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Review on Digital Elevation Model

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ABSTRACT: *Digital Elevation Models commonly known as DEM's are widely used in Terrain Analysis & image processing applications. A Digital Elevation Model is commonly used for Analysis of various features & objects which are remotely sensed by various devices & Techniques of Modern Era. Detail Literature Review of DEM by referring various Journals & Research papers is proposed in this paper. Various Remote sensing techniques to capture Terrain Surface are studied along with their practical use in the field of Geoanalysis. We enlisted various Interpolation algorithms, Global DEM's, Quality Parameters & practical use of DEM's.*

Keywords: *DEM, Geomorphology, Interpolation, Raster, Vector*

I. INTRODUCTION

The concept of Digital Elevation Model is relatively recent & came from the concept of Digital Terrain Analysis (DTM). The Term Digital Terrain Analysis (DTM) is attributed to two American Engineers namely Miller & Laflamme at the Massachusetts Institute of Technology during the late 1950s (Nasel El Shelmy).Since the 1960's the main research area was on surface modelling & contouring from DEM. The Model is an object or concept which is used to represent something else. It is reality scaled down & converted to a form which we can comprehend (Mayer 1985). Model permit abstraction based on logical formation using a convenient language expressed in a shorthand notation, thus enabling one to better visualize the main element of a problem while the same time satisfying communication, decreasing ambiguity & improving the chance of agreement on the result (Saaty & alexander 1981). According to Burrough (1986) **"**Digital Elevation Model is regular gridded matrix representation of the continuous variation of relief over space". Elevation can be defined as "the height above the horizon". The term horizon refers to the sea level. DEM involves creation of regular array of elevations in the form of squares or hexagon pattern over the terrain. DTM represents the altitude of ground itself while DEM refers to the maximum altitude everywhere. DEM Have become widely used tool & product in last 25 years for providing snap shot of landscape & landscape features along with elevation values (G.Toz, M. Erdogan).They describe as a spatially referenced Geo-dataset. DEM have ability to represent complex terrain structures with adequate resolution. They can be directly compatible with remotely sensed data sources. The need of Study highlights the importance of Terrain analysis & DEM in numerous applications for modeling & analyzing spatial topographic information. DEMs are widely used in numerous applications including military, environmental, engineering, commercial GIS applications etc. Digital Elevation Model includes four important steps namely (i) Data Acquisition (ii) data Modeling (iii) Data Management (iv) Application development. The data acquisition refers to capturing of Terrain Images with the help of various techniques including Photogrammetry, Surveying, Remote Sensing and Cartography. In Computation & modeling numerous disciplines used such as photogrammetry, surveying, cartography, geography, computational geometry, computer graphics, image processing etc. In data management & manipulation various techniques can be used such as spatial database technique, data coding & compression technique, data structuring, computer graphics. In application discipline all geosciences are involved including surveying, photogrammetry, cartography, remote sensing, geography, geomorphology, civil engineering, mining engineering, geological engineering, landscape design, Urban planning, Environmental management, resource management, facility management, flight simulation, battle simulation, tank route planning, missile & airplane navigation, computer games etc. A fundamental architecture of DEM derives from the data model which is used to represent it. Basically DEMs can be represented by Image Method or Mathematical method. Various data structures have been tried for storing & displaying topographic surfaces (i) Rectangular Grid which can also be called as Elevation Matrix structure (ii) Triangulated Irregular Network (TIN) (iii) Contours. These above models are derived on the basis of sampling method. As earth have infinite number of points that can be measured it is very difficult to record every point. So to simplify this drawback sampling method must be used which extract the representative points of the Earth Surface. According to ESRI- 1992 guidelines, the data structure should: (i) accurately represent the surface (ii) Suitable for efficient data collection (iii) Minimize data storage requirements (iv) Maximize data handling capacity (v) Suitable for given surface analysis.

