TERRAIN PARAMETER RETRIEVAL USING IRS 1C/1D STEREO DATA IN CONJUNCTION WITH DIFFERENTIAL GPS MEASUREMENTS

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ABSTRACT

In the past few decades due to enormous development in satellite photogrammetry, more opportunities are available to have a stereo pair from the space borne missions. Indian Remote Sensing satellites (IRS 1C/1D) with its steering capacity to ± 26° provides an opportunity to satellite stereo analysis. The present study was aimed at framing the methodologies for DGPS survey, data analysis, establishment of GCP coordinates and stereo data analysis. Two study areas were selected corresponding to moderately undulating to hilly terrain. DGPS survey was carried out to establish GCPs. About 64 GCPs were established altogether at two different sites. DEM and Ortho images were generated and validated using DGPS measurements. An attempt was also carried out to automatically extract drainage networks and was validated using those available at 1: 50000 toposheets. For moderately undulating terrain, DEM and Ortho images have been generated using Eight GCPs. The RMS error of GCPs were 8.13 m, 16.31 m and 8.33 m along Easting, Northing and Elevation respectively and that of 5 check points were 20.02 m, 17.10 m and 17.97 m respectively. Morphometric analysis of the drainage pattern has also been carried out by visual comparison with those in the topographic map and overlying on the Ortho image. Coordinate comparison on ortho resulted in 7.932078 m and 14.86542 m RMSE at latitude and longitude respectively. For hilly terrain, 6 GCP's, 102 tie points and three check points were used to assess the model accuracy and for generation of DEM. RMSE (planimetric) of the model for 6 GCPs and 2 check points are respectively 4.25m; 3.78m and 15.30m 22.9m at Easting and Northing respectively. DEM accuracy at GCPs (5) and Check Pts (2) were 17.0 m and 51.8m respectively. The DEM was generated at 23.4 m pixels size.

1. INTRODUCTION

Terrain parameters such as elevation, slope, aspect, contours, drainage pattern etc. are often required as input in a large number of applications such as landslide hazard zonation, cellular phone network planning, watershed management, selecting sites for sewage treatment plants, solid waste disposal in urban area, alignment of rail/road network, catchment area treatment, siting of rain water harvesting structures, wetland conservation and management etc. In addition these are also needed in modelling of soil loss, runoff and site suitability analysis. Conventionally these parameters are obtained through field measurement/surveys or from existing topographic maps depending on the purpose and level of information required. The above-mentioned terrain parameters can be extracted from Digital Elevation Model (DEM).

Toutin (2004, 2006) extensively validated the DEM derived from various platforms. Rectification accuracies were dealt by Cook and Pinter (1996). DEM extraction from SPOT stereo pair has been attempted by Bolstad and Stowe (1994), Rousan et al., (1997), Rodriguez et al., (1998) and Krupnilk (2000). Gopala Krishna et al., (1996), Srivastava et. al. (1996, 1998) discussed the use of IRS –1C panchromatic data for cartographic applications. Smit and Atkinson (2001), Kardopulas et. al. (1996) compared the rectification using GCPs derived from maps as well as GPS survey. Lawrence (1986) used DEM to automatically map the stream Channel and devide networks of watershed. Jenson and Dominigue (1988) developed algorithms to extract topographic structure and to delineate watershed and overland flow paths from DEM.

The Indian Remote Sensing Satellite IRS –1C/1D PAN camera has a spatial resolution of 5.8m and it consists of 3 CCD arrays each having 4096 sensor elements. The swath of PAN camera is approximately 70 Km on ground. The PAN camera can be steered up to ± 26^0 in the across track direction. Thus by acquiring imagery over the same area from multiple orbit, a stereoscopic coverage can be obtained. The height resolution i.e. the accuracy of DEM derived from the satellite stereo pair depends up on the horizontal resolution of the sensor (i.e. pixel size) and the B/H ratio used in acquiring the stereo pair. The relation ship is: Height resolution = Pixel size / (B/H) ratio. The accuracy of DEM and their derived products are of crucial importance. Errors in elevations, slope, and aspect will cause errors in the cartographic model outputs. The generated DEM has to be therefore evaluated before utilizing it for various applications. Several methods have been adopted in literature for accuracy assessment of DEM.

