

# **COMPARISON OF DIGITAL ELEVATION MODELS GENERATED FROM LIDAR AND INSAR DATA WITH DENSE GROUND CONTROL**

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## **1 INTRODUCTION**

### **1.1 GENERAL**

Collection of high-resolution Digital Elevation Models (DEMs) using airborne active sensors is increasing rapidly as these sensor systems become more widely available and cost-effective. These technologies include LIDAR (**L**ight **D**etection **A**nd **R**anging, also known as airborne laser scanning) and INSAR (**I**nterferometric **S**ynthetic **A**perature **R**adar, also known as IfSAR). Each technology has strengths and weaknesses and is better suited for different applications.

### **1.2 NEED FOR STUDY**

A requirement for precise digital elevation data (i.e., Digital Elevation Model) is important for different field of applications. Traditionally majority of Digital Elevation Models are generated by Photogrammetric methods and also by field surveying techniques. But these methods are not cost effective for mapping larger areas. So now a days advanced technologies such as LIDAR and INSAR are used. They are capable of generating elevation models with the same accuracy as that of traditional methods as well as they are cost effective for mapping over extensive areas.

But both these technologies are suitable for different type of applications and different kind of terrain conditions. So the effect of terrain conditions on the datasets of both the technologies has to be evaluated using precise Ground control, Landsat TM and Contour maps. And a suitability analysis has to be done to find the technology that better suits our application.

### **1.3 OBJECTIVE**

- To generate high resolution Digital Elevation Model (DEM) of the two airborne active sensors, LIDAR and INSAR.
- To evaluate DEM of LIDAR and INSAR datasets using Ground Control, Landsat TM and Contour Map.
- To develop an algorithm for extracting the desired feature and to analyse the suitability of LIDAR and INSAR for the extracted features.

## **2 LITERATURE REVIEW**

### **2.1 INTRODUCTION**

The literature reviewed here presents the idea about what has been done in the field of LIDAR and INSAR. The following papers have been to ideate the scenario.

## 2.2 LITERATURE REVIEW

**Mercer J. Bryan (2001)** has summarized the factors, which will ultimately help to determine whether LIDAR or IFSAR is appropriate for a particular application. He has focused on airborne rather than space borne IFSAR as it creates a DEM product closes to that of LIDAR in terms of its three dimensional detail, i.e., vertical accuracy as well as horizontal sample spacing. He has found out that IFSAR is more cost effective for large area applications, while LIDAR is appropriate for more detailed delineation of ground features in built up the application and the economic value of the information derived ultimately. He has summarized the experts of the two technologies from the point of view of common or shared characteristics and then from the perspective of dissimilarities. He has compared a generic set of LIDAR specifications with those of the STAR-3i IFSAR system of Intermap Technologies and has given a general price/performance relationship of both technologies. He has concluded that in sparsely vegetated and non core urban areas IFSAR is very competitive for large area coverage, while the performance may be adequate for many applications. Also LIDAR offers several advantages including better bald- earth DEM performance in many forest cover situations and better geometry for urban core building delineation.

**Hsing-Chung Chang *et al* (2004)** have used Real-Time Kinematic (RTK) GPS to examine the quality of some DEMs generated by such means as radar interferometry (InSAR), airborne laser scanning (ALS) and photogrammetry. A high resolution digital elevation model (DEM) enables easy derivation of subsequent information for many applications such as urban planning, flood plain mapping, mobility mapping in military, crop planning and mapping, etc. DEM is also sometimes used in Differential Interferometric Synthetic Aperture Radar (DInSAR) processing to remove the topographic information, in order to detect any ground surface displacement. They have demonstrates the feasibility of real-time kinematic GPS (GPS-RTK) for validating digital elevation models derived by photogrammetry, InSAR and ALS for a selected area. The accuracy of three DEMs derived using airborne laser scanning; photogrammetry and space borne radar Interferometry have been examined by comparison with GPS-RTK field survey results. Our results show that ALS has the best accuracy.

