GENERATION OF CARTOGRAPHIC QUALITY BASE MAPS USING CARTOSAT-1 STEREO IMAGES IN CONJUNCTION WITH DGPS MEASUREMENTS

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ABSTRACT:

High resolution CARTOSAT-1 satellite with its along track stereo capability has opened a number of applications. With fore and aft images looking at +26° and -5° respectively, the satellite is looking the same terrain forming a stereo pair having spatial resolution 2.5 m and a temporal resolution of, between the pairs, less than a minute. One of the application thought of is the cartographic quality base map generation and its validation. A base map on desired scales is a prerequisite of most of the studies which aims at creation of data base required for Natural resources management, development planning, facility management and infrastructure development Traditionally, these base maps are prepared by surveying. However, during the last three decades, satellite remote sensing has revolutionalized the natural resources survey and mapping. In the present study, Cartographic quality Base maps were prepared for two areas using high resolution CARTOSAT-1 data. The base features were extracted from the ortho images generated using satellite photogrammetric processing using Ground Control Points (GCPs) derived from differential GPS survey. The accuracy of the base maps were assessed by comparing the coordinates, scale, azimuth, area and perimeter with those derived using DGPS survey.

1. INTRODUCTION

Satellite images are being operationally used for preparing a variety of thematic maps, to name a few, land use / land cover, hydrogeomorphology / groundwater prospect, vegetation / forest maps, wetlands, road network and settlement maps etc. One of the primary requirement for thematic map preparation by visual / digital interpretation of satellite data is the base map. Base maps are used for georeferencing of the satellite images / data and also used as a control for interpretation of various features vis-à-vis its geographic locations. Base maps generation and its validation is one of the important requirements in the remote sensing applications in thematic mapping.

Presently, in most of the cases the base maps are generated by extracting the desired features from the Survey of India Topographical sheets. These features, include major roads, railway line, settlements / towns, water bodies, streams and drainages. Only major features from these are extracted for the purpose of base map. In addition, the base map contains attribute information on the name of the settlements / towns, rivers as well as other annotations and coordinates.

Base maps prepared from Survey of India topographical sheets are subject to, some times, restrictions on its use, especially if the digital database is to be created. This has been a cause of concern for the remote sensing applications community who are involved in interpretation and analysis of satellite data.

However, in recent years, GPS are being used for defining the GCP's cartographic Coordinates. Smith and Atkinson 2001, Cook and Pinder 1996 and Kardoulas et al 1996 have used GPS measured GCP coordinates for geometric correction and georeferencing of Landsat and SPOT images. They have also compared the accuracy of rectification using topographic map versus GPS ground control points. Di and Li (2003) and Kay *et al.* (2003) have done Geometric correction for IKONOS image for various applications. Narender et. al (2003)tried to generate and validate Base Map derived from IRS PAN+ LISS III merged product in conjunction with DGPS survey. Raggam (2006) discussed the surface mapping using different methods.

In the present study, an attempt has been made to generate a base map at 1: 25000 scale using CARTOSAT 1 data and DGPS measurements. The most traditional source of GCP cartographic coordinate, for the purpose of georeferencing the satellite images, has been to use topographic maps and a digitizing tablet. The validation / accuracy assessment has been done in both the cases.

2.0 STUDY AREA

Two test sites, one with plain terrain and other with undulating terrain, were selected in the present study. Parts of Dehra Dun Districts, Uttaranchal state (for undulating terrain) and Parts of Jaipur District of Rajasthan state (for plain terrain) were chosen for the study. The extend of the two image pairs were respectively 77° 45' to 78° 05' and 30° 10' to 30° 30' and 75° 45' to 76° 05' and 26° 45' to 27° 00' approximately.

3.0 DATA USED

CARTOSAT –1 Stereo data over Dehra Dun (Path: 0526, Row: 0258, Date Of Pass: 02OCT05, Orbit No: 2224) and Jaipur (Path: 0520, Row: 273, Date Of Pass:18MAY05,OrbitNo:194) were used in the study.

