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Potential of CartoDEM in disaster management

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Abstract: Digital Elevation Model (DEM) is one of the most important inputs for disaster prediction and management. CartoDEM over Indian land mass is generated using the Cartosat-1 stereo data under CartoDEM project. During natural disasters like landslides and floods, digital elevation model is extensively used for assessment and analysis of the damage. Advanced approach used for Cartosat DEM generation provides dense points for reliable estimation of slope. Qualitative analysis for the predictability of Kedarnath tragedy based on slope derived using CartoDEM is described in this paper. Further, quantitative analysis of different what if scenario can be done with CartoDEM supplemented alongwith ancillary information like soil type, precipitation to prepare vulnerability maps of disaster prone areas.

Keywords: Digital Elevation Model, Disaster, CartoDEM, TIN Modeling, Ortho-Image

1. Introduction

A disaster is a natural or man-made (or technological) hazard resulting in an event causing significant physical damage or destruction, loss of life, or drastic change to the environment. In simple words it can be defined as any tragic event from events such as earthquakes, floods, volcanic eruption, landslides, tsunami, catastrophic accidents, fires, or explosions. It is a phenomenon that can adversely affect the life and property and destroy the economic, social and cultural life of people (Sahni, 2001). In case of uninhabited regions probability of hazards becoming a disaster is very low but it is always important to analyse the hazards that strike in low vulnerability areas too.

With the help of many in-orbit remote sensing satellites one can predict the occurrence of such hazard in advance. Prediction cannot stop or defer or postpone such hazardous events but by providing warning in vulnerable areas or sites, the effect of damage can be managed or reduced drastically. For example, we may get an accurate weather forecast either directly from cloud coverage seen in satellite imagery captured in different bands with very high repetivity by our meteorological satellites or warnings generated by weather prediction models of applications scientists based on various geo-physical parameters like sea surface temperature, water vapour content, etc.

Indian Resourcesat and Cartosat series of satellites provide medium to very high resolution imagery which are used for natural resource monitoring and different cartography purposes. Using the data (2D images) from these satellites and the derived information like Digital Elevation Model (DEM) quantitative damage assessment is done in different what if scenarios. Slope derived from DEM is used for monitoring the landslide prone areas and flood mapping purposes (Anon., 2007).

Cartosat-1 is the first Indian satellite with stereo capability which has been used for the generation of high accuracy DEM over Indian landmass with grid spacing of 1/3 arc sec using indigenously built semi-automatic software (Anon., 2008). Finally, DEM along with the 2D ortho image is used for generating the 3D view of any area. This derived 3rd dimension information or height information is used in analysing and assessment of the damage during disaster and its predication.

This paper describes brief steps of CartoDEM generation and how DEM is used for disaster management and for monitoring the high terrain vulnerable areas in our country.

2. CartoDEM Generation

DEM is a surface model defined as a regular matrix representation of the continuous variation of relief (i.e. height) over space. DEM can be categorized in to 2 parts (Fig. 1); Digital surface model (DSM) which represents the Earth's surface with all objects like buildings, trees on it. In contrast to a DSM, the digital terrain model represents the bare ground surface without any objects like trees and buildings (Raton Boca et al, 2005).

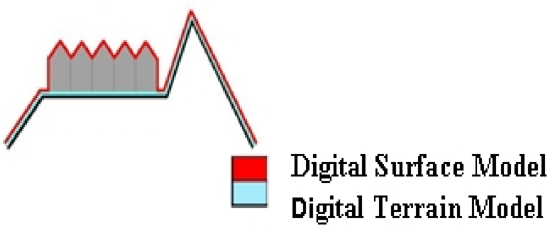

Figure 1: Types of DEM

IRS-P5 (CARTOSAT-1), the first Indian satellite with stereo imaging capability was launched on 5th may 2005. It carries twin PAN cameras onboard and is designed to deliver high-resolution spatial data of better than 2.5m in stereo (SAC/RESIPA/TN01/2008).The twin cameras, with a fixed base-to-height ratio better than 0.6, image the terrain through in-track stereo almost simultaneously (Fig. 2).