## 3 STUDY AREA

### 3.1 STUDY AREA

The present study compares LIDAR and INSAR surveys of areas in the Southern California. The extent of the study area has the following geographic coordinates:-

**Latitude** : 32° 46' 14.6568'' to 32° 51' 26.2362'' N  
**Longitude** : -117° 08' 02.7780'' to -117° 17' 33.2946'' E

## 3.2 OVERVIEW OF LIDAR AND INSAR

### 3.2.1 LIDAR

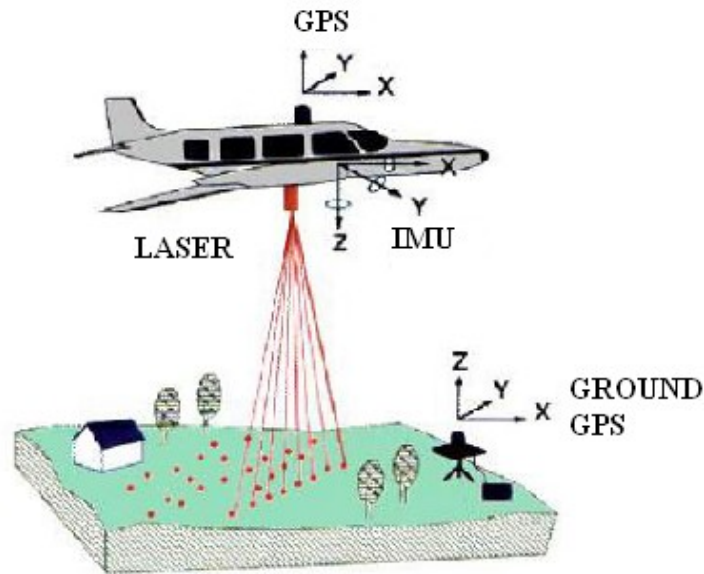
Airborne LiDAR systems are composed of three separate technologies: a laser scanner, an Inertial Measurement Unit (IMU) and a Global Positioning System (GPS) all configured together with a computer system which ensures that all of the data collected are correlated with the same time stamp. This is extremely important as all of the components require extremely accurate timing (to the millisecond). The components for LiDAR technology have been around for many years. Lasers were invented in 1958. Inertial technology has been around for a long time and GPS has been around commercially for over 15 years. The challenges faced by user of LiDAR technology is putting all of these technology components together and making them work together, at the same time ensuring that it is small enough for use in an aircraft or helicopter. In reality this has only been achieved commercially in the last eight years or so. The major limiting factor for the technology has always been the airborne GPS and it is only in the last ten years that GPS systems have become accurate enough to provide airborne positions better than 10cm. Airborne laser profiling has been around for much longer, but the absolute position of the aircraft was always very difficult to determine without a sophisticated GPS. Continued research over the last five years has meant that LiDAR systems (especially those made by the main manufacturers) have become quite robust and very dependable. Individual units still seem to have quirks and many older units were somewhat less than reliable. With respect to the use of a GPS on board the aircraft, it is necessary to provide a link to a ground GPS station on a known control point. The ground station should be located on or close to the project site, where the aircraft is flying. This is to ensure that the aircraft record the same satellites signal as the ground station. If the ground station is located further away from the aircraft or project site then it is quite possible that some of the satellites recorded by the ground station will be different from those recorded by the aircraft GPS.

Airborne LIDAR sensors emit between 5,000 and 50,000 laser pulses per second in a scanning array. The most common scanning arrays (see Fig.3.1 below), go back and forth sideways relative to the points measured on the ground. The scan angle and flying height determine the average point spacing in the cross-flight direction, whereas the flying height and the airspeed determine the average point spacing in the in-flight direction. Each laser pulse has a pulse width (typically between 0.5 and 1 meter in diameter) and a pulse length (equivalent to the short time lapse between the time the laser pulse was turned on and off). Therefore, each laser pulse is actually like a cylinder of light with diameter and length.

Several technologies operate for LIDAR to survey high-accuracy data points on the ground:

- ❖ Airborne Global Positioning System (GPS) is needed to determine the x, y, and z coordinates of the moving LIDAR sensor in the air, surveyed relative to one or more GPS base stations.