4.0 METHODOLOGY

The major steps involved are shown in Fig. 1

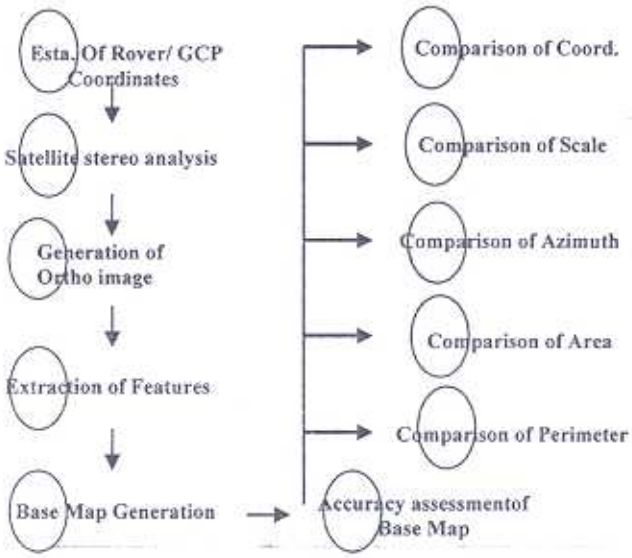

Figure 1. Methodology of base map generation and validation.

4.1 Extraction of Cartosat-1 sub image

Sub-images, of CARTOSAT-1 images corresponding to the above mentioned study area, were extracted from the digital data. Image maps were taken to the field for identifying probable locations for DGPS measurements for establishing GCPs. Features like road intersections; canal and road crossings were selected as GCP's. With the high-resolution images, the intersection of the fields and similar points improves the precision of GCPs and the accuracy of the final product.

4.2 Reconnaissance survey / DGPS Survey

High-resolution images allow one to conduct reconnaissance survey and DGPS survey simultaneously. The workload of identifying the probable points can be done in the lab and one has to check in the field, the feasibility of the points with respect to clear sky and visibility of sufficient number of satellites. While surveying, collateral information including the names of villages/settlements were also collected. The 38 GCPs points selected for DGPS survey in Dehradun and 30 points in Jaipur are shown on Ortho images in Figure 2 and Figure 3.

DGPS survey was carried out by taking one reference, and 37 GCPs at Dehradun. Similarly for Jaipur One reference point and 37 GCPs were established. 72 hrs of observations had been carried out at reference stations and observation for 1 hour was carried at each GCPs. The DGPS survey was carried out during 17th to 20th November 2005 at Dehradun and during 27th to 29th December 2005 at Jaipur.

GPS survey was carried out in differential mode where one receiver was kept at known point called reference station and other was kept at unknown point called rover station. Simultaneous observations were carried out and the data was post processed to get the coordinates. The maximum accurate baseline is restricted by the post-processing algorithm.