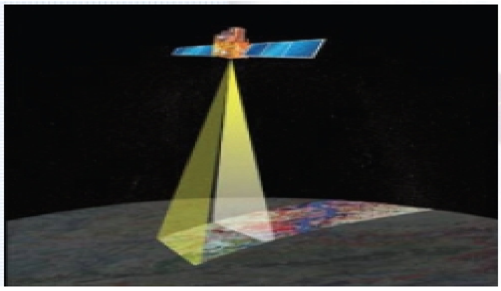

Figure 2: Cartosat -1 imaging

The primary mission goal of CARTOSAT-I is to generate a DEM throughout the country to facilitate the user communities of remote sensing and cartography (Fig. 3). Specifications of CartoDEM are given below in Table 1(Anon., 2008 and Kartikeyan et al., 2010).

Table 1: CartoDEM specifications

Sr No.	Level	Grid	Accuracy	Resolution
1.	Elevation	1/3 arc sec spacing	8 m (Lateral Error 90)	10m at Equator
2.	Ortho-image	1/12 arc sec spacing	15 m (Circular Error 90)	2.5m at Equator
Ellipsoid		WGS-84		
Projection		Geographic		

A CartoDEM set contains 2 layers of data; Digital elevation model and associated Ortho-image corresponding to 1:25000 scale (7.5’ x 7.5’) topographic map extents for the entire National frame. Indigenously developed software for CartoDEM generation uses the advanced algorithms and automatic methods for DEM generation using Cartosat-1 data.

Figure 3 : Cartosat -1 Digital Elevation Model over Indian landmass

Following are the steps for CartoDEM generationprocedure (Anon.,2008 and Kartikeyan et al , 2010)-

i. Full Strip data is modelled using very few GCP to update orientation parameters
ii. Fore and Aft Image matching for high density of conjugate points
iii. Intersection to obtain irregular DEM
iv. TIN Modeling to provide a structure to the irregular digital elevation model
v. Interpolation to obtain Regular DEM
vi. Stitching and Mosaicing to get seamless DEM
vii. Quality Verification and Tile Editing
viii. Tile Formatting , Database updation and Dissemination

Full strip data modelling is done using 1m resolution GCP library (Source: National Remote Sensing Centre, Hyderabad) for improving orientation parameters in order to achieve better planimetric and elevation accuracy. Dense DEM could be generated because of using advanced stereo image matching techniques (Radhika et al., 2007). To assure the seamlessness in DEMs indigenous mosaicing algorithm is used. Apart from this, number of steps are taken for quality verification and improvement. It involves, bias verification with SRTM DEM, noise analysis and smoothening and quality verification by visual inspection (Fig. 5). Presence of distortions like sinks, mosaic related artefacts are identified and flagged using quality verification subsystem. A facility for delineating the water-bodies and their flattening in DEM is also given as a part of Tile editing sub-system (Fig. 5).

Necessary software tools for organizing the tiles in the national frame, subsetting the DEM depending on map tile extents, tile formatting and CartoDEM dissemination to the user (Fig. 6) is made available in operations.

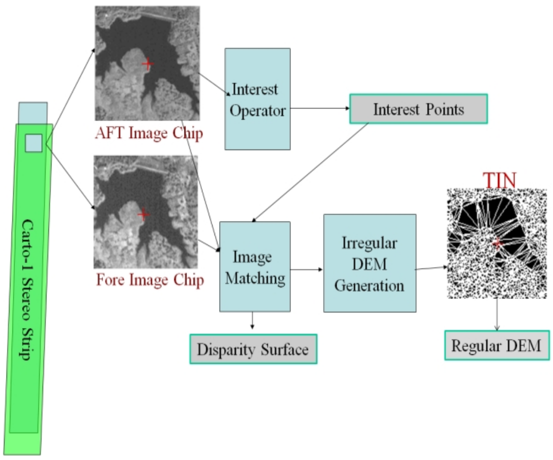

Figure 4: Software flow diagram

Development of CartoDEM generation software involves implementation of mathematical algorithms and handling large volumes of satellite data in raster format, design and development of Graphical User Interface (GUI) and database related application (Fig. 4). Software contains interactive as well as automatic computing components and requires balancing of I/O intensive and computation-intensive activities. Moreover, here Software development also addresses the need for increased matching speed through data parallelism on MULTI-CPU machine (having 64-bit computing capability).

Object-Oriented software development approach was adopted for CartoDEM generation software. JAVA programming language is used for implementing GUI, Database interfacing and Scheduler components. Geometric and image-processing components were developed in C++. PostgreSQL database management system is used for storing CARTODEM data and other ASST data (e. g. processing history) whereas qualified and formatted product i.e. DEM and corresponding ortho-images are stored into ORACLE database using ORDSYS.IMG object.