II. DEM DATA STRUCTURES

DEM data structures are usually classified as: (i) Rectangular Grids are also known as Computed DEM (Minnesota Department of Natural Resources). Grids are matrix structure that implicitly records topological relation between data points. The data structure of Grid is similar to the array storage structure of digital computers. Raster type DEM is included in it. Raster is a grid of digital, uniform, square cells covering an area on the earth's surface where each cell is given a value of whatever you want to map. In the case of DEMs, each cell is given the elevation value of the land (or water) surface that it overlies. The cells of a given DEM may be almost any size but most frequently are in the range from 5 to 30 meters square. Raster's are relatively fast to process by a computer because the location of each cell can be determined solely from its order value in the grid. Because every vertex in a vector map requires two pieces of data to be located - the x and y - it is slower to process than a raster cell. A raster also represents the values of a continuous surface such as elevation more precisely than vector. A vector contour map shows elevation only at specific intervals represented by the contour lines (e.g. 100 ft, 110 ft, 120 ft). Raster cells, however, show elevation values not only at the specific intervals but in-between them as well (e.g. 100 ft, 101 ft, 102 ft, and 120 ft). (ii) The TIN model was developed as a simple way to build a surface from a set of irregularly spaced points (Peucker et al. 1978). TIN are also known as Measured DEM. They are vector type data. It utilizes digital points, lines and polygons to represent features on the earth's surface (e.g. point: stream gage, line: roadway, polygon: forested area). Every feature in vector format is composed of a set of vertices, each having explicit x and y (or longitude and latitude) location coordinates. TIN include nodes, Edges, Triangles, Topology. The vector advantage is that it is locationally more precise than raster. A point feature in vector format is represented by a single coordinate pair (x, y) which, on the computer screen, is only a pinpoint that has no measurable width. The same point feature represented in raster, however, would be at least one cell in width (e.g. 30 m). Also, to give a vector map greater resolution is less costly in terms of data storage space than increasing the resolution of a raster map. (Resolution can be measured by the amount of data (i.e. vertices or cells) in a given area.) On a vector map, the number of *vertices* for a set of features may be doubled and this only increases the data storage requirement by two. For a raster map, however, doubling the resolution ups the data storage requirement by four or, in other words, the square of the resolution increase. (iii) Contour is also known as isolines. They are most familiar representation of terrain surface. The accuracy of contour becomes high when they have been captured as primary data from aerial photograph. However in today's scenario Grid & TIN are most widely used data structures to create DEMs. To enhance & extract the exact DEM according to end users need, topographic attributes plays very important role.

III. TOPOGRAPHIC ATTRIBUTES FOR DEM

Topographic attributes are commonly of two types (i) Primary (ii) Secondary. Primary topographic attributes are derived directly from DEM. They include: (i) Surface Derivatives- It measures the rate at which elevation Changes as per location (X & Y coordinates) (ii) Slope- It measures the rate of change of elevation in the direction of steepest descent. It affects the velocity of the surface & subsurface flow including soil water content, erosion potential, Soil formation etc. (iii) Aspect & Primary Flow Direction- Aspect is the orientation of line of steepest descent. It is useful for visualizing landscapes. (iv) Curvature- They based on rate of change of second derivative like slope, aspect etc. Basically in DEM we use Plane Curvature (Rate of change of Aspect along a contour) & Profile Curvature (Rate of Change of slope down a flow line). (v) Upslope contributing Area- It is the area above a certain length of contour the contribute flow across the contour. It is also referred to as drainage area or catchment area. (vi)Flow Width (vii) Maximum Flow Path Length- It is the maximum length of all paths from catchment boundary to a given point in the DEM. Secondary topographic attributes are computed from two or more Primary Topographic attributes. They include: (i) Topographic Wetness Index- It gives relationship between Specific catchment area & product of Slope gradient & soil transmitivity. (ii) Stream power Indices (iii) Radiation Indices (iv) Temperature Indices.

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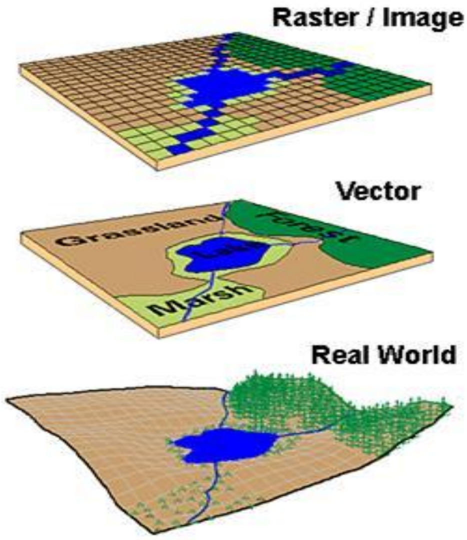