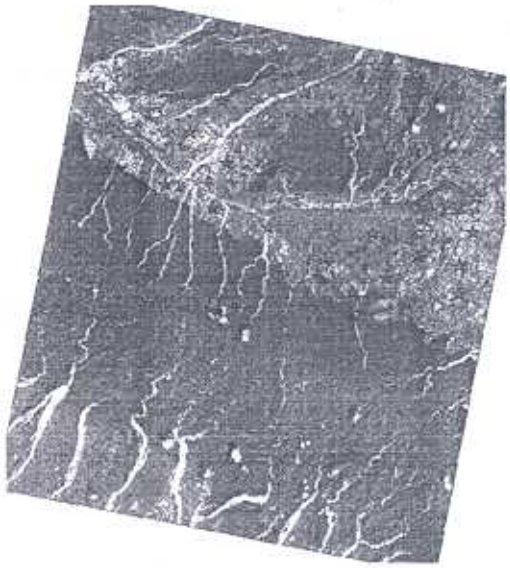

Figure:2 GCP Distribution: Dehra Dun

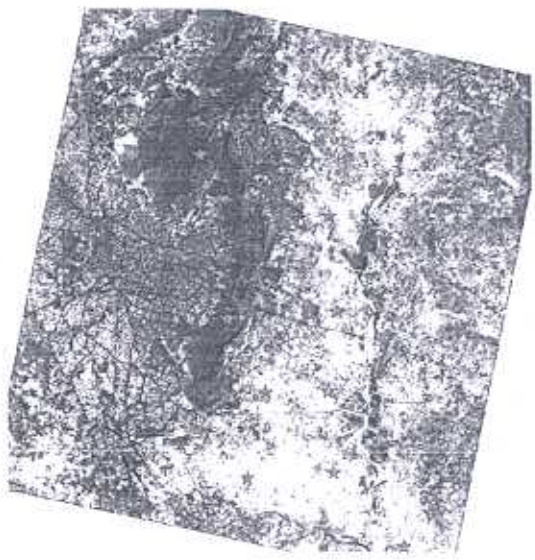

Figure:3 GCP Distribution: Jaipur

The observation period was three days. Four single frequency receivers (Leica GPS System 500). The one hour observation period was set up for rover stations based on our earlier experience. The cut of angle was selected 15° and epoch was set 15 seconds. The former will reduce the multi path effects and the latter will provide sufficient data sets for accurate coordinate computations. GDOP was better than 5 for most of the observation period.

4.3 Computation of GCP Coordinates

Post processing of GPS observations was carried out using Burnese S/W and Static Kinematic Interface (SKI v2.1) software. Processing was done in differential mode. Reference was established by network adjustment with respect to IGS stations. To handle larger baselines of the order of few kilometers, Burnese S/W was taken for establishing the reference coordinates. The GCPs were established with respect to the reference stations. These coordinates were in WGS-84 datum. The accuracy was assessed by closing error. It was within 1 ppm.

4.4 DEM AND ORTHO IMAGE GENERATION

The major issue in the images of moderately undulating or hilly terrain is the presence of the relief displacement due to the perspective geometry. Extracting reliable information requires an ortho image. Cartosat stereo data with different look angles 26° and –5° (Fore and aft images) has a capability to generate a reliable DEM and hence a reliable Ortho Image. The major steps involved in generating a DEM and ortho images using satellite photogrammetry using Rational Function Model are input data and RPCs, generation of epipolar images, identification of control points, check points and tie points for updating RPCs, and generating a TIN / DEM and ortho rectifying the product.
Satellite photogrammetric analysis of the stereo data has been carried out using commercially available S/W. DEM for Dehradun area at 10 m pixel spacing was generated by taking 17 GCPs and validation was carried out using 10 check points. Ortho image was generated at 2.5 m. Similar exercise was carried out at Jaipur after taking 20 GCPs and 7 check points. Base features were extracted from Ortho rectified image corresponding to 7.5' * 7.5' area.
A study was also carried out to assess the accuracy of ortho image and DEM generated using RPC's only and that derived using refined RPCs using GCPs. It has been shown an RMS error in Easting, Northing and Elevation the results are shown in Table 1.

Point id	Differences in meters		
	Easting	Northing	Elevations
Thelpur	91.5	144.9	-52.746
smitpitamber	87.9	143.7	-52.004
ambiwala	85.8	144.6	-52.031
Bhauwala	85.2	149.7	-48.379
Donga	85.5	149.4	-52.213
Barunvalardxn	82.8	147	-49.834
FRIcross	91.5	144.3	-53.875
Mazrazad4	94.2	148.8	-50.671
Paundha10	89.1	147	-55.065
Bulliwchok2	93.9	144.6	-50.911
RMSE	88.82	146.42	51.80549

Table 1: Validation of Ortho image and DEM generated using RPCs and refined RPC's using GCPs for parts of Dehra Dun area

4.5 EXTRACTION OF BASE FEATURES

The base map, used for preparation of thematic maps by satellite data interpretation, contains the features such as major roads, railway line, settlements, stream/drainage and water bodies. These features were extracted from ortho image by onscreen digitization.

4.6 BASE MAP GENERATION

All the vector layers extracted are taken into ARC / INFO environment. Editing of various vector layers were carried out. Final base map showing road/rail networks, canals, water bodies major settlements/towns along with the annotations is given in Figure 4 for Dehra Dun and Figure 5 for Jaipur. As mentioned earlier, the base map is in WGS-84 datum and UTM projection.

