ANALYSIS OF DEMs FROM ACROSS TRACK STEREO PAIRS FOR A PART OF KACHCHH REGION

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ABSTRACT

Orbital stereo data is acquired by covering same area from two exposure stations in space with oblique viewing capability. It is used for generating digital elevation models (DEM) and three dimensional viewing of the terrain in a softcopy photogrammetric workstation. A good base to height ratio (B/H), usually greater than 0.5, is necessary for generation of good quality absolute DEM. Processing of the data requires a few GCPs, image matching and interpolation. Therefore DEM accuracy also depends on these factors. Good image matching is one of the most important factors in governing the altitude accuracy. Two IRS 1C/1D PAN stereo pairs covering the part of Kachchh sedimentary basin were processed for extraction of DEM and its analysis for geological study. The DEM image in the first pair clearly shows the drainage, the topographic high and variation of elevation in the hilly part of the terrain. The topographic high (water divide) with brighter tone on gray scale image indicates a higher elevation than adjoining terrain. The large difference in solar elevation angles of the images of second pair results in difference in radiometry and finally resulting in difference in image matching hence a poor DEM is obtained. A height accuracy of 5-15m is obtained in first case whereas in second case due to large plannimetric errors a height evaluation has not been attempted. Though Cartosat-1 satellite, a dedicated Indian mission for along track stereo acquisition and DEM generation, is already in orbit, however experience gained from using across track PAN data from Indian Remote Sensing satellites IRS 1C and 1D, is highlighted here.

Introduction

Stereo imageries or the pair of imageries of the same ground area can be acquired by the oblique viewing capability of the sensor(s) mounted on the satellite. This type of data is normally used for generating digital elevation models (DEM) and three-dimensional viewing of the terrain in a softcopy photogrammetric workstation (Rao *et al.*, 1996; Al-Rousan *et al.*, 1997; Srivastava *et al.*, 1997; Toutin 2002). While 3D viewing helps in improving interpretation of the data, DEM finds use in many applications such as in generation of orthoimages (Ganas and Athanassiou, 2000), change detection in glaciers (Kulkarni. and Bahuguna 2002; Bahuguna *et al.*, 2004) and extracting information from lineaments (Jordan and Schott, 2005) etc. However, the application potential of stereo data depends on the quality and the accuracy of the DEM extracted. It is a function of spatial resolution of the data, GCPs, B/H ratio of stereo pair and automatic stereo matching or stereo correlation. The work described in this paper highlights the role of image matching on DEM accuracy. For this purpose a few stereo pairs from PAN sensor mounted on Indian remote sensing missions IRS 1C and its successor 1D covering mainly low relief terrains have been analysed. PAN sensor acquires data with spatial resolution of 5.8 m and for stereo acquisition it can be tilted upto ± 26 ° across track.

Study area

Two IRS 1C/1D PAN stereo pairs covering the part of Kachchh sedimentary basin were processed for extraction of DEM and its analysis for geological and geomorphological study. This region a east-west oriented pericratonic rift basin of India (nearly 400 km × 150 km block) bounded between Lat. 22° 30'& 24° 30' N and Long. 68° & 72° E. Mesozoic, Tertiary and Quaternary sediments fill up the Kutch basin. It is characterized by conspicuously high hills and extensive low plains (Fig 1). The highlands are the areas of uplift whereas the plains of low lands represent structural basins between the uplifts and are made up of alluvium, mud and salt flats (Ranns). Regionally, the structure of the Kachchh is characterised by a series of uplifts along master faults (upthrusts) and along the Delhi tectonic trend that were reactivated during geologic time. The Kachchh region abounds in evidences of continued tectonism since Mesozoic times and

its physiography is a clear manifestation of active tectonism. The altitude within the study area varies from 10 to approx. 350m msl (Biswas S.K., 1993).
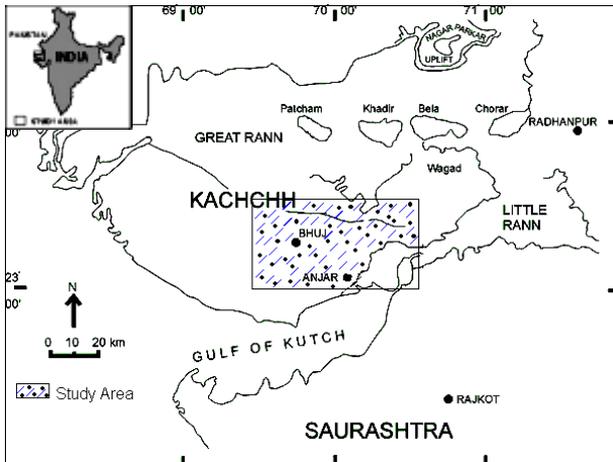

Figure 1: Location map of the study area. The stereo pair covers part of this test area.

