COMPARISION OF TIN AND GRID METHOD
OF CONTOUR GENERATION FROM SPOT HEIGHT

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Abstract

In this paper the study of two digital terrain model are carried out and to some extent the comparison are made in between them. In the past few years TIN has become increasingly popular perhaps due to the increasing popularity of the Geographic information system, that can handle the TIN structure and the increasing interest in the visualization of three dimensional objects, but in the contrary there are few investigations carried out in the selection of vertices for Tin from irregularly spaced data such as contours; due to the lack of study in this field the fruitful comparison cannot be achieved. Therefore several trail and error experiments have to be carried out in order to predict the best result.

Introduction:

Digital elevation model (DEM) has a wide applications for different purposes. It is one that efficiently represent the surface of the earth and it is the major component as well as fundamental basis of the Geographic Information processing which helps to model, analyze and display the information stored in the computer to represent the topography of the surface. Digital elevation model (DEM) is the mathematical process of representation of the terrain with the aid of electronic medium therefore it is not an exact representation of the surface where it becomes necessary to make some generalization, manipulation, for the visualization of the terrain model due to the complexity of the natural phenomena. Digital terrain model (DTM) have been used in the geosciences applications since 1950's (Miller and Laflamme1958). Since then it have become a major constituent of Geographic In formation System. It provides a basis for a great number of applications in the earth and the engineering science. In GIS, DTM provide an opportunity to model, analyze and display phenomena related to topography of the surface (R. Weibel and M. Heller). The term DEM has been tended to replace the term Digital terrain model (DTM) because it is more specific term to information being collected i.e. elevation (J. Trinder). These methods cab be considered as a representative of the contours in the digital form.
At present context there are two most commonly used data structure to construct the elevation model. They are

- Regular rectangular grid (Altitude Matrix)
- Triangulated Irregular Network (TIN)

Regular rectangular grid:

Regular grid is one of the most widely used form of data structure in DEM. This regular rectangular grid method is also called altitude matrices. Altitude matrices are useful for calculating the contours, slope angles and aspects, hill shading and automated basin delineation (P. A. Barrough). Grids represent the matrix structure that records topological relations between the data point, this structure of data manifest the storage of digital contours, in other words the grid can be stored as a two-dimentional array of elevations, therefore handling of elevation matrices is simple, and the grid based terrain modeling is straight forward (R. Weibel and M. Heller). Because of the straight forwardness this method has become most commonly available source of DEM.

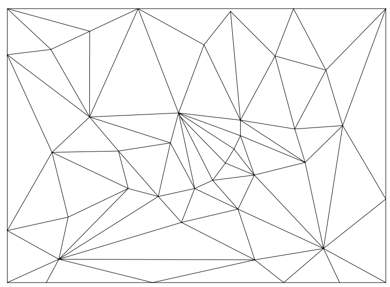
Britain and the United States of America are completely covered by coarse matrices (grid cell sides of 63.5m for USA) derived from 1: 250 000 scale topographic maps and higher order resolution matrices are based on 1: 50 000 or 1: 25 000 maps and aerial photography are increasingly available for these and other countries (P. A. Barrough). Although the regular grid method is useful for the representation of the terrain of less complexity and is particularly useful for the representation of the big areas however it still have some disadvantages as enormous data is needed to represent the terrain to a required level of accuracy.

Triangulated Irregular Network (TIN)

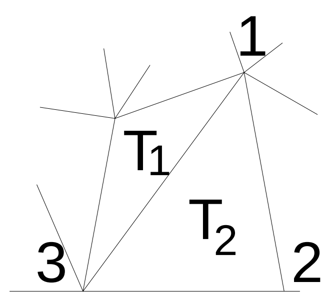
Triangulated irregular network is an alternative method introduced by Peuker and his co-workers (Peuker et at 1976, 78) to other widely used regular digital elevation model. TIN consists of a set of irregularly spaced points that are connected into a triangular network for representing the continuous surface of the earth. Since the TIN structure is based on the triangular elements therefore data structure is able to reflect the variable density of the points and rapidly changing surface as well as rugged terrain of the nature.

In the other hand it avoids the redundancies of the altitude matrix. This method is suitable for preparing the DEM for the country like Nepal which consist some of the most difficult terrain of the world.

The figure 1 shows a part of the network data structure used to define a Triangulated irregular network. The TIN model takes the nodes of the network as primary entities in the data base. The topological relations are built into the database by constructing pointers from each node to each of its neighboring nodes. The neighbor list is sorted clockwise around each node starting at north.



An example of a triangulated erregular network structure for a DEM based on a Delaunay Triangulation.



Data structure of a TIN (detail).