- ❖ The Inertial Measuring Unit (IMU) directly measures the roll, pitch, and heading of the aircraft, establishing the angular orientation of the LIDAR sensor about the x, y, and z axes in flight.
- ❖ The LIDAR sensor measures the scan angle of the laser pulses. Combined with the IMU data, this establishes the angular orientation of each laser pulse.
- ❖ The LIDAR sensor measures the time needed for each emitted pulse to reflect off the ground (or features thereon) and return to the sensor.



**Fig 3.1 A graphic representation of LIDAR data collection**

LIDAR sensors are capable of receiving multiple returns, some up to five returns per pulse. This means that a 30-KHz sensor (30,000 pulses per second) must be capable of recording up to 150,000 returns per second. The "first return" recorded by a LIDAR sensor is the first thing hit by a laser pulse. This could be a treetop, roof, ground point, or a bird in flight. When a laser pulse hits a soft target (e.g., a forest canopy), the first return represents the top of that feature. However, a portion of the laser light beam might continue downward below the soft target and hit a tree branch. This would provide a second return. Theoretically, the last return represents the bare earth terrain, but this is sometimes not the case. Some vegetation is so thick that no portion of the laser pulse penetrates to the ground. This is usually the case with sawgrass, mangrove, and dense forests where a person on the ground cannot see the sky through the canopy.

### 3.2.2 INSAR

Synthetic Aperture Radars (SAR) produce all weather, day and night, high resolution images of the Earth's surface providing useful information about the physical characteristics of the ground and of the vegetation canopy, such as surface roughness, soil moisture, tree height and bio-mass estimates. By combining two or more SAR images of the same area, it is also possible to generate elevation maps and surface change maps

with unprecedented precision and resolution. This technique is called “SAR interferometry”. With the advent of spaceborne radars, SAR interferometry has been applied to the study of a number of natural processes including earthquakes, volcanoes, glacier flow, landslides, and ground subsidence. Fig.3.3 presents imaging geometry for a repeat-pass interferometer. One interferogram is formed with images acquired from positions A1 and A2. Assume two identical antennas, A1 and A2, are receiving radar echo signals from a single source. The path length difference,  $\Delta\rho$ , of the signals received by the two antennas is approximately given by,

$$\Delta\rho = \left| \vec{\rho}_2 \right| - \left| \vec{\rho}_1 \right| \approx B \sin(\theta - \alpha) \quad (3.1)$$

where  $\vec{\rho}_i$  indicates the vector from antenna  $i$  to the target,  $B$  is the length of the baseline vector which is the vector pointing from antenna 1 to antenna 2,  $\theta$  is the desired elevation (or) look angle and the baseline orientation angle,  $\alpha$  is the angle the baseline vector makes with respect to the horizontal. If a ground resolution element scatters identically for each observation, then the difference of the two phases depends only on the path length difference.

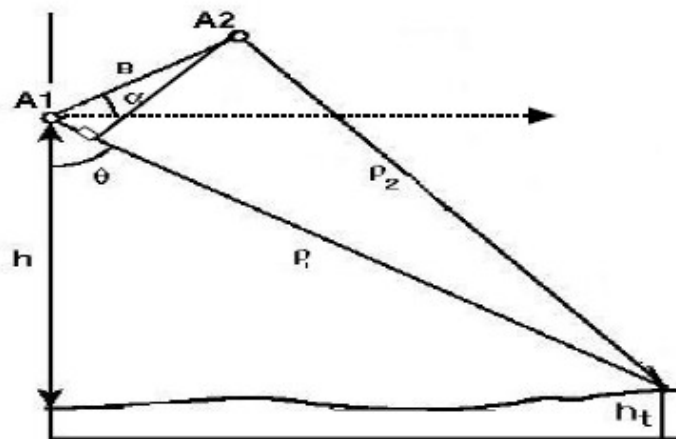
The range difference,  $\Delta\rho$ , may be obtained by measuring,  $\phi$ , the phase between two interferometer signals, using the relation

