VALIDATION OF CARTOSAT-1 DEM USING DIFFERENTIAL GPS MEASUREMENTS

A. Nadeem *, A. Ritesh, M. Anjum, P.Jayaprasad, S.K. Pathan and Ajai

Forestry, Land use Planning and Photogrammetry Group Remote Sensing and Image processing Area, Space Applications Center (ISRO), Ahmedabad. Gujarat, India
* nahmad61@rediffmail.com

Commission IV, WG-IV/9

KEY WORDS: CARTOSAT-1 Stereo data, DGPS, DEM, Ortho Image, Validation

ABSTRACT:

With the availability of CARTOSAT-1 data with stereo capability, it is possible to generate accurate Digital Elevation Model (DEM) for large area. Terrain parameters such as elevationt, slope, aspect, drainage, watershed boundaries etc., can be extracted from DEM. DEM is also a necessary input for Ortho-image generation which in turn provide a valuable input to topographic mapping and updation. Delineation of terrain features from space-borne remotely sensed data is dependent on accuracy of the Digital Elevation Model (DEM) used. Generating high-quality DEM from satellite stereo images requires precise Ground Control Points (GCP's). With the advent and use of Global Positioning System (GPS) it has become possible to provide high-quality GCP's. In the present study, an attempt has been made to use the CARTOSAT-1 stereo data for generating DEM over two different types of terrain. One stereo pair over hilly terrain of Dehradun in Uttaranchal and other stereo pair over plain area of Jaipur in Rajasthan have been processed to generate the DEM and it has been validated using Differential Global positioning system (DGPS) measurements.

1. INTRODUCTION

Digital Elevation Model (DEM) has become an inevitable component in most of the remotely sensed image applications. Updating of topographic maps, cadastral surveys, large scale mapping, road rail alignment are prominent among them. Stereo analysis of optical data has been extensively used by the scientific community in deriving the DEM. The DEM and ortho image can be generated from satellite stereo data using photogrammetric techniques. A stereo pair can be generated either from across track or along track geometry. Indian Remote Sensing Satellite (IRS) –1C /1D have the capacity to steer the camera ± 26º across track to make a stereo pair of 5.8 m. SPOT5 High Resolution Geometric (HRG) with 5m also provides across track stereo products. The major issues with the across track geometry are availability of the data for a larger extent, the radiometric differences between the acquisition of the pair. CARTOSAT–1 and The PRISM (Panchromatic Remote-sensing Instrument for Stereo Mapping will provide along track triplets with 2.5 meter spatial resolution. CARTOSAT-1 was launched in 5th May 2005. It has a forward-looking camera FORE looking at +26º and a backward looking camera AFT at –5º. The nominal B/H ratio is 0.62. The repeativity of the satellite is 126 days and revisit capability of 10 days and the swath is 30 km * 30 km.

Photogrammetric techniques have been known for decades, but the possibility of using satellite's stereoscopic images for global digital elevation data producing arise when the launch of the first of the SPOT series satellites in 1986. The quality of digital elevation models (DEMs), elaborated from stereoscopic pairs, is affected by the topography of the terrain and the data source, other variables that depend on the data, the algorithms used in the Photogrammetric workstations, and on the data structure (triangulated irregular networks versus uniform regular grids).

A digital elevation model (DEM) can be extracted from stereo satellite images. Digital elevation model (DEM) is the basic requirement for ortho-rectification of the image.

DEM extraction from SPOT stereo pair has been attempted by Bolstad and Stowe (1994), Al-Rousan et al., (1997), Rodriguez et al., (1998) and Krupnilk (2000). Gopala Krishna et al.,(1996) and Jayaprasad et. al (2000) discussed the use of IRS –1C panchromatic data for cartographic applications. They have given a theoretical assessment of cartographic potential of IRS –1C imagery and the early results from few stereo pairs. Akira et. al. (2003) validated ASTER stereo data derived DEM. The accuracy analysis of DEM using SPOT 5 HRS and HRG data was carried out by Toutin. (2004, 2006). IKONOS stereo data analysis using Rational Function Model(RFM) was carried out by Di et. al (2003), Fraser and Hanley (2003), Toutin (2004), Tao et. al. (2002, 2004).

In the present study, DEM and ortho images were generated from CARTOSAT-1 stereo pair and GCPs established using DGPS survey. Accuracy estimation was carried out by comparing the DEM with a set of check points measured DGPS survey.

