	0.6040	0.0634
00G-00IR	104	-0.8389	3.5497	1.3804	2.1327	2.1841	6.0638	1.8654	18.9467
00R-00IR	23	-0.2959	0.4806	0.6399	0.3216	-0.0086	0.3267	0.4793	0.3840

Table 3: Cross-Scene Registration, From the Matching

	# of Points	m_{dx}	s_{dx}	$m_{\|dx\|}$	95% error-x	m_{dy}	s_{dy}	$m_{\|dy\|}$	95% error-y
93G-00G	128	-7.2547	17.0062	3.0819	51.8989	0.3649	6.2748	1.9491	14.3220
93R-00R	48	1.1596	3.7103	1.5957	8.4287	1.5667	3.0748	1.4341	9.1458
93IR-00IR	34	0.7979	0.7728	0.9574	1.9674	0.7677	0.6911	0.9319	1.6771
95G-00G	101	10.4995	3.0946	3.2407	16.2305	0.8831	3.2167	1.4161	8.4333
95R-00R	77	10.7134	1.2909	3.2731	12.5094	0.7107	1.1750	1.0220	2.2899
95IR-00IR	89	10.8596	1.2312	3.2954	13.4505	-0.1002	0.8511	0.7854	1.3190
97G-00G	119	-4.8434	8.2782	2.8130	9.2352	-2.0490	13.3149	3.3569	21.3204
97R-00R	10	-1.0943	13.8384	3.4496	17.6212	7.1502	11.4829	3.4898	18.9943
97IR-00IR	106	-8.6728	35.2429	5.2521	46.8304	16.9137	32.5086	5.4844	59.2045
99G-00G	30	0.4954	0.7880	0.8735	1.6301	0.2838	0.5288	0.7005	1.0877
99R-00R	34	0.9711	0.8238	1.0134	2.3108	1.0031	0.6830	1.0115	1.8694
99IR-00IR	30	0.5625	0.8396	0.9103	1.8442	0.2974	0.5371	0.6999	0.8969

Table 4: Cross-Band Registration, After Projective Transformation

	# of Points	Level	RMSE	Ajne's	Moore's	Spearmans
99G-99R	50	5	0.206471	17	0.502575	-0.122881
99G-99IR	35	5	2.92334	8	1.30901	0.312885
99R-99IR	46	6	1.8135	11	1.86124	-0.120321
00G-00R	50	5	0.293847	15	1.06282	-0.195582
00G-00IR	104	10	3.95494	28	2.13061	-0.521519
00R-00IR	23	5	0.309557	6	0.335798	0.0998024

Table 5: Cross-Scene Registration, After Projective Transformation

	# of Points	Level	RMSE	Ajne's	Moore's	Spearmans
93G-00G	128	11	4.9373	49	1.50107	-0.300609
93R-00R	48	6	3.17521	15	0.946699	-0.314155
93IR-00IR	34	5	0.617034	11	0.365748	0.145302
95G-00G	101	10	3.11746	43	0.379975	0.0845195
95R-00R	77	9	1.08974	35	0.229249	-0.0845195
95IR-00IR	89	11	0.979426	34	1.079690	0.0735444
97G-00G	119	20	6.07572	46	0.622413	-0.0617576
97R-00R	10	5	8.13087	2	0.712911	0.660606
97IR-00IR	106	24	5.95746	42	0.67363	0.0923042
99G-00G	30	5	0.556534	8	1.30569	-0.341491
99R-00R	34	5	0.684099	10	0.801375	0.218029
99IR-00IR	30	5	0.509615	7	1.10606	0.473192

CONCLUDING REMARKS

This study serves as a preliminary evaluation of the positional accuracy of SPOT level 10 products in the ToaCheng watershed area. An automated matching scheme is applied for the evaluation. It has been shown that the radiometric differences between bands and the images of different dates have generated difficulties for matching.

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