GEOMETRIC QUALITY ASSESSMENT OF VHR SATELLITE IMAGERY WITH ORTHO-RECTIFIED CARTOSAT-1 DATA – A CASE STUDY

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ABSTRACT:

Data products from satellite instruments with moderate to high spatial resolution are assessed for their geometric accuracy with the help of topographic maps or geo-coded satellite imagery generally at 1:50,000 scale. With advancement in high precision attitude and orbital control systems onboard, considerable attention has been paid in the recent past to improve methods for better accurate assessment of geometric quality, especially for Very High Resolution (VHR) satellite imagery. These products are in general evaluated with the help of dense ground control points (GCPs) acquired through ground survey. But this survey is very expensive, and is difficult to perform in certain terrain conditions. In this paper, we propose to use ortho-rectified and mosaicked data from recently launched IRS-CARTOSAT-1 in terms of both getting sufficient number of control points and their accuracy for assessment. Ortho-rectified products supplied after single strip triangulation algorithm with limited number of GCPs have been found to yield quite accurate in terms of location accuracy and internal distortion. In this paper, we suggest to use the mosaicked ortho-rectified data as reference map for geometric quality assessment of VHR (Cartosat-1) geo-referenced (standard) imagery and IRS-Resourcesat-1 LISS-4 MS image as well.

1. INTRODUCTION

In recent past, there has been increasing interest in the practical applications of very high resolution satellite imagery. This can be attributed to launches of new spacecrafts with an attempt to meet digital technologies very close to photogrammetric solutions traditionally achieved with aerial photographs. There have been many publications on the geometric calibration and assessment of such VHR satellite data, mostly evaluated with the help of Ground Control Points (GCPs) after hectic ground survey campaign.

On the other hand, data products from satellite instruments with moderate to high spatial resolution have been traditionally assessed for their geometric accuracy with topographic maps or geo-coded satellite imagery typically available at 1:50,000 scale. With technological advancement in high precision attitude and orbital control systems onboard, it is quite important to improve methods for better accurate assessment of geometric quality of the VHR satellite imagery. These products are in general evaluated with the help of dense ground control points (GCPs) acquired through ground survey. But this survey is very expensive, and is often difficult to perform in certain terrain conditions.

In this paper, we describe the use of reference images with the help of CARTOSAT-1 ortho-rectified data products, for evaluating geometric location accuracy and internal distortion of the VHR and HR imagery. These ortho-rectified products are generated using a pass-segment of 500 km with minimum of 10 GCPs with horizontal accuracy better than 1 m. using stereo-strip triangulation (SST) algorithm (NRSA, 2006). The required stereo pair images for this algorithm were obtained from two cameras kept at +26 deg (FORE) and -5 deg (AFT) with respect to nadir. The size of the actual products is only (7.5’×7.5’), and hence single product is not adequate to generate a meaningful size of the reference images. It is thus proposed to mosaic four of these products, rectify further if necessary before realizing the final (15’×15’) size reference images.

The rest of the paper is organized as follows: Section 2 described ortho-rectified data products selected for this case study and methodology followed in detail. In Section 3, results and discussions are given, and in Section 4, our conclusions are summarized.

2. MATERIALS AND METHODOLOGY

A case study was taken up by taking ortho-rectified data products from the IRS-CARTOSAT-1 over Hyderabad and Bangalore in urban environ, and Alwar in hilly environ for generating mosaicked reference images. Table 1 gives the details of the scenes selected of these products. Specifications of the mission, payload and data products can be seen in (Krishnaswamy, 2006). For these chosen study areas, more than 100 precise GCPs are with 1m. accuracy for generation of these reference images. These GCPs were first mapped onto IRS-1D panchromatic data for easy

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visualization, and provided along with line sketch, aerial image etc. to help in marking the GCP from the neighbourhood information available from these ancillary inputs. Once identified the control points, mosaicking was carried out using the tools available with commercially available ERDAS® Image analysis software (ERDAS, 1999).

Table 1 Input ortho-rectified (Level-3) CARTOSAT-1 data for generation of reference images

DOP	Scene Id	Study Area
04.11.05	Path: 522 Row: 270	Alwar (hilly terrain)
08.06.05 14.11.05	Path: 545 Row: 316	Hyderabad City and its environ
14.11.05	Path: 545 Row: 335	Bangalore City and its environ

Table 2 Test images from CARTOSAT-1 Level-2 (Geo-referenced) products

DOP	Scene Id	Study Area
21.03.06	Path: 522 Row: 270	Alwar (hilly terrain)
20.03.06	Path: 545 Row: 316	Hyderabad City
20.03.06	Path: 545 Row: 335	Bangalore City

Table 3 Test images from RESOURCESAT-1: LISS-4 MS sensor at Level-2 (Geo-referenced) products

DOP	Scene Id	Study Area
17.03.05	Path: 202 Row: 047	Alwar (hilly terrain)
26.01.04	Path: 201 Row: 114	Hyderabad City and its environ
20.01.06	Path: 102 Row: 114	Bangalore City and its environ