2. STUDY AREA

Two test sites were selected in the present study. Parts of Dehra Dun Districts, Uttaranchal state and Parts of Jaipur District of Rajasthan state were chosen for the study. The extent of the two image pairs 77º 45'E - 78º 05'E and 30º 10'N - 30º 30' N for Dehra Dun and 75º 45' E - 76º 05' E and 26º 45' N - 27º 05' N for Jaipur.

3. DATA USED

CARTOSAT –1 Stereo data over Dehra Dun (Path: 0526, Row: 0258, Date Of Pass: 02nd October 2005, Orbit No: 2224) and Jaipur (Path: 0520, Row: 273, Date Of Pass: 18th May 2005, OrbitNo: 194) were used in the study. DGPS observations, IGS data observations and ancillary files, precise GPS satellite orbits were used in the GPS data processing.

4. METHODOLOGY

The overall methodology adopted in the study is presented in Figure-1.

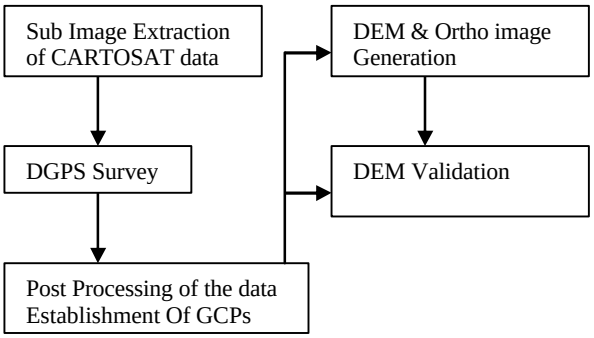

Figure 1: Schematic represention of DEM validation using DGPS Measurements

4.1 Extraction of Sub image of CARTOSAT –1 data

The sub image of the study area was extracted for the field survey. GCP's well distributed over the image were chosen for DGPS survey. Features like road intersections, field intersections, and sharp road turns were selected as GCP's.

4.2 GPS Survey in Differential Mode

One of the most important parameter for DEM generation and validation is to establish the coordinates of the GCP's. The GCP coordinates are required for georeferencing the satellite images and also in the bundle adjustment for generation of DEM. In addition to this, it is also required to have some GCP's for validation of DEM. These were established using GPS observations and post processing of the data in differential mode.

4.2.1 Experimental Design

The experiment was designed to collect GPS data at one reference station and 36 rover stations (GCPs) Dehra Dun and one reference and 30 rovers stations at Jaipur. The surveys were carried out from 17 to 20 November 2005 in Dehra Dun and 27 to 29 Dec 2005 in Jaipur The points were selected in such a way that it assured the clear sky. GPS observations were taken for 72 hours at reference station and 1 hr each at GCPs. The distribution of the GCPs is shown in figures 2 and 3 for Dehra Dun and Jaipur respectively. A representative field photographs are shown in figures 4 and 5 respectively for Dehra Dun and Jaipur.

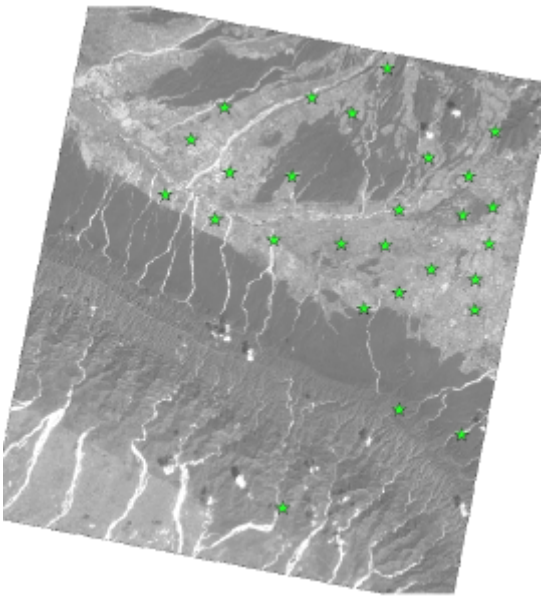

Figure2: Distribution of GCPs in and around Dehra Dun.