$$\phi = -\frac{2\pi m \Delta\rho}{\lambda}, \quad m = 1, 2 \quad (3.2)$$

Where  $\lambda$  is the radar wavelength and  $m$  equals to 1 when the path length difference is associated with one way difference, or 2 for the two-way path difference. Using the simplified geometry of Fig. 3.2, the height of a target,  $h_t$  is given by

$$h_t = h - \rho \cos(\theta) \quad (3.3)$$

Where  $h$  is the altitude of the radar antenna and  $\rho$  is the slant range from the antenna to the target. Generation of accurate topographic maps using radar interferometry places stringent requirements on the knowledge of the platform and baseline vectors.



**Fig 3.2 Radar Interferometric geometry**

INSAR is a remote sensing technique that uses radar satellite images. Those radar satellites (ERS1, ERS2, JERS, IRS or Radarsat) shoot constantly beams of radar waves

towards the earth and record them after they bounced back off the Earth's surface. Two information compose the images, one contains how much of the wave bounced back off to the satellite (signal intensity). That depends on how much of the wave has been absorbed on the way and how much has been reflected in the direction of the satellite.

The second information is the 'phase' of the wave. When a wave travels through space, it can be imagined as a hand on a clock. It starts on 12 when the wave leaves the satellite. The 'hand' (phase) keeps running round and round the clock until the wave reaches the ground. When the wave hits the ground, the hand stops and indicating a certain 'time' or 'phase'. When the wave comes back to the satellite, it tells the satellite on what value the hand/phase got stopped. Every point in a satellite image (pixel) is carrying those two information: the intensity and the phase. The intensity can be used to characterize the material in which the surface the wave bounced off is made of and what orientation it has. Oil leaks on the sea, for instance, can be spotted in that way. They look much smoother than the water surrounding. The phase is used in another way. When the radar satellite revisits the exact same portion of the Earth, the phase image should be identical. If it is not the case, then something has been going on and by combining those two images, we can measure how much and where the ground has moved can be measured.