Fig.1.dem data structures

V. DEM DATA SOURCES

Various techniques & methods are used to capture the Terrain data remotely from the surface of the Earth. (i) Aerial & Space Images- Most valuable data source for large scale production of high quality DEM. High precision photographs are taken from metric cameras mounted on aerial planes. By referring fiducial marks of Photograph the center of the photograph can be determined. Mathematically it can be expressed as;

$$1/u + 1/v = 1/f \quad (1)$$

Where, u represents distance between object & lens, v represents distance between the image plane & the lens & f represents the focal length of the lens. To determine the scale of the aerial photograph we can use;

$$1/s = f/H \quad (2)$$

Where H is flying height, f is focal length. (ii) Field Surveying- It involves capturing of terrain directly from surface data by using total station theodolite & GPS. (iii) Existing topographic maps (iv) Photogrammetry- It signifies "measuring graphically by means of light" (Whitemore & Thompson 1966). Fundamental principle behind it is making use of stereo pair of image to construct 3D object & measure the coordinates of object from generated 3D view. Stereo pair can be defined as two images of the same scene captured at two slightly different places to make certain degree of overlap. Each photograph represents six orientation elements, three angular elements (X, Y, Z) along with three translations (geocodic coordinate system). Photogrammetry basically classified as Analog & Digital type. However currently DPW technique also used widely. DPW means Digital Photogrammetric Workstation. In this method when given an image point on the left image, the system will automatically search corresponding point of right image under Image matching process. (v) Radar Interferometry- Synthetic Aperture Radar (SAR) is most widely used technique under this category. SAR is a microwave imaging radar & is based on principle of Doppler frequency shift. The radar source mounted on the flying platform transmits a cone shaped microwave beam to ground continuously & measures reflected energy. In case of Environmental monitoring & reconnaissance of remotely sensed data, SAR Interferometry is best suitable method. It is a signal processing technique which can derive height information by using the interferogram. Interferogram records the phase difference between two complex radars images of the same area taken by two SARs. (vi) Airborne LASER Scanning (LIDAR) - Various experiments demonstrated the Power of using Lasers in remote sensing including lunar laser sensing, satellite laser ranging, atmospheric monitoring, and oceanographic study (Flood 2001). It is an active remote sensing technique. The principle behind LIDAR illustrates that the transmitted electromagnetic energy can be reflected back from the surface of the earth. Depending upon the various objects of the earth the intensity of the scattered light varies which can be used to determine the height of that object. Airborne Laser scanning include: (i) Filtering- It refers to the removal of unwanted measurements such as erroneous object or obstacles. (ii) Classification- it means to find a specific geometric or statistic structure such as building, vegetation etc. (iii) Modeling- It refers to the Generalization of classified object. (vii) Cartographic Digitization- It is mainly of two type's viz. Vector based & Raster based. There are two modulating schemes used in LIDAR which are useful for obtaining range measurement (i) Pulse Modulation (ii) Sinusoidal continuous wave (CW) Modulation (Baltsavias 1999). Pulse modulation generates rectangular pulse of width from 10 to 15 ns (Wehr & Lohr 1999). The position of point can be calculated by considering distance (d), Laser angle (a) from sensor vertical axis, sensor altitude & sensor position. The distance can be calculated as;

$$t = 2(d / c) \quad (3)$$

Where, t is total elapsed time, d is the path distance or range of the pulse; c is speed of the light. There are four scanning techniques employed in LIDAR; (i) Constant Velocity –rotating mirror- Produce measurement that appear as parallel lines on the ground which removes acceleration type errors in angle observation (ii) Oscillating Mirror- All commercial users like Optech, TopEye uses this system in which the mirror rotates back & forth. As mirror always pointing towards ground the data collection is continuous. (iii) Fiber Optical array- It have fewer & smaller moving parts which increases scanning rate up to great extent. (iv) Palmer / Elliptical Scanner- This method was used in ASLRIS (Hu et al. 1999). Currently there are various commercial LIDAR systems used viz. ALTM 3100, TopoSys Falcon which have operating- 80-3500m, distance resolution-1-2 m, scan width- 0 to 25^0, Scan rate- 20-70 Hz, Effective measurement rate- 5000 to 10,000 per sec etc.