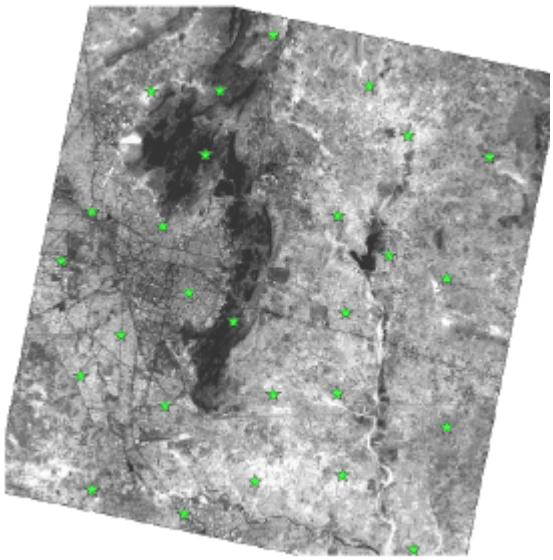

Figure3: Distribution of GCPs in and around Jaipur

Figure 4. Field photograph for Dehra Dun.

Figure 5. Field photograph for Jaipur.

4.2.2 Establishment of Reference Station and GCP coordinates.

Post processing of GPS observations was carried out using Bernese S/W v 5.0 GPS data of International GPS services for Geodynamics (IGS) stations, having a distance of 3000 km or less from the reference station, was downloaded in RINEX format along with precise ephemeris data. The IGS stations viz. the Indian Institute of Science, Bangalore, India (iisc) , Kitab, Uzbekistan (kit3), Poligan IVTAN 2, Bishkek, Kyrghyzstan (pol2), Selezaschita, Almaty, Kazakstan (sele), Diego Garcia Island (dgar), Malindi, Kenia (mali) and Manila Observatory, Phillipines (pimo) are the IGS stations with in the range mentioned above. The precise ephemerides are available after 24 days. Geometric dilution of precision was very large when the satellites visibility was very less. The reference station was established by network adjustment with IGS stations. These coordinates were in WGS-84 datum. The GCPs were established by base line processing with respect to reference station.

4.3 DEM and Ortho Image Generation

DEM was generated using satellite photogrammetric techniques using Rational Function model. The Rational polynomial Coefficients (RPCs) are available with the CARTOSAT-1 stereo data. RPCs relates object space to image space and vice versa. Even though no GCPs are available, ground coordinates can be derived from image coordinates using RPCs. The accuracy of the coordinates depends on the source of RPCs. If GCPs are available one can refine the RPCs using polynomial functions. In the present study, these coefficients were updated using GCPs established using DGPS measurements.

The major steps involved in DEM generation using Leica Photogrammetry Suite (LPS) S/W are creation of a block file using CARTOSAT rational functions after defining the input projection, adding the raw images along with RPC files, identification of GCPs, Check points, refining the rational polynomial coefficients using GCPs, generation of epipolar image, image correlation for automatic extraction of tie points, TIN using stereo triangulation, DEM and Ortho image.

The S/W does the following steps internally. They are interior orientation (which will be done at sensor calibration level itself), setting up of Datum and Projection, input data, GCP/TP identification, bundle adjustment, model calculation, epipolar image generation, DEM generation and Geocoding of the DEM and generation of Ortho image.

The model accuracies at GCPs for Dehradun were respectively in Easting, Northing and elevation were 2.48 m 2.25m, 3.97m for 17 GCP. The results for Jaipur were 2.43m 2.4m, 2.60m in Easting, Northing and elevation for 21 GCPs. DEM was used to generate an Ortho Image. Since the AFT image is a near Nadir image, it was used for Ortho image generation. The DEMs generated for Dehra Dun and Jaipur are shown in Figures 6 and 7.

4.4 DEM Validation:

DEM generated using CARTOSAT-1 stereo data was validated using GCPs established using DGPS survey. The Ortho image was overlaid on DEM, the planimetric and elevation values at all check points were computed from ortho image and DEM and were compared with DGPS measurements. The RMS Error for planimetry and elevations were shown in table 1 and Table2

Point ID	**Residuals (m)**		
	Easting (m)	Northing (m)	Elevation (m)
Thelpur	-4.30	1.86	2.17
Selakui	-1.87	-0.42	-1.69
Ambiwala	-0.76	-0.52	1.39
Barunvalardxn	-2.04	0.33	3.58
Milmilchouky	-2.29	-0.12	-0.23
Kainchitrngle	0.56	2.82	-0.89
Kandli11	-0.51	-0.68	-2.34
Mazrazad4	-0.58	-3.52	5.90
FRI Cros1	1.30	-0.95	-7.42
Tunnel turn	0.31	2.67	8.54
RMSE (m)	**1.86**	**1.81**	**4.38**