In the present study, DEM and ortho images are generated using IRS-1C/1D stereo data. DEM accuracy was evaluated using GCP's derived from DGPS measurements.

2. STUDY AREA

Part of Alwar district of Rajasthan state in Western India ($76^0 35'$ to $76^0 45'$ E longitude and $26^0 35'$ to $26^0 45'$ N latitude) and Part of Chamoli District Uttaranchal (79^0 10' 79^0 25' in longitude and 30^0 15' to 30^0 30' N in latitude) were selected for moderately undulating and hilly terrain respectively. The elevation ranges between 200 – 600 in Alwar site and 700 to 4000 in Chamoli site.

3. DATA USED

For moderately undulating terrain, IRS-1C PAN stereo digital data has been used (November 11 and 22, 1996; B/H=0.67). IRS-1D PAN stereo digital data (on November 11 and 22, 1998; B/H=0.73) were used for hilly terrain. DGPS observation and navigation data along with IGS observations and precise orbit data were also used in this study.

SACDEM software developed at Space Applications Centre (SAC), Geomatica Ortho Engine, SKI PRO S/W were used in the present study.

4. METHODOLOGY

Major elements covered in the study are GPS survey, DEM generation and validation, studies on effects of distortion and automatic extraction of drainage network. The methodologies of various elements taken in this study will be discussed theme wise.

4.1 Extraction Of IRS 1C / 1D PAN

Sub-images, of PAN images corresponding to the above-mentioned study areas, were extracted from the digital data. These images were used to identify ground control points (GCP's) and were also used for reconnaissance survey. GCP's well distributed over the images were chosen after the reconnaissance survey for further analysis. Features like road intersections; canal and road crossings, Sharp peaks on hills were selected as GCP's.

4.2 DGPS Survey And Establishment Of Coordinates

The major steps for the differential GPS survey, data processing and accuracy assessment are:

4.2.1 Reconnaissance Survey

Prior to GPS deployment and measurement, a reconnaissance survey was carried out for two days through out the study area. It was essential to find out the suitability of the GCP's identified on the image for the GPS deployment and measurements. GCP's, which were also the GPS measurement points, were selected in such a way that it ensured the visibility of sufficient number of satellites to the GPS receivers with out any obstructions. As far as hilly terrain is concerned the roads along the slope of the hills are partially visible. The GCPs has to be selected in such a way that sufficient number of satellites should be available at those points. The major difficulties in the hilly terrain with steep slopes are that among the available satellites only 50 % is available as compared to the plain region. Only 1/3 rd to 1/2 portion of the sky will be visible from most of the GCP points.

4.2.2 GPS survey in differential mode

One of the most important parameter for DEM and Ortho image generation is establishing the coordinates of the GCP's. These were established using GPS observations and post processing of the data in differential mode. The static observation methodology is selected for establishing the reference and rover stations. The Experimental design is similar for an ideal survey. i.e. establish a reference station with IGS station and the rover stations with reference station. Since the plain and moderately undulating terrain the approach was to establish one or two subreference points in the study area with respect to the reference station. For hilly terrain one reference station was established in the study area and all the rovers were established with the reference station.

A reference point was established at Ahmedabad by taking 55 hours observation and adjusting with IGS stations. One sub reference point was established at Alwar, by taking 24 hours observation simultaneously with respect to reference point. In Chamoli, observations at reference point were taken parallel to reconnaissance survey and continued during the GPS survey for almost 8 days to establish a reference station in the study site. One hour observation time was set for all rover points. No of GCPs established at Alwar and Chamoli were 29 and 30 respectively. The dustribution of GCPs were shown in Figure 1 and 2.