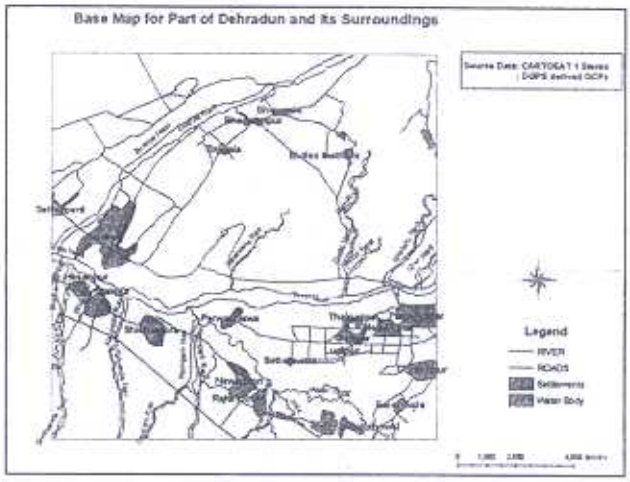

Figure 4: Base Map of Dehra Dun and Surroundings at 1:25000 scale

5 ACCURACY ASSESSMENT OF BASE MAP

Validation/accuracy assessment of the base map has been carried out by:

i) Comparing the cartographic coordinates of the control points on the base map with the respective coordinates as established by GPS measurements.

ii) Evaluating the cartographic quality of the maps using the following parameters.
   - i) Scale
   - ii) Shape (angular distortions)
   - iii) Area

iv) Perimeter

5.1 COMPARISON OF COORDINATES

Coordinates of all the checkpoints as extracted from base map were compared with that of the respective GPS established coordinates. The differences in latitude and longitude were computed and are given in Table-2 for DehraDun and Table-3 for Jaipur.

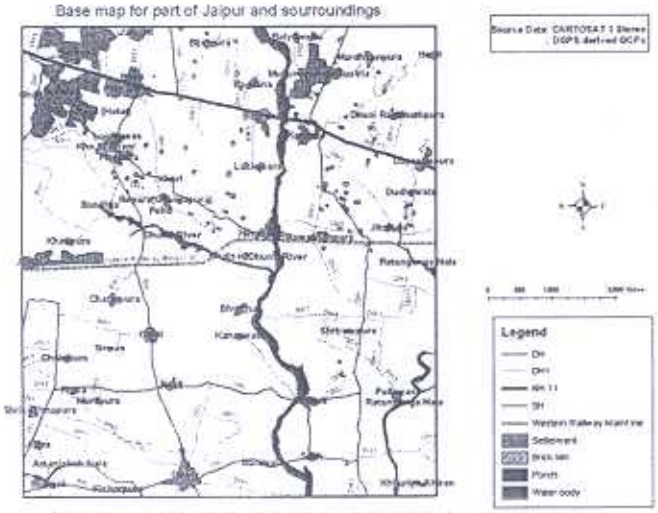

Figure 5: Base Map of Parts of Jaipur and its Surroundings At 1:25,000 scale

Point id	RESIDUALS (m)	
	LON	LAT
Ropara7	-5.78	-1.15
Ratanpura10	2.09	1.138
Jawahar2	-3.25	1.11
Rampurx3	2.51	-0.37
Hirawala5	4.22	2.74
Ghati7	-0.63	-2.94
Sricol	-0.62	-0.27
RMSE	**3.24**	**1.70**

Table-2 Comparison of Coordinates: Dehra Dun

5.2 EVALUATION OF CARTOGRAPHIC QUALITY

5.2.1 Comparison of Scale

The baseline distances between control points on base map were compared with the corresponding baseline distances computed from GPS observations. The results are shown in Table-4 for Dehra Dun and Jaipur.

5.2.2 Comparison of Shapes (Angular Distortions)

The angles of baselines from true north (azimuth) on base map were compared with that computed from GPS observations. The results are shown in Table- 4.