Table 1: Validation of DEM for Dehra Dun

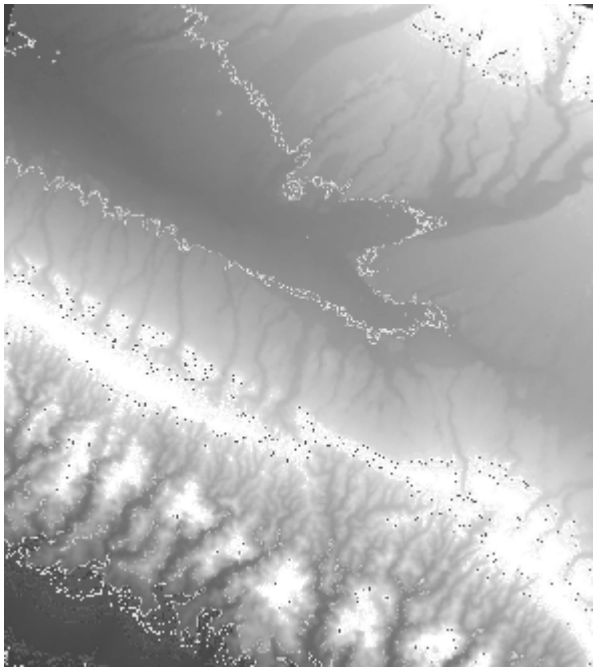

Figure 6: The DEMs generated for Dehra Dun

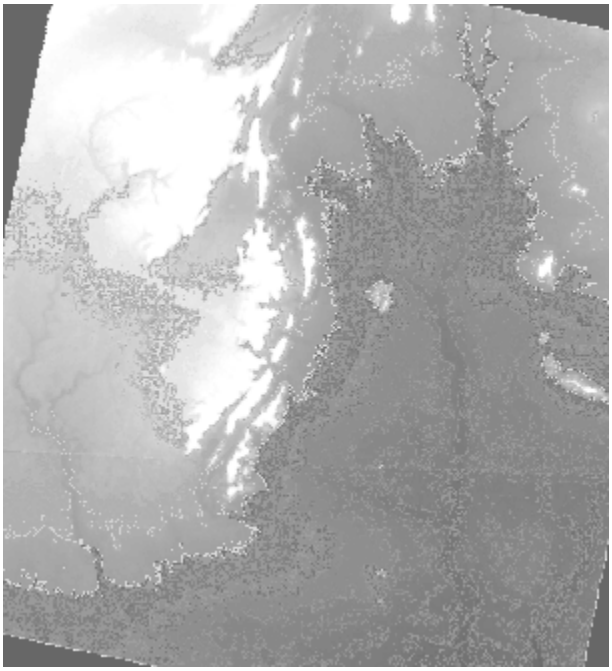

Figure 7: The DEMs generated for Jaipur

Point ID	Residuals in		
	East. (m)	North. (m)	Elevation (m)
Ropara7	1.27	1.22	1.52
Ratanpura10	-0.57	1.42	2.10
Jawahar2	-0.04	-0.63	-2.63
Rampurx3	-0.28	-2.14	3.13
Hirawala5	-2.57	-0.39	-4.30
Ghati7	2.36	3.28	4.82
Sricol	1.66	1.45	3.17
RMSE (m)	**1.56**	**1.75**	**3.28**

Table 2: Validation of DEM for Jaipur

5. RESULTS and DISCUSSION

The comparison between planimetric and elevation values were carried out to find out the differences between DEM and those of DGPS measurements. The result shows that for Dehradun area for the residuals in Easting, Northing and Elevation for 10 check points distributed over the image 1.86m, 1.81m, 4.38m respectively. The larger residuals at one of the check point may be due to the point identification in the hilly area. The RMS error shows the application potential of the stereo data for an accurate orthoimage generation. DEM accuracy also well within the acceptable limit in a moderately hilly terrain.