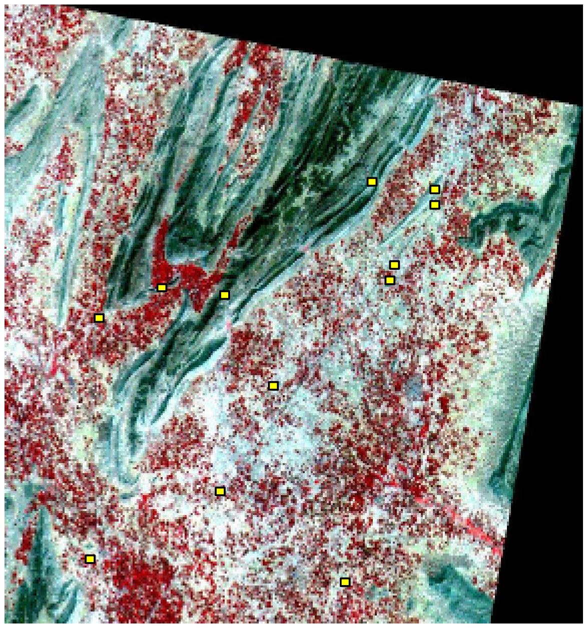

Figure1. Distribution of GCPs for DEM generation: Alwar

Dual frequency receivers were used for GPS survey (Leica SR 520)were used for Alwar and Chamoli DGPS survey. The cut of angle was selected 15° and epoch was set 15 minutes. The former will reduce the multi path effects and the latter will provide sufficient data sets for accurate coordinate computations. GDOP better than 7 were selected for computation of the baselines and coordinates. The major issue for GPS survey in a highly hilly terrain with steep slopes is the visibility of the satellites. Fifty percentages of the satellites were obstructed by mounts for most of the prominent points, which were visible in the image.

Initially reference stations were established by Network adjustment of with IGS stations. Secondly subreference station was established with respect to reference station and rover stations (GCPs) were established with respect to reference / subreference stations.

Figures 3 and 4 represents the field photographs of DGPS survey

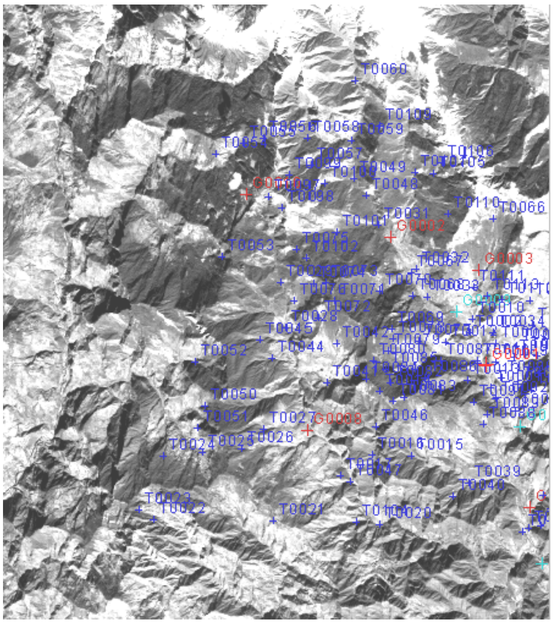

Figure2. Distribution of GCPs for DEM generation: Chamoli

Figures 3 : Field photograph of DGPS survey: Alwar

Figures 4 : Field photograph of DGPS survey: Chamoli

4.2.3 Accuracy Assessment of GPS Observations

Accuracy assessment of GPS observations was carried out using vector closure method. Here, simultaneous observations of three receivers forming a triangle were taken. Algebraic sum of the components of the side vectors of the triangle was computed. Ideally the vector sum should be zero. Any deviation from this was treated as a measure of error occurred in closing the triangle, known as vector closure or closing error. Ideal condition is that the triangle should be near equilateral and observation period should be same for all the three receivers kept at the vertices. Any deviation from this will also introduce larger closing error. Back computation of reference IGS station is also attempted.
For moderately undulating terrain the results were shown in figures 5 and table 1. Figures 6, 7 and tables 2 represent the DGPS data analysis and accuracy assessment of rover stations at Chamoli.