The data products for scenes given in Table 1 were obtained to obtain four (or six) floating geo-coded 7.5′ × 7.5′ after ortho-rectification with UTM Projection and WGS84 Datum after the SST processing. These quadrant products were then mosaicked to realize the image data of size 15′ X 15′ also in UTM Projected with WGS84 Datum. These mosaicked images are further rectified with GCPs. Once the reference images are made, test images are evaluated for geometric location accuracy and internal distortion. As mentioned above, all the test images are corrected to provide geo-referencing, and hence each image is provided with geographical co-ordinates, in latitude and longitude, for its four corners. Each estimated latitude (λ), longitude (φ) values of each image point is related to line (x) and pixel (y) by

$$\lambda \cos\varphi = A + B\,x + C\,y$$
$$\varphi = D + E\,x + F\,y. \qquad (1)$$

Here (A, B, …, F) denote transformation coefficients which are to be estimated with the help of six points identified both in the reference image and test image (Robinson, 1955). Once the above transformation is done, the difference between the reference and test images is computed at selected GCP (i) as

$$\Delta\lambda_i = \lambda_{R,i} - \lambda_{T,i}$$
$$\Delta\varphi_i = \varphi_{R,i} - \varphi_{T,i} \qquad (2)$$

The difference in radial direction at a given GCP is given by

$$\Delta R_i = \sqrt{\Delta\lambda_i^{\,2} + \Delta\varphi_i^{\,2}}\ . \qquad (3)$$

The residual errors are defined as the magnitudes of root mean square (RMS) errors in the along (AL) and across (AC) track direction of the satellite path and are given by

$$E_{AC} = \sqrt{\frac{\sum(\Delta\lambda_i)^2}{n}}\ ; \qquad E_{AL} = \sqrt{\frac{\sum(\Delta\varphi_i)^2}{n}} \qquad (4)$$

Internal (length) distortion is defined as the residual error left uncorrected after the linear bias due to location error estimated as above in both directions is corrected. To compute this, one of the GCPs (or corner co-ordinate) is considered as a reference point, and length of each other GCP to this reference GCP is computed in both the reference and test images. The relative differences in each length between the reference and the test image are estimated. The RMS error of the length error is taken as the representative of the internal distortion.

3. RESULTS AND DISCUSSIONS

Each of the individual ortho-rectified products was first subjected to geometric quality assessment using precision GCPs. Out of the four (or six) products, the one with minimum error is taken as reference tile, and other images are warped with respect to GCPs of the reference tile. Input ortho-rectified images were first tiled horizontally into two sets so that resampling can be restricted to 3 times before realizing the final mosaicked image. Each set was mosaicked by identifying minimum of about 10 to 12 relative control points in the overlap region, followed by histogram normalization. The final reference image was obtained by tiling the two sets of intermediate data with 30 to 40 control points. Final mosaicked image was evaluated with more than 30 precision GCPs and corrected simultaneously. Figure 1 shows the tiling process as described above and four tiles of actual data were shown in Figure 2. Figure 3 shows one reference image of size (15’ × 15’) over the Alwar study area. Result of re-rectification of the mosaicked image with precision GCPs is shown in Table 4. As can be noted, the geometric inaccuracies, especially the internal distortions present in the image, have been reduced considerably.

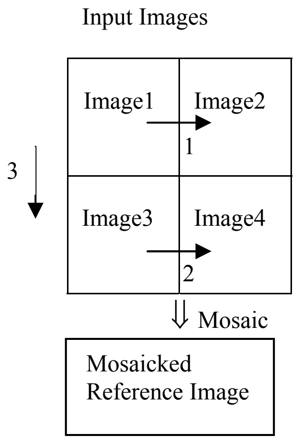

Figure 1 Scheme followed to mosaic the ortho-rectified reference image generation.

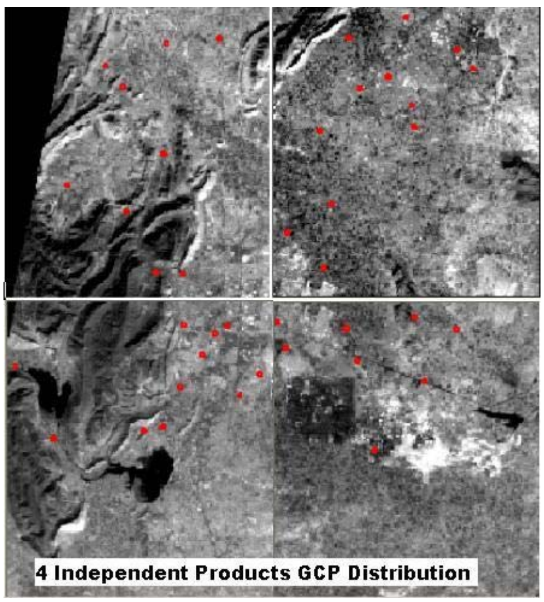

Figure 2 Four quadrant ortho-rectified products along with distribution of GCPs.