The second area, namely Jaipur is almost plain except at one or two positions where the Arravalli hills are exposed. The RMS Error in Easting, Northing and elevation are 1.56 m, 1.75 m, 3.28 m and are less compared to the corresponding ones at Dehra Dun. The model accuracy in both the test areas show remarkable confidence level for generating accurate DEMs.

6. CONCLUSION

DEM and Ortho images were generated from CARTOSAT-1 stereo data over parts of Dehra Dun and Jaipur Districts. The study reveals a reasonably accurate DEM with RMS errors less than 4m can be generated using refined RPCs. DGPS measured GCPs were used to refine the RPCs. The along track stereo provides same radiometry for the stereo pair which nullifies the issues in the image matching for across track stereo pair.

ACKNOWLEDGEMENTS

The authors express their sincere gratitude to Dr. R. R Navalgund, Director, and Space Applications Centre for his interest and encouragement in this study. We are also thankful to Dr. K.L.Majumdar Deputy Director, RESIPA for his constant inspiration. We also express our sincere gratitude to Dr. Dadhwal, Director, Indian Institute of Remote Sensing, Dehra Dun for his help and guidance during the DGPS survey at Dehra Dun. Our sincere thanks also to our colleagues Dr. M. M. Kimothi, R. J. Bhanderi, Shweta Sharma and J.A. Vinoth Kumar who made the DGPS survey a grant success.

REFERENCES

Akira Hirano, Roy Welch and Harold Long 2003. Mapping from ASTER Stereo image data: DEM validation and Accuracy assessment. *ISPRS Journal of Photogrammetry and Remote Sensing. 57 356-370*

Al-Rousan, N. Cheng, P. Petrie, G. Toutin, Th. And M.J. Valadan Zooj. 1997. Automated DEM Extraction and Orthoimage Generation from SPOT Level 1B Imagery. *Photogrammetric Engineering & Remote Sensing 63(8) 965-974.*

Bolstad, P.V. and Timothy, S. 1994. An Evaluation of DEM accuracy: Elevation, Slope and Aspect. *Photogrammetric Engineering & Remote Sensing 60 (11) 1327-1332.*

Di, K., R. Ma and R. Li. 2003. Rational Function and Potential for Rigorous Snsor Model Recovery, *Photogrammetric Engineering & Remote Sensing 69 (1) 33-41*.

Fraser, C.S. and Hanley, H.B. 2003. Bias Compensation in rational function of IKONOS Satellite imagery, *Photogrammetric Engineering & Remote Sensing 69 (1) 53-57.*

Gopala Krishna B, Kartikeyan. B, Iyer K.V. Rebantrea Mitra and. Srivastava P.K.,1996 Digital photogrammetric workstation for topographic map updating using IRS-1C stereo imagery, *International Archives of Photogrammetry and Remote Sensing* **31** (1996) (Part B4), pp. 481–485.

Hu, Y. and Tao C.V 2002. Updating Solutions of the Rational Function Model Using Additional Control Information. *Photogrammetric Engineering & Remote Sensing 68 (7) 715-723.*

Jayaprasad P. Narender B. Arya A.S and Ajai 2002. Extraction of terrain parameters from IRS-1C PAN stereo data using Photogrammetric Techniques. *Current science 82 (3) 333-337.*

Krupnilk A.,2000. Accuracy Assessment of automatically Derived Digital Elevation Models from SPOT Image. *American Society for Photogrammetry and Remote Sensing 66 (8) 1017-1023.*

Rodriguez V. Gigord P. de Gaujac A. C., and Munier P. 1998 Evaluation of the Stereoscopic Accuraccy of the SPOT Satellite. *American Society for Photogrammetry and Remote Sensing 54 (2) 217-221*.

Tao C.V Hu, Y. and Jiang, W. 2004. Photogrammetric exploitation of IKONOS Imagery for Mapping Application. *Int. J. Remote sensing 25 (14) 2833-2853.*

Toutin. T. 2004. Comparison of Stereo-Extracted DTM from Different High-Resolution Sensor: SPOT-5, EROS-A, IKONOS-II, and QuickBird. *IEE Transactions on Geo science and Remote Sensing 42 (10) 2121-2129.*

Toutin. T 2006. Generation of DSMs from SPOT-5 in-track HRS and across-track HRG stereo data using spatiotriangulation and autocalibration. *ISPRS Journal of Photogrammetry and Remote Sensing. 60 (3), 170-181.*