3D Surface Representation and Manipulation Scheme for Web-based 3D Geo-Processing

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Abstract

For given 3D geographic data which is usually of DEM(Data Elevation Model) format, we have to represent and manipulate the data in various ways. For example, we have to draw a part of them in drawing canvas. To do this we give users a way of selecting area they want to visualize. And we have to give a base tool for users to select the local area which can be chosen for some geographic operation.

In this paper, we propose a 3D data processing method for representation and manipulation. The method utilizes the major properties of DEM and TIN(Triangular Irregular Network), respectively. Furthermore, by approximating DEM with a TIN of an appropriate resolution, we can support a fast and realistic surface modeling. We implement the structure with the following 4 level stages. The first is an optimal resolution of DEM which represent all of wide range of geographic data. The second is the full resolution DEM which is a subarea of original data generated by user's selection in our implemeatation. The third is the TIN approximation of this data with a proper resolution determined by the relative position with the camera. And the last step is multi-resolution TIN data whose resolution is dynamically decided by considering which direction user take notice currently. Specially, the TIN of the last step is designed for realtime camera navigation. By using the structure we implemented realtime surface clipping, efficient approximation of height field and the locally detailed surface LOD(Level of Detail). We used the initial 10-meter sampling DEM data of Seoul, KOREA and implement the structure to the 3D Virtual GIS based on the Internet.

1 Introduction

The techniques to serve a various geographic information via GIS(Geographic Information System) is getting developed over a new dimension for a vital improvement of Internet and 3D computer graphics. Compared to the quantities and features of Off-line GIS, 3D Geo-processing in the internet environment needs more data and time to proceed their compression, transmission.

To visualize the user-demanding area in GIS, we need to show global visualization and local visualization. By helping users indicate their target area from the global data, this system makes users find their local area conveniently and exactly. Also they can change the area whenever they want by checking through a visual image and interactively control the boundary box of selected area. One of the techniques for this requirement in the system architecture can be said, for example, to find the user's selection area in real time and clip the area and reorganize them as the original format. To implement the technique, we chose DEM(Data Elevation Model) as a basis data format so that we only needed the maximum, minimum point among the data made by user's selection.

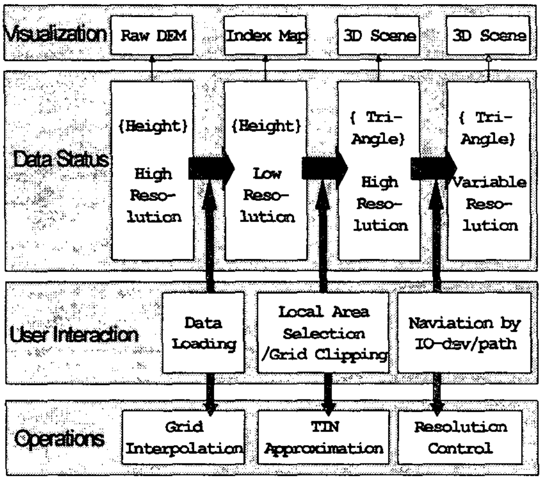


Figure 1-1 System overview

DEM data which representing height field is usuallyused in data input and representation. Usually, the geographic data taken by airplane or satellite is hight field form. With the sampling records like width, depth, the data is useful to management since its form is regular grid and it save the storage in relative to TIN(Triangulated Irregular Network). Also in visualization, for its regular form, we can easily draw the as a triangular mesh by connecting heights values in a simple rule. In this paper, we show how simply extract user selection area from the DEM data for the properties. But the demerit of DEM data is non-adaptibility in visualization. The adaptibility in visualization means that the size of triangle to represent geographic data must change by and complexity of the data like mountain slope. Since DEM data has a height in every place, the flat area can have unnecessary data though the area can visualize with a few triangles.

In contrast to DEM data, TIN does not have the constraint about the data regularity. The trangular mesh can vary based on the geographic complexity. This means we need less number of trangles to represent geographic data. By this property, ths data type can represent complex geography with samll and a lot of triangles and simple, flat area with large and a few trangles. This property of TIN can reduces visualization load like redering process, input/output process. As a result, most of visualization system tends to use TIN structure more than DEM data. DEM data is used data storing and exact representation of configuration of the earth. In this paper, we present an implementation model which use DEM format when user want to select an area exactly and use TIN format when user want to visualize the area and want to fly or naviate on the area.

The 4-step visualization model we present is shown in Figure1. Each step can be said as follow in short.