DEM extraction from satellite stereo data- an outline

The software used for the generation of the DEM and the orthoimages by processing of IRS PAN stereo data in digital mode has been developed at Space Applications centre, ISRO, Ahmedabad (Mitra *et al*., 1994; Gopalakrishna *et al*., 1998; Srivastava *et al*., 1998). It has been developed on an UNIX platform on Indigo 2 R 10000 system. The essential components of DEM generation from satellite stereo data are as following:

Photogrammetric model

A Photogrammetric model is the base for entire DEM to be generated. It is set up using GCPs identified on the pairing images. It requires minimum four GCPs to get invoked initially. The model indicates errors in GCPs in terms of latitude, longitude and altitude. Though the use of topographical maps is not valid for absolute positioning however the relative accuracy can be determined for varying conditions of B/H or terrain slope. Mostly sharp bends of roads or canals or railway lines or confluences of the streams are taken, as GCPs. The contour interval at 1:50000 scale of maps for this region is 20 m. Table 1 shows GCP model error in the two pairs. The table shows that RMSE of northing easting and height is relatively better in second case than first.

Image matching

Hierarchical matching strategy is used (implemented) operationally for IRS-1C/1D stereo data processing in deriving DEM. (Gopalakrishna, 2000). At the highest level of pyramid the seed points are identified manually or through an interest operator on reference image and blind correlation of these points in the other image i.e. the match points of a particular level will be used to establish the local correspondence between the stereo pair images at next level. After this at each

level first interest operator is obtained to get some candidate points for match. Local mapping using the previous level's match point establishes a correspondence with the second image for all the interest points. Then digital correlation finds the exact location of the interest points in the second image. Blunder detection at each stage eliminates mismatches, if any. This procedure is repeated upto the last level i.e. level 1, full resolution. The match points obtained in the last level are the conjugate points used for DEM generation. However, the matching may suffer from good correlation on shadows, homogeneous areas and steep sloped surfaces etc (Kasser and Egels, 2002).

GCPs	Easting (m)	Northing (m)	Height (m)
1	-8.75	9.59	16.57
2	20.53	18.96	11.26
3	2.32	-17.95	2.49
4	-20.09	-14.16	-11.33
RMSE (1st pair)	15.057	15.605	11.574
RMSE (2nd pair)	14.245	10.174	7.768

Table 1: GCP model error of DEM generated for the study area, along with RMSE.

Interpolation

An irregular DEM is generated based on the estimation of coordinates at the match points. For rest of the area coordinates are interpolated from the known coordinates at match points making a regular DEM. Weighted average method of interpolation has been incorporated as an algorithm in the software.

Accuracy assessment

Coordinates derived from DEM were checked against their corresponding locations on topographical maps in order to compare the deviation. Some geomorphic features were selected as checkpoints. The deviations were analysed with respect to results of image matching during stereo data processing.

Results and discussion

Two stereo pairs were processed for DEM generation. DEMs were converted to a gray scale image. In the processing of stereo pair II the gray scale image was not formed corresponding to topography. This is because the DEM had poor plannimetric or elevation accuracy. The probable reason for this distortion is image matching. In first pair 170243 match points are obtained against 185069 interest points whereas in second pair only 21492 match points are obtained against 137172 interest points (Fig 2).