VI. GLOBAL DEMS

It is also known as Global Elevation Data Sources. According to International Steering Committee for Global Mapping (ISCGM), global data is defined as that which meets certain criteria: covers the entire earth, is at a scale of 1:1,000,000 or as resolution of 1 KM & is includes specific core data layers (ISCGM 1996). On the basis of above criteria some of the global elevation data which are used in current applications are enlisted: (i) GLOBE- It is Global Land One Km Base Elevation. It have nominal 1 Km grid, Absolute vertical accuracy of 10 to 500 m. There are plenty of sources like satellite imagery, aerial photography, satellite altimetry, cadastral survey data & hardcopy topographic maps. The Source data can be converted to 16 bit binary raster grids. (ii) DTED- It is Digital terrain elevation database. It is provided by National Imagery & Mapping agency (NIMA). It has resolution of 30 arc seconds (nearly 1 Km). (iii) GTOP30- It is widely used by U.S. It has resolution of 30 arc seconds (1 Km). (iv) SRTM- It is Shuttle Radar Topographic Mission. It is joint project between National Geospatial Agency (NGA) & National Aeronautics & space administration (NASA). It has capability to analyze terrain surface through clouds. It has resolution of 3 arc second (1 arc second= 30 meter).

VII. SPATIAL SCALES FOR DEM

Fine Toposcale- It has resolution about 5-50m.It can be obtained from Airborne & space borne radar & laser, Aerial photography. It is Used in spatial analysis of soil properties, hydrological modeling, Topographic aspect correction of remotely sensed images, study of effects like solar radiation, evaporation etc. (ii) Coarse Toposcale- It has resolution about 50-200m. It can be obtained from contour & stream line data analysis, digitization of data from existing topographic maps etc. It is used in analysis of broader scale distributed parameter hydrological modeling, sub catchment of lumped parameter hydrological modeling etc. (iii) Mesoscale- It has resolution about 200m – 5Km. It can be obtained from surface specific points & streamline data digitized from existing topographic maps. It is used in analysis of surface roughness, continental drainage divisions. (iv) Macro scale- It has resolution about 5-500 KM. It can be obtained from ground surveys, Extraction of data from digitized maps etc. It is used in generation of circulation models.

VIII. SURFACE CLASSIFICATION FOR DEM

Based on representation, continuity, smoothness the DEM surfaces can be classified as: (i) Functional Surface:- It is capable of storing a single Z value for a given (X,Y) locations. Functional Surfaces are used to represent statistical surface describing climate, demographic data, concentration of resources, biological data etc. They can also be used to represent mathematical functions & arithmetic expressions which denotes surface. Ex. Terrain surface of earth (ii) Solid Surface:- They are true 3D models capable of storing multiple Z values for a given (X,Y) location. Ex. Buildings, Bridges, Dams etc. (iii) Continuous Surface:- When approaching a given (X,Y) location on a functional surface from any direction, will get same Z value. It is the type of Functional Surface. (iv) Discontinuous Surface:- Different Z values can be obtained based on direction of approach. Ex. Vertical fault across the surface of the earth. (v) Smooth Surface:- The direction of normal vector remains same irrespective of direction of approach towards specified location. The smoothness property mainly deals with changing surface normal from one location to another. (vi) Rough Surface: - The surface normal varies continuously across the surface. However Surface normal is normal vector to the surface's first derivative usually slope Ex. Ridges, Valleys, Mountains.

IX. FACTORS AFFECTING DEM QUALITY

The quality of a DEM is a measure of how accurate elevation is at each pixel (absolute accuracy) and how accurately is the morphology presented (relative accuracy). These factors are mentioned as below: (i) Accuracy of data source (ii) sampling density (iii) Terrain roughness (iv) Grid resolution which also noted as Pixel size (v) Interpolation Source. The accuracy of source data varies with technique depends upon various techniques used to capture it like active airborne sensors, field surveying etc. Terrain roughness is the representation of characteristics of the surface such as flat, hilly, mountainous etc. Standard deviation of slope, standard deviation of elevation, slope convexity, variability of plan convexity (contour curvature), or some other measure of topographic texture is known as terrain roughness. The sampling density is the number of recorded samples per unit distance. For more accurate & detail terrain data sampling density should be high. Interpolation algorithms also affect quality of DEM. On the basis of some factors like aim of study, required output, type of area like hilly, smooth etc. we can choose best suitable algorithm. Interpolation is a method of constructing new data points within the range of a discrete set of known data points (Thomas K Poikar). Interpolation is required to generate DEMs from surface specific points & from contours & stream line data. Basically DEM interpolation methods classified in two approaches as Global Interpolation Methods like thin plate splines & Local Interpolation methods like IDW, Local Kriging, TIN etc.

