Qualification Test of ROCSAT-2 Image Processing System

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ABSTRACT: ROCSAT-2 mission is to daily image over Taiwan and the surrounding area for disaster monitoring, land use, and ocean surveillance during the 5-year mission lifetime. The satellite will be launched in December 2003 into its mission orbit, which is selected as a 14 rev/day repetitive Sun-synchronous orbit descending over (120 deg E, 24 deg N) and 9:45 a.m. over the equator with the minimum eccentricity. National Space Program Office (NSPO) is developing a ROCSAT-2 Image Processing System (IPS), which aims to provide real-time high quality image data for ROCSAT-2 mission. A simulated ROCSAT-2 image, based on Level 1B QuickBird Data, is generated for IPS verification. The test image is comprised of one panchromatic data and four multispectral data. The qualification process consists of four procedures: (a) QuickBird image processing, (b) generation of simulated ROCSAT-2 image in Generic Raw Level Data (GERALD) format, (c) ROCSAT-2 image processing, and (d) geometric error analysis. QuickBird standard photogrammetric parameters of a camera that models the imaging and optical system is used to calculate the latitude and longitude of each line and sample. The backward (inverse model) approach is applied to find the relationship between geodetic coordinate system (latitude, longitude) and image coordinate system (line, sample). The bilinear resampling method is used to generate the test image. Ground control points are used to evaluate the error for data processing. The data processing contains various coordinate system transformations using attitude quaternion and orbit elements. Through the qualification test process, it is verified that the IPS is capable of handling high-resolution image data with the accuracy of Level 2 processing within 500 m.

1. INTRODUCTION

National Space Program Office (NSPO) is developing a ROCSAT-2 Image Processing System (IPS), which aims to provide real-time high quality image data for ROCSAT-2 mission. The IPS is an integrated hardware and software system that provides full capabilities for the reception, archiving, cataloging, processing, and user query of the remotely sensed image data. The IPS system functions are grouped into four functional blocks: Data Ingestion Subsystem (DIS), Data Processing Subsystem (DPS), Data Management Subsystem (DMS), and Planning and Scheduling Subsystem (PSS). DIS is to perform frame synchronization, level 0 processing, and moving window display. DPS is for Level 1A and Level 2 data processing for radiometric correction and system geometric correction. DMS provides the functions for image data inventory, image data management, and web service. PSS performs the satellite simulation and imaging scheduling.

Level 2 image geometrical quality depends on Spacecraft ancillary data accuracy and direct image to ground localization / model quality and geographic to cartographic conversion [1]. Level 2 localization intrinsic model accuracy (i.e. error with perfectly known parameters and terrain elevation) should be much smaller than the systematic localization accuracy. For ROCSAT-2, the uncertainty in position is about 10 meters, the pointing knowledge error (including instrument and structure distortions and attitude determination errors) is 450 meters [2]. So the georeferencing/geocoding function error should be has the order smaller than 100 meter.

One set of test data based on Level 1B QuickBird image and simulated ROCSAT-2 orbit/attitude with no measurement noise is generated for IPS level 2 image verification. To generate this data, we need to apply Direct image to ground localization model and Quick Bird RPC (Rational Polynomial Coefficients) file, so the model error should be estimated first; One Level 2 image created by the same ground localization model combined with the WGS84 to UTM (or TWD 67/97 to TM2) model will be used for DPS Level 2 product comparison [2] [3]. This is forward approach for pre-defined Level 0 image size. The Ground Control Point, as an extended and independent reference data, will be applied to estimate the test data error. Once the simulated raw image has been generated, we need to add the auxiliary information together to create the Generic Raw Level Data format file [4], which is the IPS/DIS output format.

The DPS subsystem use the backward approach to process the Level 2 image based on known Area Of Interested (AOI). The same AOI as in the forward Level 2 image is selected, to perform two image comparison, select the same GCP point on the images, corresponding to this location, there is (column, raw) information for each image, the difference in distance is just the difference in (column, raw) multiplied by image resolution, for ROCSAT-2, say, 2 meter. Once the difference is smaller than the 100m order, we can conclude that IPS is capable to handle high-resolution image data with the accuracy of Level 2 processing within 500 m.

2. QUICKBIRD LEVEL 1B GEOREFERENCEFUNCTION

To make sure we can process QuickBird image in accuracy to 50 meter order—regardless of the effect of aberration of light, which is caused by relative motion between the telescope and the target, and to compare with RPC mapping result, we applied Level 1B Pixel to Ray Transformation [5] and the GEO file delivered with the image to get the four corner geodetic coordinate. The procedure for the Pixel to Ray Transformation is as follows:

Step 1: find the attitude of the S/C coordinate system at time t in the ECF system by interpolating the quaternion time series in the attitude file.

Step 2: Use the ECF quaternion to represents the rotation from the ECF system to the S/C body system at time t.

Step 3: For any column and row measurement (c,r) of a pixel in a snap, find the corresponding position of the image point in the detector coordinate system.

Step 4: convert these detector coordinates to camera coordinate.

Step 5: convert this vector first to the S/C coordinate system and then to the ECF system, to get a unit vector in the ECF coordinate system that is parallel to the ray using the Spacecraft to camera quaternion.

Step 6: Use S/C interpolated ECF Position and the unit vector derived in step 5 to find the ray paralleled vector intersection point with the Earth.

Step 7: Transform from ECF to geodetic coordinate

Compared with the 4-corner geodetic coordinate described in the metadata with the above calculation, we got an error to within 30 meters.