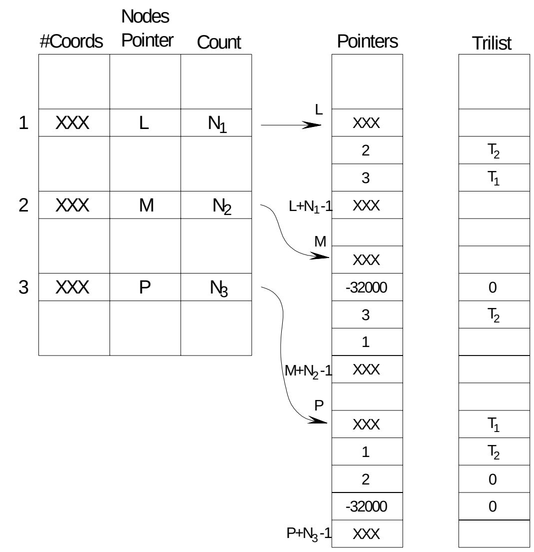


figure:1

The outside area modeled by the TIN is represented by a dummy node on the ‘reverse side’ of the topological sphere on to which the TIN is projected. This dummy node assists with describing the topology of the border points and simplifies their processing. In the above figure we find three nodes and two triangles at the edge of the area. The database consists of three sets of records which are called nodelist, a pointer list and trilist which is also called triangle list. The node list consists of three sets of records identifying each node nad containing its co-ordinates, the number of neighbouring nodes and the start location of the identifier of these neighbouring node in the pointer list. As demonstrated in the figure 1 the triangle T2 is associated with three directed edges held in the pointer list, namely from node 1 to 2 from node 2 to 3 and from 3 to 1.
The data either collected by manual digitizing or from automated point selection and triangulation of dense raster data gathered by automated orthophoto machine and be used to built up TIN structure. It was demonstrated by Peuker et al (1978). It was also demonstrated that this TIN structure is used to generate contour maps, slope maps, profiles, block diagrams, and the map showing the shaded reliefs.

Sources of Data for DEM

For the qualitative result of Digital elevation model the important aspect is the selection of suitable data source and the terrain data sampling technique. At the mean time there are three sources of alternative data for the DEM. They are

- Ground survey method
- Photogrammetric data source, Cartographic data source

- Radar or laser altimetry

The ground survey data is very accurate but is time consuming and cannot be applied for the large areas. Therefore it is applied to specific project areas. From the economic point of view this is very costly method of data collection.

Photogrammetric data capturing technique is commonly used and it is based on the interpretation of the aerial photograph and satellite imagery using photogrammetric instruments. The remote sensing method is also applied in order to overcome the data collection effort consequently large areas can be handled in relatively short amount of time period. Photogrammetric method of data capturing technique is often applied for nation wide data collection and this method is also used in large project areas. It is also an accurate method of data collection.

Cartographic data is an another means of the data source. The cartographic documents i.e. the contour maps, profiles, also serves as a source of data for DEM. Therefore in order to change into the digital form we have to digitize analogue data either by manual digitization or by means of automatic raster scanning and vectorization. The collection of the terrain data as well as the photogrammetric method of data collection is relatively more costly in comparison to converting the analogue data into the digital format. The existing cartographic documents are of least cost and already existing valuable source of information for generating the DEM.

Contour generation

Contours represent line of equal elevation and are the traditional form of relief depiction used in the map to represent and interpret the elevation of the terrain. In the digital elevation model generation of the contour is one of the important method which generally involves the interpolation. There are various methods of data structure that can be applied in the contour generation in order to represent the DEM such as

- Patch structure
- Line structure
- Point structure

Patch structure

It is the mathematical structure that is used to depict the surface and it rely on the polynomial functions which are valid for the terrain, therefore these mathematical functions are able to represent the complex forms with high degree of smoothness. This method is advantageous for modeling the complex surfaces with computer aided design. It split the complete cell into a irregularly shaped patches approximately of the same dimension and then the surface are fitted to the point observation with the patch, consequently the piecewise approximation can be used for interpolating the surface. With the aid of this method contours can be obtained by solving the equations for given z-values and then tracking the contour by following the z-solution (T. K. Peuker).

Line structure

The most common line model of the terrain is given by the set of contour lines that describe the hypsometric curve. The line structure as well as the point structure are similar because both of them are defined by the series of points but the decisive factor here is the order in which the point are stored has as well as a geometric as well as topological significance. The line structures have in common that subsequent points and they are linked by the straight line which can be linearly interpolated in arbitrary interval and then the straight line segment is smoothened during the display stage.

Generally contours are the output of the photogrammetric digitizing. This system of contours has the advantage that the density of the contour changes with the dynamics of the relief consequently which keeps the volume of the redundant data low, although the density of the points along the contour is very high (Goltschalk and Neubauer 1974) and this search is time consuming. Therefore it was found that the comparision of the regular grid of points with contour system that the former are more efficient for the data manipulation where as the second needs the data storage (Boehm, 1976). He explained this by comparing the line of sight test.