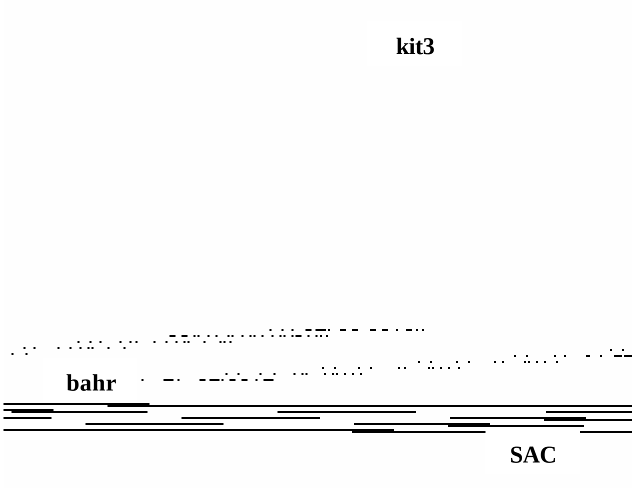

Fig. 5: Vector closure analysis for SAC w.r.t. kit3 & Bahrain:

Side	**Slope distance (m)**	**dx** m	**dy** m	**dz** m
kit3_ bahr	2078603.6564	1688963.7129	-131376.3808	-1204464.6045
bahr_ SAC	2231921.1483	-1869482.4648	1176373.3850	-320395.0451
SAC_kit3	1857364.4507	180518.6505	- 1044997.0940	1524859.5978
Sum_comp_ vector (m)	**6167889.255**	**-0.1015**	**-0.0898**	**-0518**

Table 1: Vector closure analysis for SAC w.r.t. kit3 & Bahrain with base line distances

4.3 DEM AND ORTHO IMAGE GENERATION

In moderately undulating and hilly terrain the images are distorted due to relief displacement caused by the elevation of the terrain. This has to be corrected before extracting any reliable information.

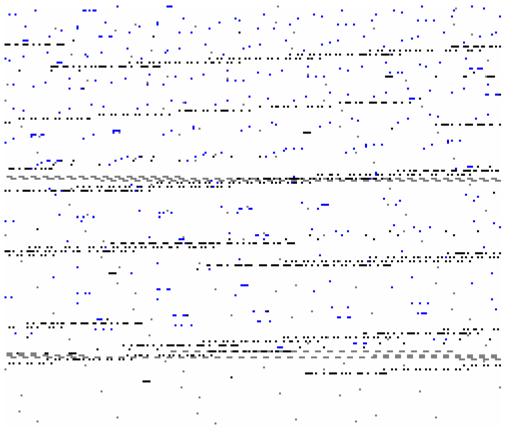

Fig. 6. Establishment of GCP coordinates by baseline computation with respect to Reference station

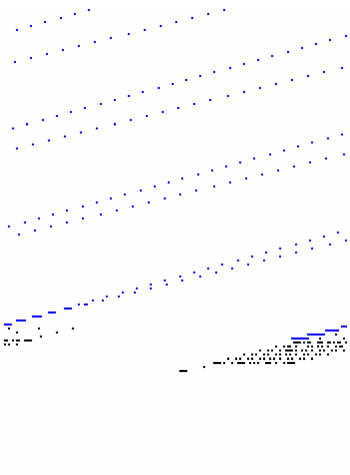

Figure7: Vector Closure at Rover Station (hrdi _ pathalganga _ghatironbridge)

Side	**Slope distance (m)**	**dx m**	**dy m**	**dz m**
hrdi-_ pathalganga	18439.1246	-16821.8077	-1346.4103	7430.6985
pathalganga _ ghatirb	25683.5506	5767.1045	11941.5542	-21995.1031
ghatirb _ hrdi	21132.4343	11054.381	-10595.312	14564.3332
Sum_comp_ vector in m	65255.1095	-0.3222	-0.1681	-0.0714
closing error (ppm)	5.67561E-06			

Table: 2: Vector closure analysis of rover stations with Reference station

4.3.1 Moderatelly undulating Terrain

Since the relief displacement is much more prominent in these types of terrain, rectification of the images are necessary to extract any reliable information. Stereo data of IRS 1C were analysed and DEM and Ortho images were generated. The major steps involved 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 Ortho image generation.