3. GENERATION OF SIMULATED ROCSAT-2 IMAGE

Generally, we use basic QuickBird image, RPC + constant DEM (100 m) as "Ground Truth", simulated ROCSAT-2 orbit ephemeris in ECF and attitude(ECI to body quaternion) with no noise were applied. The procedure for the simulated ROCSAT-2 image and related GERALD file is as follows:

Step 1: for each (line, pixel)-(i, j), derived the line-of-sight vector in body coordinate based on RS2/RSI calibration parameters[6].

Step 2: apply ECI quaternion to get body-to-ECI transformation, then get ECI line-of-sigh vector, then transform to ECF line-of-sigh vector.

Step 3: Use ECF line-of-sigh vector and S/C ECF Position to get intersection of LOS ECF vector with Earth Surface.

Step 4: Transform from ECF coordinate to geodetic coordinate system.

Step 5: Apply RPC mapping to QB L1B image (i' , j').

Step 6: Apply Bi-Linear resample in QB L1B image (i' , j') ,(i' +1, j'), (i' , j' +1), (i' +1, j' +1) to get ROCSAT-2 (i,j) image.

Step 7: Put RS2 orbit + RS2 attitude in GERALD header then put ROCSAT-2 raw image to generate GERALD format file.

4. ROCSAT-2 Level-2 IMAGE PROCESSING

There are two approaches based on different input in Level-2 image processing, forward and backward. The forward approach give the raw data height and width as input for processing, while the backward one which is IPS/DPS approach use the AOI as input. For the forward one we applied most the same algorithm as in simulated data generation (Step 1 to Step 4), applied Geographic to cartographic conversion WGS84 to UTM (or TWD 67/97 to TM2), Cubic Convolution resample method etc.; we treat IPS/DPS as a black box, only the same input file, select AOI, select projection method, select resample method, then got a level 2 output image with predefined AOI.

Total error of IPS/DPS approach including two parts, the first one is error between Ground Truth and forward approach, the second one is error between forward approach and backward approach.

5. FORWARD IMAGE GEOMETRIC ERROR ANALYSIS

To estimate forward image (image 1) error, we compared with GCP data in Shin-Chu (SZ02~SZ07, SZ09), and summarize the distance (difference) in the following table. Most error is caused by the RPC calculation error due to const DEM (we use 100m).

Table 1: Forward Image Geometric Error

GCP #	GCPTM2 97 N (meter)	GCPTM2 97 E (meter)	Point in test data TM2 97 N (meter)	Point in test data TM2 97 E (meter)	Distance of GCP & point in test data (meter)
SZ02	2742179.249	244872.241	2742181.387	244866.576	6.055
SZ03	2748027.087	243099.063	2748063.679	243117.113	40.802
SZ04	2745820.811	246822.675	2745862.865	246834.378	43.652
SZ05	2743190.382	251304.565	2743209.886	251295.873	21.353
SZ06	2741571.320	250410.889	2741604.716	250388.999	39.931
SZ07	2741717.588	249738.410	2741717.576	249725.873	12.537
SZ09	2739188.820	245793.082	2739233.125	245799.159	44.720
average distance (meter)					29.86420759

6. BACKWARD IMAGE GEOMETRIC ERROR ANALYSIS

After processing the forward Level 2 image with 12000 * 12000 size, we got the Upper Left (UL) and Lower Right (LR) coordinate, Use this information as DPS Level 2 AOI, given the same input, we now got two Level 2 image with the same area of interest; the following table summarized the difference in (column, raw) of the two images w.r.t. different GCP. The forwarded one is denoted as image1, while the DPS processed image is denoted as image 2. The average distance between the two images is less than 60 m, which is contributed from the different ancillary data interpolation method, difference in transformation model etc.

Table 2: Backward Image Geometric Error

GCP #	(column, row) in image1	(column, row) in image2	Distance of image1 & image2 (meter)
SZ02	(6110, 4131)	(6108, 4115)	16.492
SZ03	(5243, 1197)	(5282, 1164)	102.176
SZ04	(7099, 2292)	(7134, 2290)	70.114
SZ05	(9338, 3624)	(9307, 3655)	87.681
SZ06	(8887, 4436)	(8859, 4446)	59.464
SZ07	(8549, 4370)	(8530, 4390)	55.172
SZ09	(6589, 5613)	(6591,5606)	14.560
average distance (meter)			57.951

7. CONCLUSION

Once the forward image error been estimated, say error 1, and the difference between the forward and backward images achieve a not bad value in average - error 2, the worst case for the DPS level 2 image geometric error is the sum of error 1 and error 2, for these check point we have made, we got a result less then 100m. We can conclude that IPS is capable of handling high-resolution image data with the accuracy of Level 2 processing within 500 m.

REFERENCES

1. S&DE Document, "ROCSAT-2 Image Corrections & Test Data Simulation" Power point file--IPS_CLIN3_Ed00_Rev01.ppt by Claude LEDEZ ; 2003
2. A.M. Wu and Y. Y. Lee, "Geometric Correction of High Resolution Image Using Ground Control Points", ACRS 2001 paper No. 164.
3. Y. Y. Lee, A. M. Wu, and F. Wu, "An Algorithm for Geometric Correction of High Resolution Image Based on Physical Modeling", ACRS 2002 paper No. 149.
4. S&DE Document, "ROCSAT-2 Raw Level Data Format"; 2001.
5. Digital Globe Document, Image Support Data Format Specification Document - Appendix A ; 2002.
6. S&DE Memo, "R2T Calibration parameters", Reference R2T-NE-3-00038-SDE ; 2003.