## **4 METHDOLOGY**

### **4.1 DATA COLLECTION**

#### **4.1.1 INSAR**

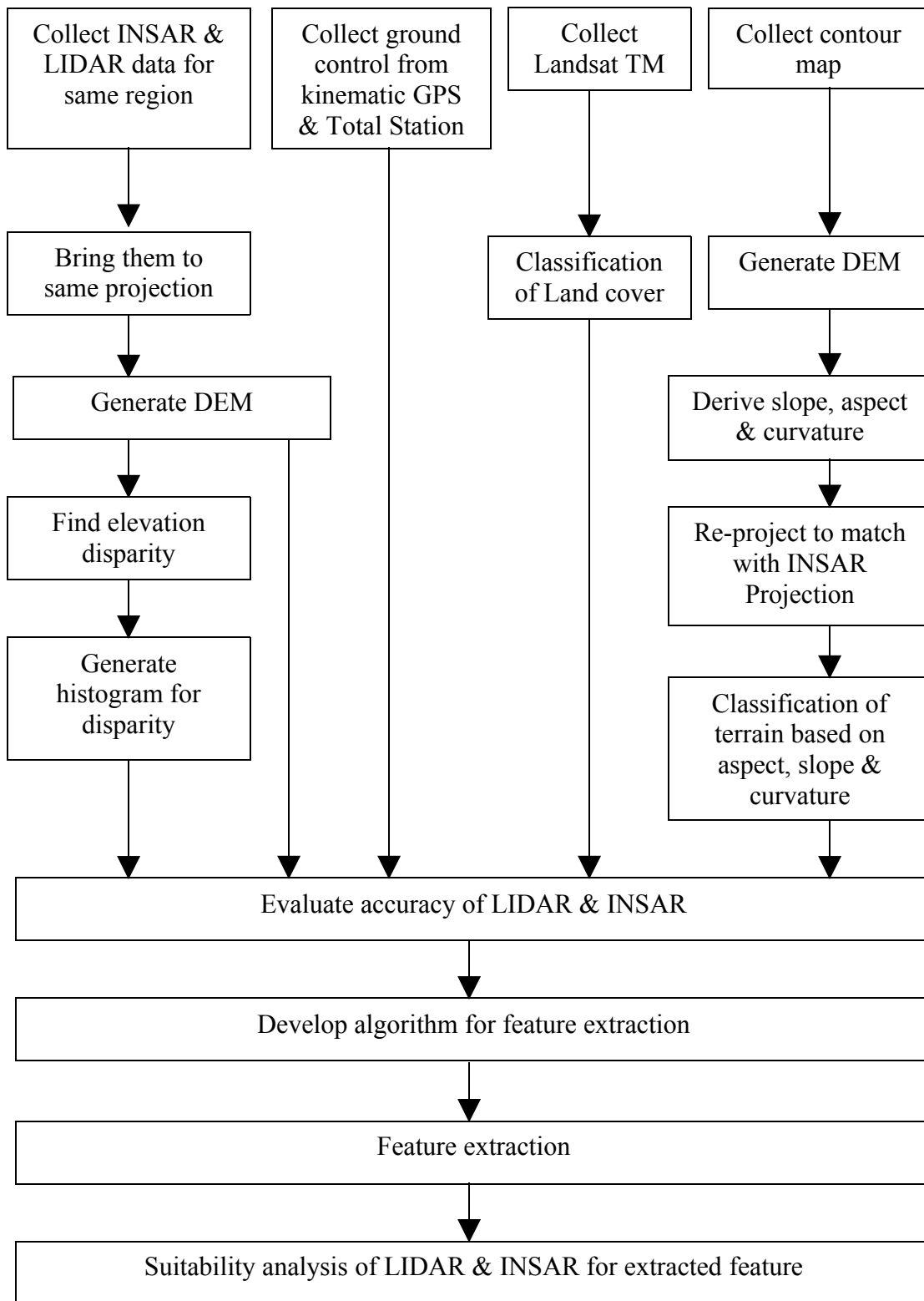
INSAR data has been collected for the region of Southern California. Collection consists of topographic elevations from the California counties of Santa Barbara, Ventura, Los Angles, Orange, and San Diego, and the hydrologic units within those counties that drain to the Pacific Ocean along with offshore islands within the Channel Islands. The contractor acquired single-pass X-band and two-pass P-band interferometric SAR data in Jan 2002– Jan 2003. The resulting data include (1) Digital Elevation Model (DEM), (2) Raw magnitude radar reflectance data, and (3) Height Variance data. This dataset contains DEM data (NAVD88).

#### **4.1.2 LIDAR**

The U.S. Geological Survey (USGS) contracted a LIDAR survey in the same general area. The contractor flew the area in early 2002 in the Southern California. The LIDAR data was delivered in UTM Zone 10, datum NAVD88.

#### **4.1.3 Ground Control**

An extensive ground control has to be taken real-time kinematic GPS, and total-station techniques. This is needed to better evaluate both the data sets. Initially that control points have to be measured on planar surfaces, not curbs, building margins, or other corners in the landscape. Then the points have to be measured by total-station offset from GPS locations, permitting precise surveying of ground elevations beneath dense canopy.



**Fig 4.1 Methodology for Suitability Analysis**

#### **4.1.4 Land Cover**

To evaluate the effect of land cover on the accuracy of different survey techniques, Landsat TM image has to be used. The image has to be classified using hybrid supervised/unsupervised approach which will yield various land cover categories present in the study area.