X. DEM FILE FORMATS

The DEM format originates from 1992. Starting in 1995, the 7.5-minute USGS DEM data was converted to the newer SDTS format. In 2011, DEM datasets in SDTS format are available for download from GeoCommunity at the GIS Data Depot. Starting in 2006, USGS no longer distributes elevation data in the DEM format. However, USGS elevation data in the DEM format is available from other sources, e.g., WebGIS Terrain Data. Other entities still issue elevation data in the USGS "native". Currently we have four DEM file formats viz. (i) USGS DEM (ii) SDTS DEM (iii) DTED (iv) DIMAP. The USGS DEM standard is a geospatial file format developed by the United States Geological Survey for storing a raster-based digital elevation model. It is an open standard, and is used throughout the world. It has been superseded by the USGS's own SDTS format but the format remains popular due to large numbers of legacy files, self-containment, relatively simple field structure and broad, mature software support. The USGS DEM format is a self-contained (single file) set of ASCII-encoded (text) 1024-byte blocks that fall into three record categories called A, B, and C. There is no cross-platform ambiguity since line ending control codes are not used, and all data including numbers is represented in readable text form. There is no known binary analogue of the format, although it is common practice to compress the files with gzip. Floating-point numbers are encoded using Fortran scientific notation, so C/C++ programs need to swap the "D" exponent-indicating character with "E" when parsing (and vice versa when writing). The A record appears once as the file's header, the C record also appears once as the trailer, and multiple B records (called Profiles) comprise the elevation data. A and C records each fit within one block but a single B record typically requires multiple blocks. When such block-spanning occurs, data is shifted to start cleanly on each block boundary. A records also come in "old" and "new" flavors, because the USGS added several fields to the A record. The fields in the A record hold the origin, type, summary statistics and the measurement systems used by the profiles. One of the key items is the quadrangle, which is a set of four terrestrial coordinates describing the four-sided polygon enclosing the area of interest. B records (profiles) are a variable-length longitudinal column of raster elevations that start at a specified location. They are some multiple of 1024 bytes long and contain a small header summarizing the profile. The elevations are contiguous; breaks or other discontinuities are expressed using "void" elevations of value -32767. Each elevation is described as a six-character readable integer occupying a fixed location in a block. The profile header only appears in the first block, so subsequent blocks hold more elevation values. When reading the DEM file from first byte to last, one reads the profiles as columns from west to east. The elevations within a profile run from south to north. The variable-location and variable-length nature of profiles stems mainly from the use of the UTM (Universal Transverse Mercator) ground reference system. Since measurements within UTM employ fixed distances (e.g., 30 meters between elevation samples), the quadrangle must slightly distort to map such locations onto the spherical Earth. This distortion usually manifests as a rotated square, hence the elevation columns near the east and west edges start more northward and contain fewer samples. The C record contains root-mean squared error (RMSE) quality control data, using ten six-character integer fields. A USGS DEM can be classified into one of four levels of quality. This is due to the multiple methods of data collection, and certainty in the data. The levels are (i) Level 1 which gives DEM series of 7.5 minute & 30 minute (ii) Level 2 which gives all DEM series (iii) Level 3 which gives DEM series of 7.5 minutes (iv) Level 4 which gives all DEM series. SDTS is a standard used to describe earth-referenced spatial data. It was designed to easily transfer and use spatial data on different computer platforms. DTED (or Digital Terrain Elevation Data) is a standard of digital datasets which consists of a matrix of terrain elevation values. This standard was originally developed in the 1970s to support aircraft radar simulation and prediction. Terrain elevations are described as the height above the Earth Gravitational Model 1996 (EGM96) geoid, not the WGS84 reference ellipsoid. DTED supports many applications, including line-of-sight analyses, terrain profiling, 3-D terrain visualization, mission planning/rehearsal, and modeling and simulation. DTED is a standard National Geospatial-Intelligence Agency (NGA) product that provides medium resolution, quantitative data in a digital format for military system applications that require terrain elevation. The DTED format for level 0, 1 and 2 is described in U.S. Military Specification Digital Terrain Elevation Data (DTED) MIL-PRF-89020B, and amongst other parameters describes the resolution for each level: Level 0 has a post spacing of ca. 900 meters, Level 1 has a post spacing of ca. 90 meters, Level 2 has a post spacing of ca. 30 meters. The precise spacing is defined by dividing the world into zones based on latitude North South as 0^0-50^0, 50^0-70^0, 70^0-75^0, 75^0-80^0, 80^0-90^0. The DIMAP format is the format for SPOT products, introduced for the SPOT 5 launch in May 2002 and developed with CNES. The DIMAP format is a public format for describing geographic data. Although it was specially designed for image data, it can also handle vector data. SPOT products in DIMAP format now consist of two parts, one for the image and the other for a description of the image. (i)Image- By default it is described in GeoTIFF format, consisting of a TIFF part, as TIFF is the most widely used image format in the world, recognised by all software on the market and easily integrated and a Geo part, recognised by all geographic information processing software. It adds georeferencing information for the image file (coordinates in the upper left-hand corner of the image and pixel size) to the basic TIFF file and may also describe the map projection used and its corresponding geographic system (ii) Metadata -This is written in XML. XML, similar to HTML, is more highly structured and allows users to create their own keywords with their corresponding values. It can be read directly by standard Internet browsers and can be linked to an XSL style sheet which sorts and does the HTML layout of the information contained in the XML file.