The image matching, which is analogous to registration of two images in the X and Y direction, depends on angle of tilt and the dates of image acquisition and slope of the terrain. Image matching is the process, which identifies a match point of the pairing images based on radiometric consideration around a specific pixel. The large difference in solar elevation angles of the images of second pair might have resulted in the difference in radiometry of the pairing images (Table 2) and finally resulting in difference in image matching.
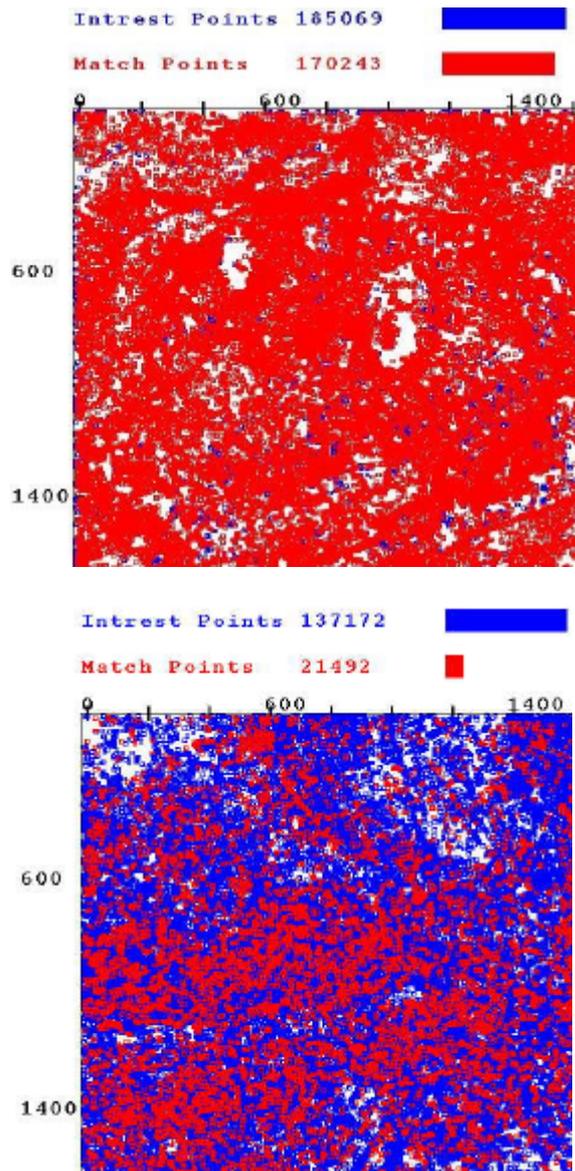
Intrest Points 185069

Match Points 170243

Intrest Points 137172

Match Points 21492

Figure 2: Comparison of the image match points as obtained from stereo pair I and pair II. Note the poor image matching in stereo pair II.

In the present study we find that in one of the pairs, both the images have reasonable good tilt of the order of 18.31° and - 19.34°, whereas in the second pair the tilt are -17.46° and 15.42°. In the first case the sun elevation angles are 71.66° and 69.18° whereas in other pair the angles are 58.251° and 46.799°. We find that the tilt angles of pairing images in both the stereo pairs are comparable. This suggests a good B/H ratio for the two stereo pairs. Referring back to table 1 we also see that RMSE of northing easting and height is better in second stereo pair than the first which should result in better DEM accuracy. However the dates of image acquisition are different for pairing images in stereo pair II. For good image matching dates of image acquisition should be as close as it can be so that there is no change in the scene radiometry of the pairing images. Referring table 2, we find that there is large difference in solar elevation angles of the second pair than the first pair. Probably this is the reason for difference in radiometry. As the B/H ratio increases, the accuracy of height determination improves. The time of image acquisition in case

of IRS 1C and 1D satellites at equator is 10:30 AM. As a result of tilting of sensors, viewing from different locations cause different illumination conditions at the time of image acquisition. Therefore the Cartosat -1 data will be much useful than the across track data.

Specifications	Stereo Pair I		Stereo Pair II	
	Left Image	Right Image	Left image	Left Image
Path-Row	90-55	90-55	90-55	90-55
Sub-scene	C8	C8	D9	D8
Date of acquisition	13-05-2003	25-04-2003	16-03-1997	10-11-1997
View Angle	18.311°	-19.339	-17.464	15.421
Scene Centre (Lat)	23.261°	23.286	23.262	23.293
Scene Centre (Long)	70.03°	70.022	70.068	70.189
Sun Elevation angle	71.66°	69.18°	58.251°	46.799°

Table 2: Specifications of IRS-1C/1D PAN stereo data covering parts of the Kachchh area in an around the Kas Hills, Jawaharnagar, Gujarat.

A height accuracy of 5-15m is obtained in first case (Table 3) whereas in second case due to large plannimetric errors a height evaluation has not attempted. Though generation of good quality DEM from second pair was not appreciable however the depth perception of the landforms was possible using either of the stereo pairs. Depth perception helped in identification of circular ridges and regions of breaking slopes, the level of water in the reservoir etc. The study suggests the advantages of stereo data over mono data in identification of landforms and characterizing the terrain provided the images have good correlation in radiometry.