Point id	RESIDUALS (m)	
	LON	LAT
thelpur	-4.30	1.86
selakui	-1.87	-0.42
ambiwala	-0.76	-0.52
barunvalardxn	-2.05	0.33
milmilchouky	-2.29	-0.12
kainchitrngle	0.56	2.82
kandli11	-0.51	-0.68
mazrazad4	-0.58	-3.52
fricros1	1.30	-0.95
tunnelturn	0.31	2.67
RMSE (m)	1.86	1.81

Table-3 Comparison of Coordinates: Jaipur

5.2.3. Comparison of Areas (Equivalence)

A surface was created from the GCP coordinates and was projected in to the UTM projection in WGS 84 datum. The area extracted from the base map was compared with the corresponding area. Plain area was taken so that the area represented by both surfaces are identical. A comparison of the perimeter was also carried out. The differences in the areas are mainly due to the human error introduced while digitizing even at the finer level and also due to the larger area exposed in the satellite imagery. The results are shown in table 4.

5.2.4 Comparison of Perimeter

The perimeter of the corresponding triangles, computed from the base map and that of DGPS measurement were compared and tabulated in the table 4.

6. RESULTS & DISCUSSION

Stereo analysis of CARTOSAT data was carried out using GCP's established by GPS measurements in differential mode. If proper GCPs are not available one has to only depend on RPCs. To see the accuracy of the ortho images generated using RPCs and that derived from the Refined RPCs, DEM and ortho images have been generated in two methods. The validation results in table one shows that for applications where the accuracy matters it is not advisable to use RPCs only. One has to refine the RPCs using GCPs. Fine tuning of the number and distribution of GCPs for accurate DEM and ortho images is thought in the future studies.

The accuracy of the Ortho images generated using RPCs refined using accurate GCPs show that planimetric accuracy of the ortho images were less than a pixels for both Dehra Dun and Jaipur (Table 2 and 3). Proper identification of points on hills covered by dense forest is very difficult.

Table-4 shows the % differences in scale, azimuth, area and perimeter in those computed between base map and DGPS measurement. 5 base lines and areas are selected for the comparison in Dehra Dun. Six baseline and five areas were seleted at Jaipur. % differences are very less in all cases and

shows that an accurate base map can be prepared using the CARTOSAT stereo data.

% Differences between Base Map and DGPS measurements in			
Scale	Azimuth	perimeter	Area
Dehra Dun			
-0.016	0.213	0.004	0.001
0.038	-0.026	0.025	0.004
0.108	0.077	0.023	0.006
0.066	0.034	-0.010	0.001
0.036	-0.002	0.024	0.008
Average % differences			
0.046	0.059	0.013	0.004
Jaipur			
-0.075	0.015	0.020	0.012
0.064	-0.049	0.011	0.009
0.004	-0.074	0.008	0.001
0.027	-0.046	-0.004	-0.002
-0.027	0.001	-0.013	-0.005
0.046	-0.053		
Average % differences			
0.006	-0.034	0.004	0.003

Table 4: Showing comparison of scale azimuth, area and perimeter between Base Map and DGPS observations

7. CONCLUSIONS

Feasibility study on the preparation of base map (to be used in preparation of thematic maps by interpreting satellite imageries) using CARTOSAT-1 data in conjunction with GPS measurements in differential mode has been carried out. GPS measurements in differential mode has been used to establish the cartographic coordinates of the GCP's which are used for orthorectofication of the imagery as well as base map validation. The base map features namely major roads, railway line, major settlements / towns, main rivers / streams and water bodies have been extracted from the Ortho iamge.

The final base map is at 25,000 scales in UTM projection and WGS-84 datum. The assessment of the locational accuracy of the base map vis-à-vis GPS observations shows that the base map is within the standards followed, i.e. 6.25 m at 1:25000 scale. Evaluation of the cartographic qualities of the map in terms of scale, equivalence and conformality shows that the accuracy standards in terms of these parameters are also acceptable.

The present study has demonstrated that the base map, for thematic map preparation by satellite data interpretation, can be prepared using CARTOSAT-1 stereo images along with the GPS measurements.

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