We also know that contours are on most existing maps. They are the ready structure of data for the DEM and many efforts have been made to capture them automatically using scanners. But there is a argument that digitizing the existing contours are poor quality DEM than direct photogrammetric measurement (Yoeli 1982). Unfortunately in the computation of the slopes as well as making shaded relief model the contour that are digitized are not suitable, therefore they have to be converted into the point model. Ceruti(1980) and Yoeli(1984) developed algorithms for interpolating contour lines to altitude matrix. Oswald and Raetzsch(1984) described a system for generating discrete matrices from the sets of polygons representing contours that have been digitized either manually or by raster scanning. The system is known as Graz terrain model.

Point structure:

There are two methods of contour generation. They are regular rectangular grid and irregular grid(TIN). These methods have already been described in the beginning. Regular grid method of contour generation is most frequently used because of its implicit definition of topologic relation. In this method the computation of the contour is relatively simple to program.

Once the the grid is constructed the contours have to be drawn. The mathematical algorithm of contouring is Delunay triangulation also there are number of other names that have been ascribed to the two structures for instance, Vorodnoi network, Drichlet tessellation and deltri analysis, all of these describe the same principle in their own field. Algorithm time for triangulation is related directly to the number of points in the data set and is virtually linear function. Compared to the fact that time is also related to the number of rows and columns of the rectangular grid. Therefore with the aid of this method automatic creation of triangulation and subsequent contouring is obtained. A number of efficient algorithms for constructing a Deluney Triangulation, Voronoi diagram is introduce3d by Guibas and Stoli 1985; Heller 1990. In terms of the contouring the interpolation procedure are based on the triangulation which is obtained by locally fitting the polynomial to triangles. Therefore triangulation plays a vital role in both the methods of terrain modeling.

The contour maps are generated from the TIN model by intersecting the horizontal planes with the network. The secondary data structure of the ridge and the channels is used as guide to the starting point of the contour envelope. The contour envelope may need secondary processing to remove artifacts from the edge of the triangles (Peuker et. al. 1978).

Comparisions:

Very few literatures are found where the comparison is made in the contour generation by regular grid and the TIN method. The study carried out by Mark P. Kumler on the "Quantitative comparison of regular and irregular Digital terrain model" was made.
In this paper investigation was carried was carried out on the accuracy for two Digital terrain models i.e. Grided digital elevation model and TIN. The research was carried out in USA on the basis of different surface characteristics and the availability of the digital elevation data. During the study TIN were constructed for each study area from the existing DEM and from the digitized contours and the spot heights in the USGS hypsography line graph. The literature make the comparative study of different TIN to each other as well as to the grided DEM.

Study area:

The study areas were selected on the basis of availability of the USGS 1: 24,000 Digital line graph (DLG) hypsography files. The files contain digital versions of all contour lines and spot heights that appear on the corresponding 7.5 minute topographic maps. Four quadrangles were selected for the study. They were west of Drinkwater Lake, CA, Tiefort Mountains, CA, Crater Lake West, New Britain CT. The DEMs and DLGs for each area were acquired directly from the National Digital Cartographic data base.

In the study the accuracy of different elevation models are compared by estimating at over 1500 test points. The models were used to estimate elevations of the test points and root mean square errors (RMSE) were computed.

Table No. 1

	No. of test points	RMSE for DEM	RMSE for (regular)DEM based TIN	RMSE for (irregular) DLG based TIN
West of Drinkwater Lake, CA	1637	2.7	2.5	1.8
Crater Lake West	1643	3.1	3.5	2.8

Tiefort Mountains, CA	1516	5.5	5.0	4.0
New Britain, CT	1705	5.5	5.7	4.0

According to the result of the table no.1 the DLG based TINs yield significantly lower RMSE than DEM based in the four study areas. The shaded relief images produced from DLG based TIN were superior to those from DEM, giving the more realistic impression of the terrain.

Conclusion:

According to the Mark P. Kumler's study the comparision that he has made in-between the regular and irregular digital terrain model triangulated irregular networks yield better estimates of the surface elevations at over 1500 test points and also the shaded relief images derived from the irregular structure very similar to the orthophotos.

It is difficult to come to the conclusion without through study. The TINs are more popular for its efficiency in the data storage and this method includes a greater number of points of the rugged terrain it also can locate the important points at their required location but on the other hand this advantage is encountered as problematic in the storage and manipulation. The location of every point in the TIN must be specified in 3D coordinates, where as in the grided structure the horizontal location is implicit tin the order of the grid. In fact there is very little works were done in this comparative study therefore in the mean time it is hard to say which method is superior.

Also because of the different terrain structure its application to these different earth surface may give different result therefore only on the basis of many experiments can come to the decisive point and can predict the best.

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