DEM and Ortho image were generated from IRS 1C stereo pair using satellite photogrammetric techniques. The various steps involved in DEM and Ortho image generation are space resection, image matching, space intersection, interpolation, DEM generation and Ortho image generation. DATDEM software developed at SAC was used for DEM AND Ortho image generation. Out of 14 GPS derived GCPs, 8 were used to generate DEM and ortho image. Ortho image was generated in LCC.

The images PAN & LISS III were projected to UTM system (Zone 42) having origin at the intersection of central meridian (75^{0} 0$^{'}$ 0$^{"}$). GCP coordinates established from GPS measurements were used to geo reference both PAN and LISS III separately. Registration accuracy (RMSE) for PAN image was 0.50 and 0.52 pixels (worst 0.99 and best 0.07). Ortho image was generated with WGS 84 datum in UTM projection. The results are shown in Figure 8 and 9.

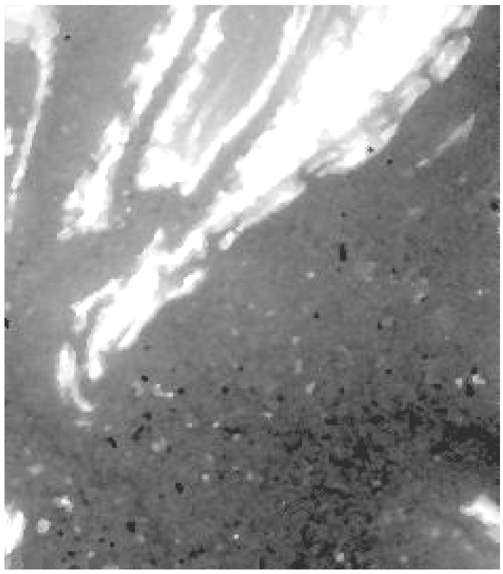

Figure 8: DEM, Part of Alwar District

4.3.2 Hilly Terrain.

Initially the GPS survey was designed and executed for 20' * 20' area anticipating the availability of the data. Geomatica Ortho engine was used for DEM generation. DEM was generated for a subset of the study area due to the unavailability of the data. The major steps involved 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.

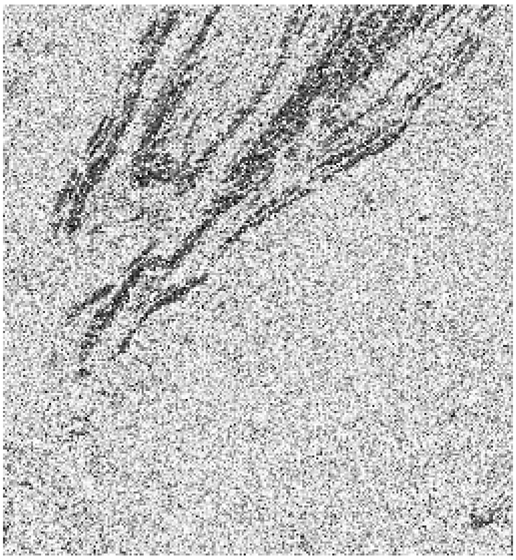

Figure 9: Ortho image, Part of Alwar District

The following parameters were selected as input to the S/W Satellite orbital Modeling: Toutins Model; Out projection: UTM (44 R for Chamoli); Earth Model: D00 (WGS 84); GCP Projection: Lat/long; Data format: IRS Superstructure; GCPs in WGS 84 datum.

Bundle adjustment is the procedure for computing interior, exterior and absolute orientation in a single step. In model set up, a model is formed between the known ground position and corresponding image positions on stereo pair and sensor parameters to have the position and orientation of the satellite using GCP's. The model will compute parameters separately for left and right images using the GCP's, tie points and image coordinates (scan and pixels). Epipolar images are the stereo images after removing parallaxes in Y direction. It is generated by orienting both the images with respect to the model and extracts the overlap area corresponding to the first oriented one. This will make it easy to find out the conjugate points in the stereo pair by searching along a line. Bundle adjustment will compute the ground coordinates of matched points from the available orbital and image informations.