Check Points	Elevation map/topo (mts)	Elevation DEM (mts)	Deviation
1	96	81.2	-14.8
2	98	84.67	-13.33
3	79.1	74.30	-4.8
4	56	57.23	1.23
5	55	51.44	-3.56
6	40	45.86	5.86
7	53.8	62.93	9.13
8	43.8	52.53	8.73
9	88	81.05	-6.95
10	80	71.25	-8.75
11	50	54.14	4.14
12	80	79.59	-0.41
13	53	58.07	5.07
14	43	48.82	5.82

Table 3: Comparison of elevation for checkpoints derived from stereo data based DEM and SOI topographical map for stereo pair I.

The DEM image in the first pair clearly shows the drainage, the topographic high and variation of elevation in the hilly part of the terrain. The topographic high (water divide) with brighter tone on gray scale image indicates a higher elevation than adjoining terrain. Without this gray scale image it is extremely difficult to identify or map the water-divide on the PAN scene. Considering its continuity, smoothness and shape, probably this is the expression of sub-surface ridge dividing the area in northern and southern half. A prominent NE-SW lineament is seen conspicuously on a gray scale image (Fig 3). The lineament finds its reference as Bhuj-Bhachau lineament in a few geological literature of this area of the past. However considering its prominence and length and since no other major lineament is seen in this study area the lineament is worth further investigations.
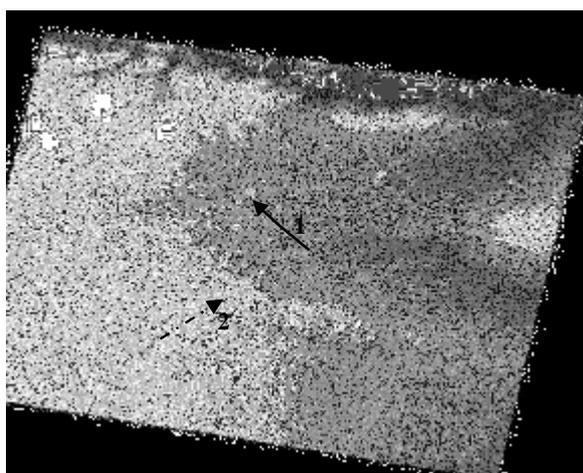

Figure 3: The final DEM prepared from stereo pair 1. Note the prominent hill ranges and the prominent river channels. The arrow marked 1 indicates the prominent NE-SW trending lineament whereas the arrow denoted 2 indicates the water-divide which is not so clearly visible in the PAN image.
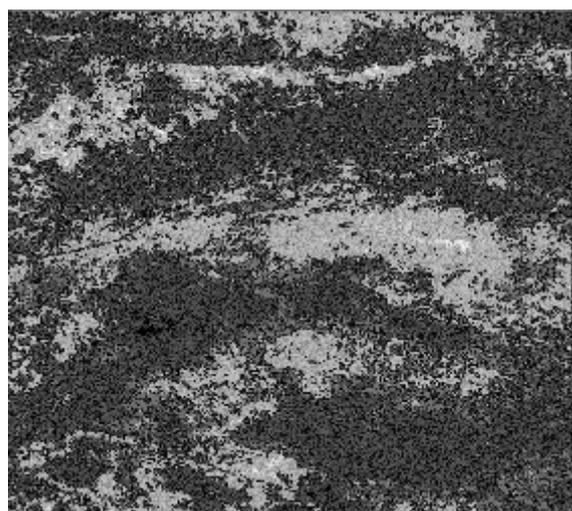

Figure 4: The corresponding PAN image of the study area, wherein the hill ranges are clearly visible but minor variations in relief are not conspicuously seen.

The PAN image of the study area shows the Kas hill ranges at the top along with minor geomorphic features (Fig 4). Though the terrain relief is fairly observed in the PAN image however the minor variation of relief are not conspicuously seen on the image. Secondly the lineaments are not sharply seen on the PAN image than as on the DEM image.

Conclusion

DEM generated from stereo data has been found useful for the interpretation of lineament and topographic high delineation. The image matching plays a very important role in controlling the altitude accuracy indirectly. The two pairs used in this study have a good B/H ratio however due to difference in Sun elevation angle on different dates of image acquisition in one of the pair image matching has been found to be poor resulting in the mis-registration of pairing images and ultimately affecting the geographical locations of features.

Acknowledgements

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