VISUALIZATION OF A DIGITAL ELEVATION MODEL

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ABSTRACT

In recent years, Geographic Information Systems (GIS) have gradually changed from using the traditional 2D map expression to 3D visualization. The combination of visual techniques and GIS is a multi discipline, leading edge field, the development of which needs advancement in many fields. This paper introduces related theories and algorithms of Digital Elevation Model (DEM) visualization. Advantages of the Triangle Irregular Network (TIN) model and data structure are illustrated. The algorithms include the visualization process and methods to increase the realism of the DEM. Illumination models and a special technique to map remote sensing images onto DEM are also presented.

Keywords: Digital Elevation Model (DEM), Triangle Irregular Network (TIN), Illumination model, Texture, GIS

1 INTRODUCTION

There are two ways to visualize the terrain: in two-dimensions and in three-dimensions. The two-dimensional method represents three-dimensional terrain using two dimensional maps such as contour maps, layered maps, and so on. This is the traditional method. In recent years, with the development of computer graphics and computer hardware, the traditional 2D map expression has gradually changed to 3D visualization. Compared with two dimensional maps, three dimensional maps provide viewers with a real and vivid experience.

Three kinds of models can be used to depict objects: wire, surface, and solid. The digital elevation model based on a three-dimensional surface model is most widely used in topographic expression and GIS applications. The construction and visualization of this model is called 2.5 dimensional GIS. This paper illustrates the procedure of 2.5D GIS visualization, which includes the following steps:

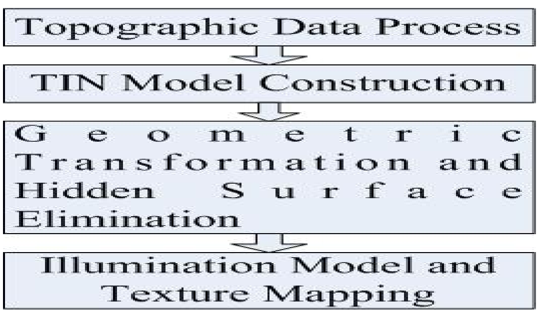


Figure 1. DEM visualization procedure

2 TOPOGRAPHIC DATA

2.1 Data source

An effective and common way to generate a DEM is to interpolate digital topographic data, including contours, spot heights, rivers, and lakes. This method of DEM extractions is widely used, and its precision relies on the quality of the input data, the interpolation algorithms used, and the parameters input to the algorithm.

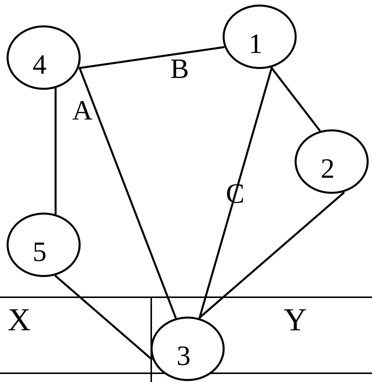
With the development of remote sensing technology, there are many new data sources to generate moderate resolution DEMs. Topographic data can be generated through processing high resolution airborne image pairs. Interferometric and radar or laser altimetry can be effective topographic data sources. Recently, Shuttle Radar Topography Mission (SRTM) data has also been used in terrain data extraction.

2.2 Data structure

Grid data models and triangular data models can both be used to represent surface models in geographic information systems, computer graphics, and virtual reality (VR). The two methods have different advantages. However, compared with the grid data model, the triangular model, particularly the Triangle Irregular Network, is more popular because it has a simple data structure and can easily be rendered using common graphics hardware. Furthermore, Bisheng Yang (2005) showed that many sophisticated algorithms and models have been developed for constructing multi-resolution TIN models.

There are several data structures for the storage of TIN. One way centering on triangle storage is illustrated in Figure 2.