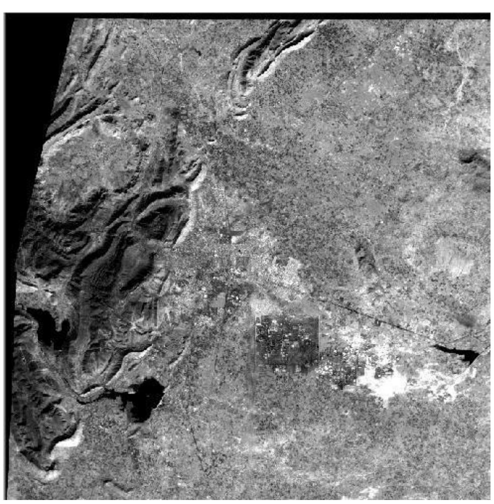

Figure 3 Mosaicked reference image of Alwar data

Table 4 Reference Images before and after re-rectification with GCPs

Scene	*Before Correction*		*After Correction*	
	Loc. Acc. (m)	Int. Dist (pix)	Loc. Acc. (m)	Int. Dist. (pix)
B'lore	9.73	6.47	7.35	3.17
Hyd	15.01	5.81	11.48	4.81
Alwar	36.99	21.75	28.66	17.78

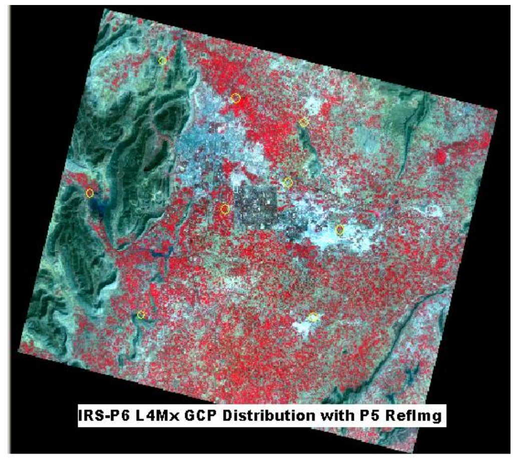

Figure 4 Resourcesat-1: LISS-4 MS test image.

Table 5 Comparison of geometric quality parameters with LISS-Geo-referenced Images and ortho-based reference images proposed here.

Scene	Dirn.	Loc. Err. (m)		Int. Dist. (pix)	
		L3-Ref	P5-Ref	L3-Ref	P5-Ref
Hyd	AL_Tr	273.4 N	291.3 N	6.4	3.2
	AC_Tr	234.3 E	118.0 E	14.5	1.6
	Radial	360.1	314.3	15.85	3.58
B'lore	AL_Tr	168.1 N	65.7 N	6.4	1.6
	AC_Tr	56.1 W	140.8 W	6.1	4.5
	Radial	177.21	155.37	8.84	4.78
Alwar	AL_Tr	452.8 N	324.8 N	11.2	4.04
	AC_Tr	318.6 W	410.5 E	8.4	4.94
	Radial	553.65	523.45	14	6.38

Table 6 Geometric assessment of Cartosat-1 Georeferenced (Level-2) products with the help of ortho-mosaicked image

Scene	Dirn.	Loc. Acc. (m)	Int. Dist. (pixels)
Hyd	AL_Tr	61.51 S	9.6
	AC_Tr	50.64 E	3.5
	Radial	79.67	10.22
B'lore	AL_Tr	97.42 S	8.0
	AC_Tr	55.97 E	3.4
	Radial	112.35	8.69
Alwar	AL_Tr	56.25 S	9.3
	AC_Tr	59.91 E	4.7
	Radial	82.14	10.42

Table 5 gives the comparison analysis with evaluation of a product with LISS-3 geo-referenced image and Ortho-mosaicked image proposed in this study. The LISS-3 geo-reference images are obtained after precision correction with respect to Survey of India maps at 1:50,000 scale. It can be inferred that the location accuracies of the Resourcesat-1 LISS-4 MX test image were nearly identical, but the internal distortions were significantly different. Please refer to (NRSA, 2003) for further details on Resourcesat-1. The reason may be attributed to the fact that the LISS-3 GR image is not corrected for terrain undulations. The difference is more significant for Alwar due to its hilly terrain nature.

Table 6 shows the results of geometric assessment of Cartosat-1 GR product with the help of the ortho-mosaicked image as the reference data. The location error on the average is about 100 m., while the internal distortion is approximately 10 pixels in radial direction for the standard level correction with satellite ephemeris available.

3. CONCLUSIONS

From this study, it is evident that high precision ortho-rectified reference image is best suited for geometric quality assessment of very high spatial resolution satellite data products. In general, wide-swath reference image is required to provide adequate ground control points for evaluation. This can be achieved by mosaicking many moderate-swath ortho-rectified products. It was also shown that it would be required re-rectification of the mosaicked image with the help of precise control points before use. Geometric assessment of HR Resourcesat-1: LISS-4 multispectral image with mosaicked reference image is found to be better than using conventional LISS-3 geo-referenced image. Results obtained with the experiment encourage us to take up extending this to development of hierarchical ortho-rectified image library with image resolutions available from VHR to moderate spatial resolution sensors like Resourcesat-1: LISS-3 and AWIFS sensors.

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