AN INTEGRATED APPROACH FOR TOPOGRAPHICAL MAPPING FROM SPACE USING CARTOSAT-1 AND CARTOSAT-2 IMAGERY

Amitabh*, B. Gopala Krishna, T P Srinivasan and P K Srivastava

Space Applications Centre, Indian Space Research Organisation, Ahmedabad -380 015 (ISRO), India - (amitabh, bgk, tps, pradeep)@sac.isro.gov.in

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ABSTRACT:

Topographical mapping constitutes an integral component of the process of managing land resources, and mapped information is the common product of analysis of remotely sensed data. High resolution space-borne remote sensing image data show a high level of detail and provide opportunities to be integrated into mapping applications. For mapping, the geometric potential and also the information content in the satellite images are important. Today Cartosat-1 provides the along track stereoscopic coverage at 2.5 m resolution globally while Cartosat-2 acquires images at less than 1 m which is comparable to any of the globally available high resolution satellites. Topographic maps are designed to be a multi-purpose base maps and typically depict a variety of map features on the landscape on a particular scale. A topographic map contains terrain, forest, vegetation, roads, lakes, buildings, and geographic names. From Cartosat-1 data, terrain (DEM) can be extracted while the achieved accuracy of the DEM is depending upon the pixel size, the base to height relation, the contrast and slope of the area, but also the time interval between imaging both scenes. On these parameters of accuracy Cartosat-1 fits perfectly. The other information content (viz- forest, vegetation, roads, lakes and buildings) have been extracted by Cartosat-1 stereo images (3-D feature extraction) and further can be supplemented by Cartosat-2 (2-D feature extraction). DEM generated from Cartosat-1 data is being used for ortho-rectification of Cartosat-2 data. Older maps, City/district maps and Mobile mapping system (Palmtop & hand held GPS) are the other sources to collect the geographic names. There is a tremendous reduction in the ground truth data collection (field verification) by using Cartosat-1 and Cartosat-2 datasets together. The accuracy and morphologic information contents in both the satellites are sufficient for most of the mapping application. This paper describes a methodology to generate/update 1:25000 topographical map using Cartosat-1 and Cartosat-2 images in an integrated approach. This approach include data pre-processing, modeling of space imagery, DEM and Ortho-image generation with or without GCPs, accuracy improvement of DEM and Ortho-image, Image to Image registration, 2D and 3D feature extraction and mapping in a standard cartographic environment. This study also provides a guideline for the 2D or 3D extraction for different feature types.

1.0 INTRODUCTION

Digital mapping constitutes an integral component of the process of managing land resources, and mapped information is the common product of analysis of remotely sensed data. High resolution space-borne remote sensing image data show a high level of detail and provide opportunities to be integrated into mapping applications. For mapping, the geometric potential and also the information content in the satellite images are important. The demand for accurate and up-to-date spatial information is increasing and its availability is becoming more important for a variety of tasks. Today's commercial high-resolution satellite imagery (HRSI) offers the potential to extract useful and accurate spatial information for a wide variety of mapping and GIS applications. The extraction of metric information from images is possible due to suitable sensor orientation models, which describe the relationship between two-dimensional image coordinates and three dimensional object points.

ISRO remote sensing program provides a constellation of polar satellites at various resolutions to map the globe. Cartosat-1 and Cartosat-2 are the two ISRO satellites used for cartography. Cartosat-1 was launched on May 2005 with two cameras fore and aft. Cartosat-1 provides the along track stereoscopic coverage at 2.5 m resolution globally. One of the most significant application of Cartosat-1 is to generate digital elevation models (DEMs). A DEM is a discrete expression of topography in a data array, consisting of a group of planimetric coordinates (X,Y) and the elevations (Z) of the ground points and the breaklines. Cartosat-2 is another satellite of ISRO having a single panchromatic camera which acquires images at very high resolution (less than 1 m) which is comparable to any of the globally available high resolution satellites. This satellite was launched in January 2007 by PSLV. With the advent of image processing and remote sensing systems, the use of imagery for collecting geographic features has become more frequent. This imagery included: radiometric corrected imagery, geometric corrected imagery and ortho-rectified imagery. Each type of imagery has its advantages and disadvantages, although each is designed to the collection of geographic information in 2D and 3D [1].

The typical digital mapping project requires DEM generation, Contour interpolation, Ortho-image generation and Feature extraction. Topographic maps are designed to be a multi-purpose base maps and typically depict a variety of map features on the landscape on a particular scale. A topographic

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* **Corresponding author**

map contains terrain, forest, vegetation, roads, lakes, buildings, and geographic names. Synthesizing the concepts associated with photogrammetry, remote sensing, GIS, and 3D visualization introduces a new paradigm for the future of digital mapping. Correctly combining height information with existing 2D maps has a great potential for a fast, accurate and highly automated generation of maps [2].