Triangle ID	Adjacent triangles
A	B，C
B	A
C	A



Triangle ID	Nodes
A	1 3 4
B	1 2 3
C	3 4 5

Node ID	X	Y	Z
1	X1	Y1	Z1
2	X2	Y2	Z2
3	X3	Y3	Z3
4	X4	Y4	Z4
5	X5	Y5	Z5

Figure 2. TIN Data Structure

Appropriate algorithms can be chosen to generate and store TINs in this data structure. Different algorithms have been developed to raise the DEM generation rate. The Delaunay triangular is popular in TIN generation.

3 THE VISUALIZATION PROCESS

The first step in DEM visualization is a geometric transformation. Geometric transformation maps points from object coordinates to screen coordinates. It is essentially a perspective transformation process. The process transforms the object coordinates in the world coordinate system to a viewpoint-centered coordinate system and then projects it onto the screen.

To increase the reality of the graphics, during the visualization process the unseen parts should be removed from the scene. This process is called hidden surface elimination. There are two kinds of hidden surface elimination algorithms: image space algorithms and object space algorithms. Commonly used algorithms are: painter's algorithm buffer algorithm, scanning line algorithm, and regional sample algorithm. If the number of triangular points is under 10 thousand, the painter's algorithm is most efficient. If it is above 10 thousand, the Z buffer algorithm is most efficient.

4 ILLUMINATION MODEL AND TEXTURE MAPPING

After the elimination of hidden surfaces, the color of each pixel should be determined to simulate the illumination effect in the real world. Various illumination models that build the relationship between the reflection intensity of the pixel and the light source and environments have been developed. The first influential illumination model was put forward by Phong (1975). This model is easy to use. Some improvement has been made, and many new models have been developed since.

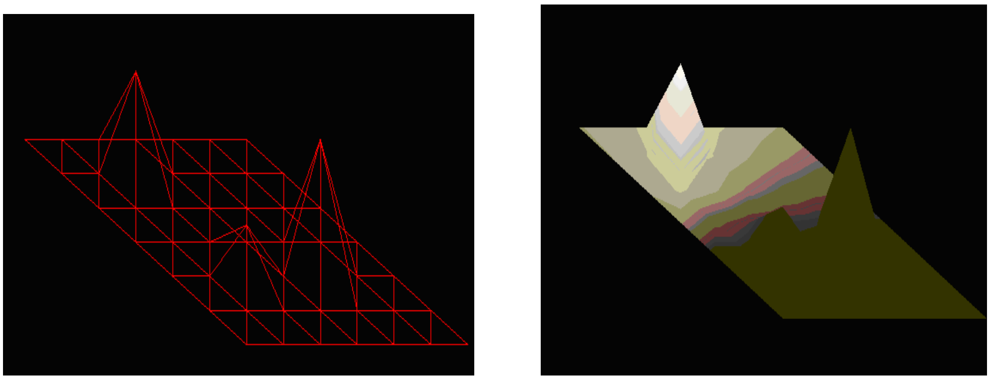


Figure 3. Illumination effect

Texture mapping techniques add realism and interest to topographic images. Texture mapping applies a pattern of color to an object. It can be divided into two-dimensional and three-dimensional techniques. Two-dimensional techniques place a two-dimensional image onto an object using methods similar to pasting wallpaper onto a wall. Three-dimensional techniques are analogous to carving the object from a block of marble.

In the GIS visualization process, remote sensing images are used as two dimensional textures and are mapped onto the digital elevation model. There are three steps to mapping the images: the spatial index, the image load, and texture mapping. Because of the large computer memory usage of remote sensing images, the whole image cannot be loaded into the memory at one time. Some special techniques have been invented to solve this problem. The whole terrain is divided into several districts, and then the texture is mapped dynamically according to the viewpoint position in the visualization process.

5 CONCLUSION

From theoretical exploration and practice in DEM visualization, the visualization process includes the following steps: topographic data acquisition, DEM model construction, and the visualization process. To improve reality, illumination models can be used to calculate the reflection intensity of each pixel. In GIS, visualization special techniques should be used to increase remote sensing image mapping efficiency.

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