XI. INTERPOLATION

Interpolation can be defined as “the process of estimating the value of attributes at some sites from measurements made at surrounding point locations which can be denoted as sample points & can be used for reference purpose”. The basic need of Interpolation technique for DEM creation is: (i) Remove the errors due to sampled surface having different level of resolution & Orientation (ii) the sampled elevations need to be transformed from one format to another. (iii) The point data must be converted to surface representation for analysis & modeling purpose. The Interpolation methods can be classified on the basis of criteria’s like: (i) Compatibility between the interpolated elevations at the sampled points & original elevations (ii) The spatial extent of the utilized samples for the estimation of the elevation at a given interpolation point. (iii) The utilized terrain & data characteristics within the Interpolation mechanism. On this basis they are classified as: (i) Exact Interpolation- Estimates an elevation at a reference point location that is the same as the given elevation at that point. It generates a surface that passes through the reference points (ii) Inexact Interpolation- It yields a different elevation value at the reference points when compared to given elevations at that point. The quality of Inexact Interpolation can be determined by statistical difference between the given & interpolated elevations at the sample points. (iii) Global Interpolation- It uses all the available samples to estimate the elevation at the interpolation point. Ex. Kriging, Trend Surface analysis, Fourier analysis (iv) Local Interpolation- It estimates the unknown elevation using nearest sample points. Ex. Triangular Irregular Networking (TIN), Inverse Distance Weighting (IDW) (v) Stochastic Interpolation- It consider statistical properties of the surface like slope, elevation & sampled elevations at the reference points throughout the Interpolation procedure (vi) Deterministic Interpolation- It does not consider the statistical properties of the surface & sampled elevations within the Interpolation mechanism. Few of the most popular Interpolation methods are enlisted below: (A) Triangulation: - Rather than using a grid, the triangulation method defines a surface from irregularly spaced points. This characteristic often results in more accurately defined features. Since triangulation does not average information during interpolation, it is better equipped to deal with data sets with abrupt peaks or changes. The triangulation method can be computed quickly because it uses fewer points than Kriging, but it will not create as smooth of a surface. The formation of TIN based mainly on following 3 aspects (i) Method of Picking sample points which include Flower & Little Algorithmic Method, Very Important point Algorithmic Method & Drop heuristic method. (ii) Method of connection of points to form triangle which include Distance ordering & Delauney Triangulation (iii) Method of modeling surface within each triangle. (Thomas K Poikar). On the basis of above aspects most popular implementations are: (I) Very Important Point Algorithm (VIP)- VIP works by examining the surface locally using a window. This is a simplification of the technique used in ESRI's ARC/INFO. Because of its local nature, this method is best when the proportion of points deleted is low. It is less satisfactory on curved surfaces diagram. Procedure:- (i)Each point has 8 neighbours, forming 4 diametrically opposite pairs, i.e. up and down, right and left, upper left and lower right, and upper right and lower left (ii) For each point, examine each of these pairs of neighbours in turn, connect the two neighbors by a straight line, and compute the perpendicular distance of the central point from this line diagram & average the four distances to obtain a measure of "significance" for the point (iii) Delete points from the DEM in order of increasing significance, deleting the least significant first (iv) This continues until one of two conditions is met: (1) the number of points reaches a predetermined limit (2) the significance reaches a predetermined limit. (II) Delauney Triangulation - 3 points form a Delaunay triangle if and only if the circle which passes through them contains no other point diagram. Procedure:- (i)Partition the map by assigning all locations to the nearest vertex. (ii) The boundaries created in this process form a set of polygons called Thiessen polygons or Voronoi or Dirichlet regions overhead - Delaunay triangles from Thiessen polygons (iii) Two vertices are connected in the Delaunay triangulation if their Thiessen polygons share an edge. This method is preferred for Fat triangles. Convex hull is again an important parameter in TIN. It is formed due to boundary edges of Delaunay network. (B) Spline is a polynomial between each pair of tabulated Points, but one whose coefficients are determined “slightly” non-locally. The non-locality is designed to guarantee global smoothness in the interpolated function up to some order of derivative. Splines are basically of 3 types (i) Linear Spline (ii) Cubic Spline (iii) Simple Spline. Out of all 3 types' Cubic spline method is more popular. Spline interpolation avoids the problem of Runge's phenomenon, which occurs when interpolating between equidistant points with high degree polynomials. (i) Cubic Spline - The goal of cubic spline interpolation is to get an interpolation formula that is continuous in both the first and second derivatives, both within the intervals and at the interpolating nodes. It will give us a smoother interpolating function. In general, if the function you want to approximate is smooth, then cubic splines will do better than piecewise linear interpolation;