#### **4.1.5 Independent DEM**

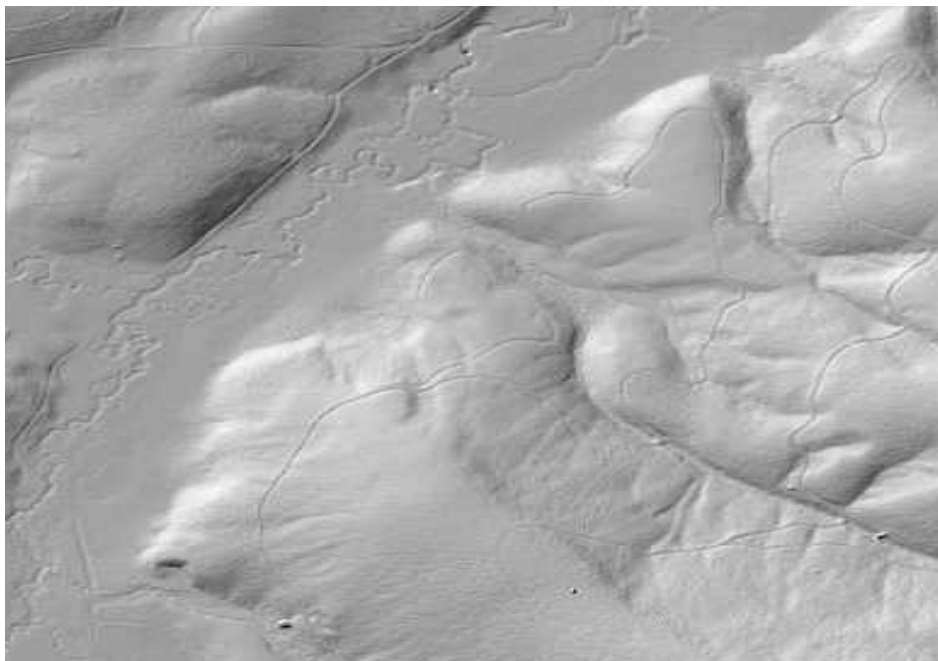
The effects of terrain on the LIDAR and INSAR data can be evaluated using contour maps. Generate DEM from the contour map and derive various parameters such as slope, aspect and curvature. The derived parameters will give an overview about the terrain characteristics in the study area.

#### **4.2 DEM GENERATION**

A high resolution DEM has been generated for LIDAR data using Microstation with Terrasolid software for bare earth (Fig 4.2) and density points (Fig 4.3). Similarly digital elevation model will be generated for INSAR dataset also. To compare the elevation model of both the datasets, generate elevation disparity which can be used to produce a histogram. This will give the overall the characteristics of the datasets.

#### **4.3 EVALUATION OF LIDAR AND INSAR**

For evaluating the individual LIDAR and INSAR surface models, compare them with the control points. The effect of land cover will be analysed by overlaying the elevation models over the land cover categories derived from Landsat TM. The disparity dataset will be overlaid with remain categories such as slope, aspect, curvature and the terrain effect will be analysed.



**Fig 4.2 LIDAR – DEM for Bare Earth**



**Fig 4.3 LIDAR – DEM for Density Points**

#### **4.4 SUITABILITY ANALYSIS**

An algorithm will be developed using Macro Development Language (MDL) which will extract the desired feature from the dataset analysis will be performed to find the whether LIDAR or INSAR is suitable to generate elevation model for the extracted feature.

#### **5 RESULTS**

The project involves two phases out of which phase II is in progress now.

##### **5.1 WORK DONE IN PHASE I**

The work carried out in the first phase is listed below:

- Studied various literatures related to the work and framed the methodology for the project.
- Collected LIDAR data for the study area of Southern California
- A high resolution DEM is generated using Microstation with Terrasolid.
- Collected Interferometric SAR data for the same region.

##### **5.2 WORK TO BE DONE PHASE II**

The further work to be carried out in the second phase is listed below:

- DEM will be generated for INSAR.
- Ground control, Landsat data and Contour maps will be collected for the study area of Southern California.
- Hybrid supervised/unsupervised Classification will be done for Landsat TM.
- Accuracy of LIDAR and INSAR datasets will be evaluated using Ground control.

- Effect of Land cover and terrain conditions on the datasets will be evaluated using Landsat TM and DEM generated from contour maps.
- An algorithm will be developed for desired feature extraction.
- Suitability analysis will be done for finding the appropriate technology for the extracted feature.

## REFERENCE

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