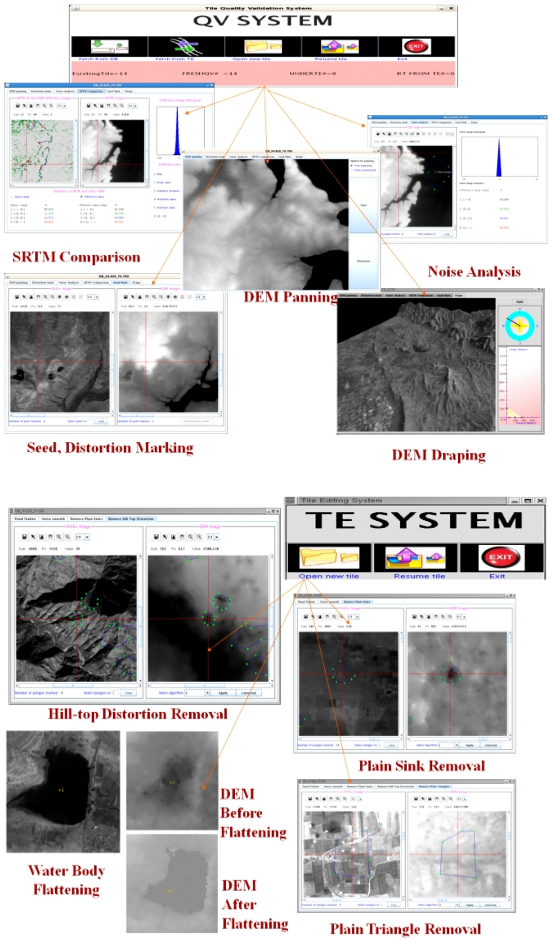

Figure 5: Tile Quality Verification and Editing System

3. Use of CartoDEM for Disaster Monitoring and Management

CartoDEM generated is used to provide an elevation reference of the existing topographic conditions. It is also used for the generation of ortho rectified images in the Data Product facility on operational basis. An ortho-image is a satellite image that has the geometric properties of a map which are used as maps to make measurements and establish accurate geographic locations of features and ortho-images are also useful as raster base maps to define and demarcate the features like: land use/land cover, topography, roads, rivers, open water bodies and forest density.

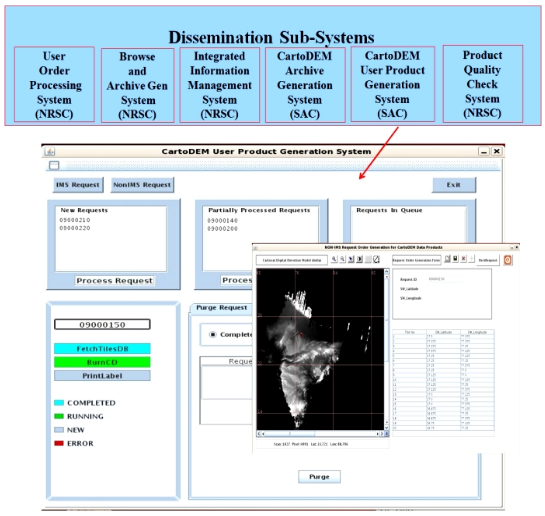

Figure 6: CartoDEM Dissemination System

By virtue of in built correspondence between DEM and ortho-image, perspective views can be generated for any area. These views provide the user an appreciation of terrain relief and other visually discernible characteristics. Topographic data are fundamental to resource modeling and will be an essential element of the database.

DEM products are extremely useful in the GIS environment, providing a terrain model to facilitate drainage network analysis, watershed demarcation, erosion mapping, contour generation and quantitative analysis like volume-area calculation. Some of the example for Cartosat DEM applications can be found in references - Burman and Sarma, 2012 and Ratnam et al., 2013.

In this study we have tried to establish usefulness of Cartosat DEM for disaster monitoring and management taking an example of Kedarnath tragedy. Here, a qualitative analysis is presented using Cartosat DEM. Fig. 8 shows the perspective view generated using DEM in support to our analysis.

Kedarnath is a small Town of Rudraprayag district in Uttarakhand state, India. On 16th June 2013 evening 8.30 p.m. due to incessant rains a dreadful landslide happened and water entered into the valley with heavy force. Again on the very next day i.e. on 17th June 2013 at 6.40 a.m. enormous water entered in Kedarnath valley with stones, boulders, silts etc. The reason for the flash floods was the breaking of the Kedar dome that led to the rupture of Glacial lake near shrine after a cloud burst.