Figure 10 and 11 represent the DEM and Ortho images generated from the stereo pair. The ortho images generated at higher resolution (5.8 m) shown stretching effects. The DEM was overlayed on the ortho images of the respective left and right images. The palnimetric and elvation accuracy of ortho images were computed by comparing the coordinates of GCPs and Checkpoints on ortho image with the corresponding coordinates measured using DGPS measurements.

4.4 VALIDATION OF DEM AND ORTHO IMAGE

DEM validation was carried out by, comparing the elevation values computed at GCPs from DEM and DGPS survey. By comparing the Latitude and Longitude of GCPs, planimetric accuracy of ortho image was assessed. The results for moderately undulating terrain were shown in tables 3. Results for hilly terrain were shown in tables 5 to 6 for hilly terrain.

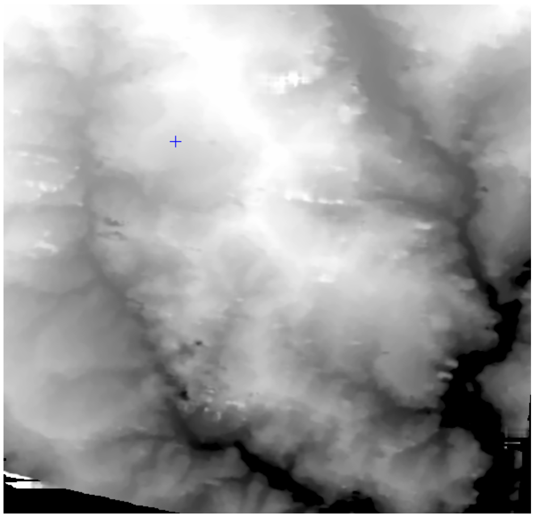

Figure 10: DEM for Part of Chamoli District.

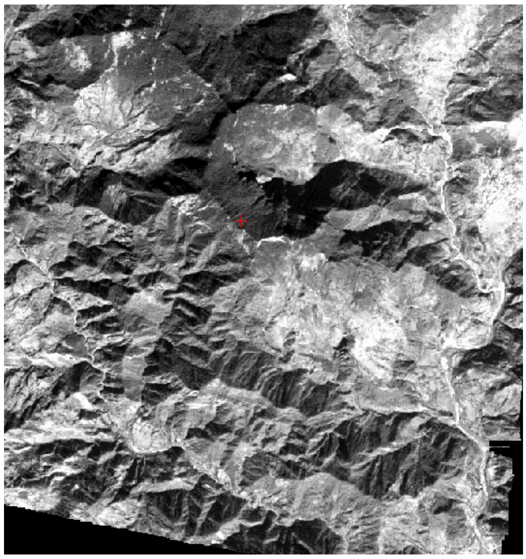

Figure 10: Ortho for Part of Chamoli District

The relief displacement at hilly points is much larger in quantities. Hence while applying correction on the stereo images, they are stretched in the direction opposite to the of relief displacement. For left looking images the stretch effects are towards the right and for the right looking images the stretch effects are in the opposite direction. The effects are more prominent if the direction of slope is across track.

Sr. No.	Point_ID	Difference in height (GPS-SATDEM)
01	chikturn	6.22
02	chikhill	40.70
03	pahariwas	14.09
04	karoli	18.39
05	09octkhoa	-12.38
06	kithmos	28.063
07	08octrata	11.05
08	untwal	-1.51
09	bassirail	5.72
10	bhullabas	17.37
11	chikani	0.46
RMSE		16.71 m

Table 3: DEM validation at Alwar

Sr. No.	Type of point	RMS Error (m)	Average Error (m)	Maximum Error (m)
1	**GCPs (5)**	17.0	11.0	23.3
2	Check Pts (2)	51.8	25.7	70.7

Table 5: DEM validation at Chamoli.