This paper describes a methodology to update 1:25000 topographical map using Cartosat-1 and Cartosat-2 images in an integrated approach. The other objectives are to test the capability of feature extraction in stereo mode from the Cartosat-1 stereo data and comparison between features directly traced from Cartosat-2 ortho-image. This approach include data pre-processing, modeling of space imagery, DEM and Ortho-image generation with or without GCPs, accuracy improvement of DEM and Ortho-image, Image to Image registration, 2D and 3D feature extraction and mapping in a standard cartographic environment. This study also provides a guideline for the 2D or 3D extraction for different feature types.

2.0 STUDY AREA

Covering an area of 7.5'X7.5' of the test site is bound between geo-coordinates 17^0 22'30" N to 17^0 30' N and 78^0 22'30" E to 78^0 30' E. The study area forms part of Hyderabad City and the general elevation of the area ranges from 400 m to 630 m above mean sea level.

3.0 INPUT DATASETS

Cartosat-1 stereo images and Cartosat-2 datasets have been acquired for the study area. Both the satellite datasets were accompanied by respective RPC files. The verification was made for the datasets after receiving the datasets. There were 20 Ground Control Points used for this project for modeling and accuracy evaluation.

4.0 METHODOLOGY

A systematic framework of the algorithm used to generate digital maps is presented in figure-1. The analysis of methodology can be grouped into three stages. The first stage incorporates the Cartosat-1 processing for DEM generation and 3D feature extraction. The second stage related to Cartosat-2 processing and feature extraction in 2D. The final stage used a set of overlay decision rules to inject a knowledge-based feature comparison based on suitable features for mapping from the two satellites.

A project for DEM generation and stereo processing is created in Lieca Photogrammetry Suite (LPS) S/W and the Cartosat-1 stereo images were imported. The interior orientation has been computed for both fore and aft camera images (BandA & BandF) using RPC. 15 GCPs have been identified on both the images for Exterior orientation computation. Image matching has been performed between the fore and aft images. A total number of 6326 match points called as Tie points have been generated at more than 0.80 correlation coefficients. Triangulation has been performed with RPC at 2nd order polynomial refinement. The regular DEM has been generated at 10 m grid interval. Finally Ortho-image is generated and features have been extracted in 2D mode by on screen digitization. The same model has also been used for 3D feature extraction. All the man made structures (buildings, fence etc.) and Trees have been captured in 3D environment in stereo

mode. The accuracy achieved for DEM and orthoimage is better than 5 m.

The Cartosat-2 image has been registered with Cartosat-1 ortho-image using the Automatic Point Measurement (APM) Software tool [3]. APM uses image matching technology to automatically recognize and measure the corresponding image points between the two images. APM deliver the coordinates of evenly distributed corresponding points between an input image and a reference image. The search and cross-correlation window sizes for matching were set to 17 and 11 respectively. The window size for least square matching for this project has been taken as 10 pixels. The limit for cross correlation coefficient was 0.80. A total of 500 well distributed points between the images have been generated at an RMS 0f 0.42 pixels with a standard deviation of 0.25. An image to image affine transformation was performed to register the Cartosat-2 image with respect to Cartosat-1 image. Final resampled Cartosat-2 image has also been visually compared with Cartosat-1 orthoimage. List of features captured in 2D and 3D mode from Cartosat-1 and Cartosat-2 ortho-images is given in table-1.
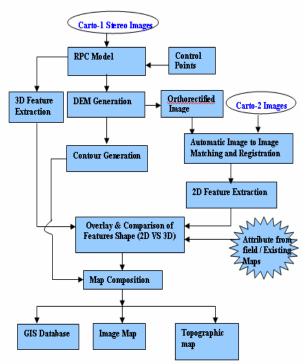

Figure 1: Mapping schematic work-flow frame work

5.0 RESULTS AND CONCLUSIONS

A comparative study has been made for the features extracted in 2D from Cartosat-1 and Cartosat-2 ortho-images and it has been observed that feature extracted from Cartosat-2 is giving better result with respect to features shape and size. This is obvious due to the higher resolution of Cartosat-2 with respect to Cartosat-1. The resolution difference has been shown in figure 1(a) and 1(b). It has been observed that capturing features in the city like Hyderabad using Cartosat-1 in 2D is very difficult. One can only capture the building blocks from Cartosat-1 [figure-2] which depends on the density of buildings. But buildings can be captured in stereo mode in 3D [figure-3] with Cartosat-1 data, which nearly match with those derived from Cartosat-2 in 2D mode.