$$f = Afk + Bfk + 1 \quad (4)$$

The problem with a linear function is that, the first derivative is not continues at the boundary between two adjacent intervals, while we want the second derivative to be continuous, even at the boundary. Cubic spline technique is used to generate a function to fit the data. Moreover, it can be shown that data generated by a particular function is interpolated by a spline which behaves more or less like the original function. This is testimony to the consistency of splines (Sky McKinley and Megan Levine). (C) Kriging- The weights are determined according to the distance between the interpolation & reference points as well as the stochastic properties of the surface. The elevation at the interpolation point is determined as a weighted average of the observed elevations at the reference points. Optimal interpolation based on regression against observed *z* values of surrounding data points, weighted according to spatial covariance values. Kriging assigns weights according to a (moderately) data-driven weighting function, rather than an arbitrary function. Simple Kriging, Ordinary Kriging, Cokriging & Arbitrary kriging are some types of Kriging. Kriging Help's to compensate for the effects of data clustering, assigning individual points within a cluster less weight than isolated data points (*or*, treating clusters more like single points). It Gives estimate of estimation error (kriging variance), along with estimate of the variable, *Z*, itself (but error map is basically a scaled version of a map of distance to nearest data point, so not that unique). Availability of estimation error provides basis for stochastic simulation of possible realizations of *Z*(u) (Geoff Bohling 1999).

XII. CONCLUSION

In this paper we proposed all basic information regarding DEM & its applications. Raster DEM is easy to process & extract the DEM due to its Matrix structure which is compatible with current computer systems as compared to TIN. Satellite Photogrammetry can be useful for extraction of high quality of DEM with the help of Remote sensing software's like ENVI, Geomatica etc. while extracting DEM from any source one should consider Scope of work & purpose of extraction & then apply respected Interpolation techniques. There is no "best" interpolation algorithm that is clearly superior to all others & appropriate for all applications. To get best general result for more advanced analysis & visualization use Kriging method while to get fastest result use IDW. In future we are going to implement all basic algorithms like Kriging, IDW, TIN with the help of MATLAB & IDW (Interactive Data Language). Also we are going to extract DEM of same area from two different sources & fuse them to analyze the difference.

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