Sr. No	GCP ID	Accuracy assessment of Ortho image		
		Diff. Lat (")	Diff Long (")	Diff. Ht (m)
1	GCP1	0.03	-0.04	17.06
2	GCP2	-0.16	0.26	-14.38
3	GCP3	-0.31	-1.45	63.33
4	GCP4	0.12	-0.14	10.46
5	GCP5	-0.34	-0.28	23.41
6	GCP6	-0.14	-0.24	4.03
7	GCP7	-0.69	1.12	-12.62
	Min	-0.69	-1.45	-14.38
	Max	0.12	1.12	63.33
	Average	-0.21	-0.11	13.04
	RMSE	0.09	0.27	10.48

Table: 6 Accuracy assessment of Ortho image

4.5 Drainage and morphometric analysis

Drainage extraction from DEM requires 3 initial conditioning procedures, namely i) Filling depressions in DEM. ii) calculation of flow direction. iii) Calculation of flow accumulation data set. The technique is based on decision about individual grid cells based on the value of it's eight surrounding neighbours and routes the flow in to the cell that gives the direction of the steepest slope (Jenson and Domingue, 1988). In the present case the size of grid cell is 23 m.

Depressions occur in DEM, when a cell is surrounded by higher elevation cells. Depressions are filled by raising each cell's elevation to the elevation of its lowest neighbourhood cell. Flow direction was determined for every cell, and by using this information flow accumulation for each cell is calculated by the number of cells that flow to that particular cell. Drainage network is formed by highlighting cells, which have flow accumulation value greater than the given threshold value. PCI EASI/PACE software module DWCON and DRAIN were used for conditioning procedure and to delineate drainage pattern.

Drainage network was extracted from the DEM for Chamoli is shown in Fig 11. Visual comparison has been made with those seen on toposheet and Ortho image. The drainagenetwork for one of the stududy area is shown in Figure 11

5. RESULTS & DISCUSSION

The accuracy of DGPS derived coordinates were assesses by vector closure method and the results shows the reference and rover accuracies better than a ppm.

Eight GCPs were used to generate DEM and Ortho image at Alwar. The RMS error of GCPs were 8.13 m, 16.31 m and 8.33 m along easting, northing and elevation respectively and that of 5 check points were 20.02 m, 17.10 m and 17.97 m respectively. Table 11 shows the accuracy of DEM as compared with that obtained from GPS measurements. The height variation in the hilly terrain may be due to the poor image matching during photogrammetric processes or because of interpolation at an interval of 62.5 m. At some other hilly points, the error may also be due to the exact identification of points. The larger errors are due to the lack of well-distributed GCPs and check points, since the GCPs were taken along the roads and the number of GCPs were also less in number. It is very difficult to get well distributed GCPs in hilly terrain for GPS survey because of the steep slope and high elevation.

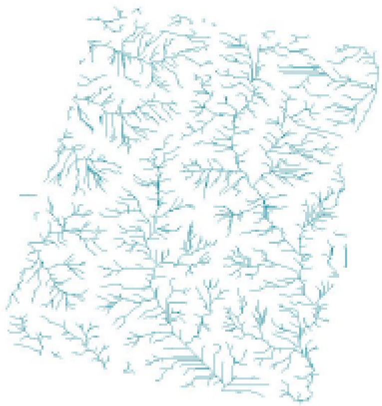

Figure 11: Automatic drainage extraction from DEM

6. CONCLUSION

Feasibility study on the generation of a DEM and preparation of Ortho image using IRS-1C/1D stereo 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 (Ground Control Points) which are used in bundle adjustment of the photogrammetric procedure and also for Validation of DEM and Ortho image. The RMS Error at Alwar was 16. 71 m and that at

The automatic drainage network extraction and validation and the quantification of relief displacement and datum differences will be included in the future studies.

The experiences achieved during each study were highly progressive and the fine-tuning of the methodologies was carried out at the later stage. The drawbacks of each exercise were well taken in to account in the further studies. These exercises enabled the team to develop their skills in project planning and execution of DGPS survey analysis of the DGPS data, accuracy assessment studies and various photogrammetric techniques. Preparedness for the CARTOSAT-1stereo analysis, is the achievement of the present study.

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