S. No.	Level-1	Mode of Feature Extraction	Level-2
1	Communication Line	2D (C1 & C2)	Road with Trees
			National Highway
			City Roads / Streets
			Cart Track
			Railway Line
			Rail under Construction
			Road Under Construction
2	Construction	2D & 3D	Building / Building Blocks
			Houses in Rural Area
			Stadium
			Aerodrome
			Railway Station
			Industrial area
3	Hydrography	2D (C1 &C2)	River / Stream permanent
			River / Stream Temporary
			River with trees
			Canal
			Lake / Pond / Water bodies Permanent
			Lake / Pond / Water bodies temporary
			Barrage / Reservoir
4	Orographie	3D (C1)	Index Contour
			Contour Normal
5	Vegetation	2D / 3D	Vegetation Limit
			Forest
			Plantation / Trees

Table – 1: List Of features Captured from Cartosat-1 and Cartosat-2 Orthoimages in 2D and Cartosat-1 stereo mode in 3D

Terrain (DEM) can be accurately extracted from Cartosat-1 stereo data, while the achieved accuracy of the DEM is depending upon the pixel size, the base to height relation, the contrast and slope of the area, but also the time interval between imaging both scenes. On these parameters of accuracy Cartosat-1 fits perfectly. The DEM from the Cartosat-1 data has been generated at 10 m grid interval as shown in figure-4. The other information content (viz- forest, vegetation, roads, lakes and buildings) have been extracted by Cartosat-1 stereo images (3-D feature extraction) and further supplemented by Cartosat-2 (2-D feature extraction) as in figure-5. Older maps, City/district maps and Mobile mapping system (Palmtop & hand held GPS) are the other sources to collect the geographic names. There is a tremendous reduction in the ground truth data collection (field verification) by using Cartosat-1 and Cartosat-2 datasets together in an integrated manner. The accuracy and morphologic information contents in both the satellites are sufficient for most of the mapping application at the 1:25000

scales, which can further be extended to 1:10000 scales (with the information content as shown in figure 1(a)).

Figure-1(a) Cartosat-1 and Cartosat-2 images at 1:10000 scale

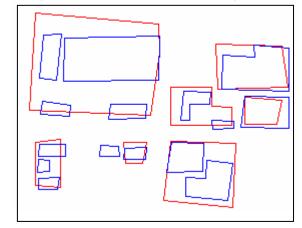Figure-1(b) Cartosat-1 and Cartosat-2 images at 1 m

Figure-2(a) Comparison of features extracted in 2D mode (Red: Cartosat-1 & Blue: Cartosat-2)
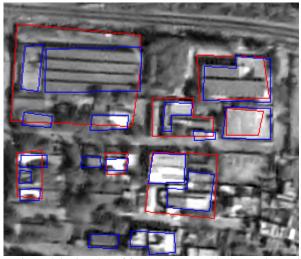
Figure-2(b) Overlay of features extracted in 2D mode (Red: Cartosat-1 & Blue: Cartosat-2) over Cartosat-2 ortho-image
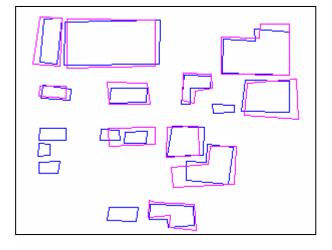

Figure-3(a) Comparison of features extracted in 2D mode from Cartosat-2 and 3D mode from Cartosat-1 (Magenta: Cartosat-1 & Blue: Cartosat-2)
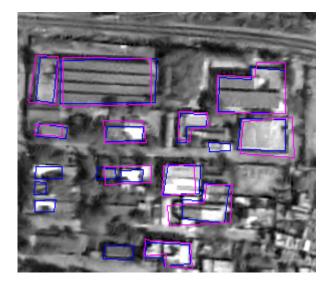

Figure-3 (b) Overlay of features extracted in 2D mode from Cartosat-2 and 3D mode from Cartosat-1 (Magenta: Cartosat-1 & Blue: Cartosat-2) over Cartosat-2 Ortho-image
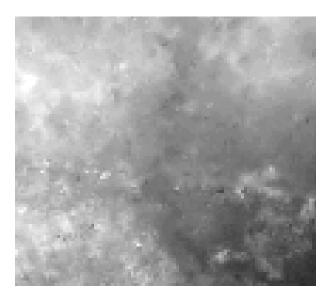

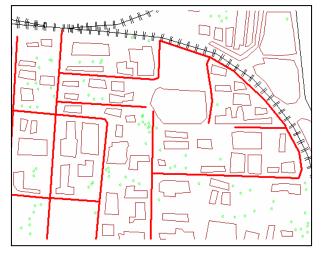Figure-4 Overview of a portion of the DEM generated

Figure-5 Overview of a portion of the final map generated

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