Geographically, Kedarnath town is surrounded by Kedarnath peak (6925m), Kedarnath dome (6824m) Fig. 7(a-c) and other ranges. A cloud burst occurred due to extreme pressure created on rain bearing clouds when they got trapped in a valley which got burst and the entire water fell on that area with massive force.

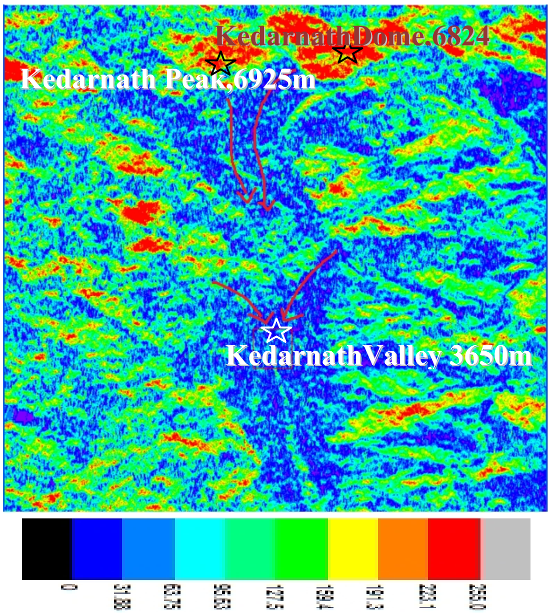

Figure 7a: Slope map of Kedarnath valley using CartoDEM

This can be well seen in the slope map and DEM of Kedarnath area generated using Cartosat-1 data (Fig 7a-c). DEM slopes are clearly indicative of the possibility of such hazardous event. However, for applications like watershed demarcation, flood mapping other parameters like soil type and precipitation needs to be incorporated which is beyond the scope of this paper.

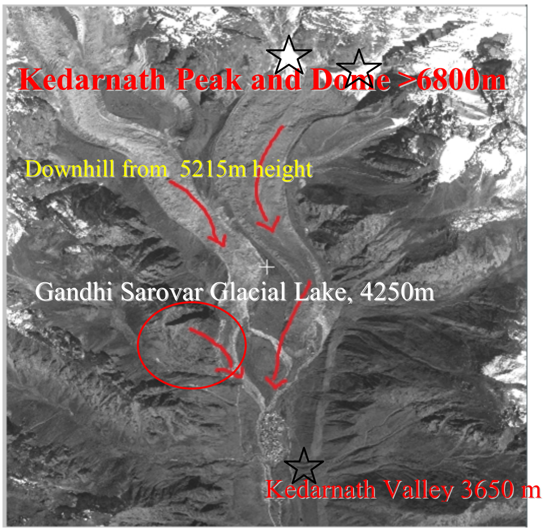

Figure 7b: Ortho-image of Kedarnath valley

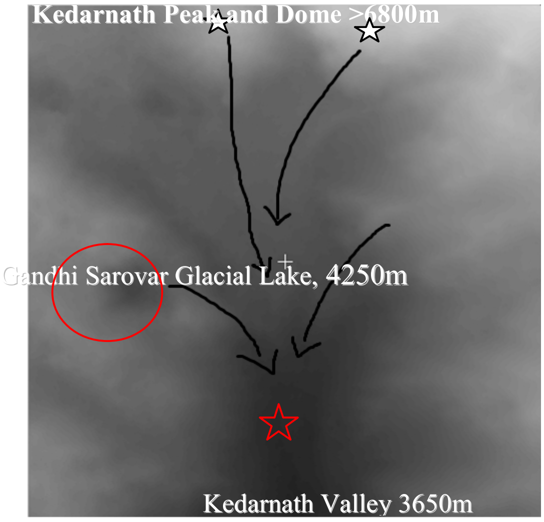

Figure 7c: Digital Elevation Model of Kedarnath valley

Figure. 8: Perspective view of Kedarnath valley (Source: Uttarakhand Space Applications Centre, Dehradun)

4. Conclusion

Generation of seamless CartoDEM is done over Indian landmass under Carto DEM Project using Cartosat-1 data. Advanced approach used for the CartoDEM generation ensures the uniform quality for all types of terrains. Cartosat DEM corresponds to Kedarnath region is analysed and examined in terms derived slope map. It clearly shows the vulnerability of Kedarnath town to the kind of disaster it went through.

High quality of Cartosat DEM can be used in hydrology models alongwith ancillary information like soil type, precipitation to prepare vulnerability maps for many disasters.

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