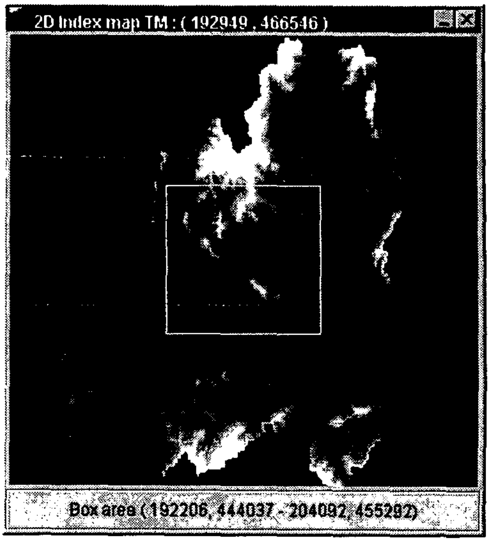
- **Optimal DEM interpolation:** Based on the measured data, we resample them to the extent that we can easily visualize them in a small and rough index map. Height interpolation technique makes us compute exact data we need. We use them to draw a terrain roughly and prepare for taking user selection input on the data visualizing area.
- **Local area clipping by user selection:** After user selects an area with selection box control, we compute the corners in real coordinate and clip the area in the original high-resolution DEM file. By virtue of grid regularity, we can do that with only corner data.

- **TIN approximation of local height field:** With the high-resolution local height field, we compute TIN data, which approximate the data. The output TIN data is light in size and can represent the original feature of terrain. With is data, we visualize the area in detail fastly.
- **TIN resolution control by the viewers position:** By computing local resolution variance, we change the local resolution so that the area beside and near to the viewers position is represented in detail, and other place like back of viewer. And the area of a long distance from viewer is represented with a large and low resolution triangles. View culling techniques and backface culling is used to this step.

2 Manipulation of 3D Surface Data

2.1 DEM Interpolation

The first step in our system is to visualize the global DEM data so that user can select where they want to see and manipulate. The existing 2 dimensional GIS, theis function is implemented as an index map. We locate the camera of 3D scene at the top of the scene. To get the low-resolution grid, we use technique to measure the height of the position we want.To affect like an index map in 2D GIS, we used DEM data as an image format to represent height model and tested an image representing Seoul regions as in figure 2-1 and 2-2



interpolation figure 2.1 index map representing heights

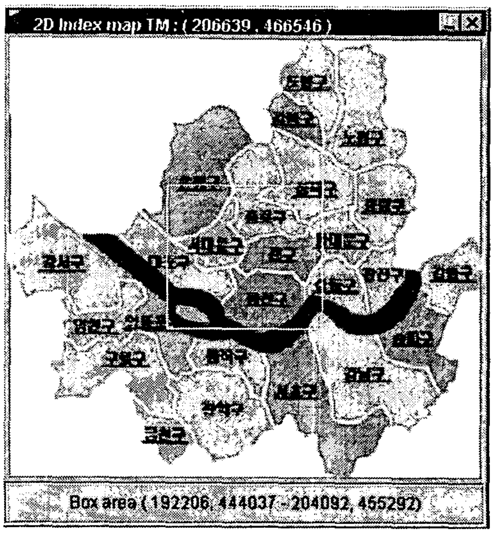


figure 2.2 index map representing regions

2.2 Fast clipping of DEM

As explained above, in this step we clip the user selection area with only left lower position and right upper position of rectangle area. Usually, the DEM file is of binary form, we cannot open in a normal tool. Instead of that, there is a header file that represent the real coordinate of each corner of data, and sampling numbers which we can compute the offset of sample values in parallel and in vertical. By these properties we can make group the area included in the user defined selection area in the high-resolution original data.

Since the data we used is of 10meter-resolution and 30km2 area approximately, if we select too broad area, its boundary is 40,000 points, we suffer from memory over-full error. So we have to cope with the area as following two paragraphs explains.

- Normal Case: if the area we selected is smaller than the boundary we specified, we simply transfer all selected data to next module for simplification.
- Special Case: if the area we selected is larger than or equal to the boundary, then control the number of selected points. The way how to control is to enlarge the sampling offset which was usually one unit in normal case above. To find out the sampling offset, we use the following equations. The sampling offset D is given by

$$D = w(src)/w(target)$$

where w() is the number of sample points of a certain data, src is a original index map area, and target is required data set to be drawn in main canvas of area.

2.3 Tin approximation of high resolution DEM

This step is to approximating DEM data by using Tin simplification technique. This is also understood as a conversion or mapping form set of height data to triangular mesh. Since this mapping does not have inverse, we have to note the necessity of this step as in the chapter 1. But the additional interest of this operation is that we can get a geograhic configuration like valley line, more precisely. Most of DEM does not consider feature line of terrain, such a features can be ignored in DEM visualization. But this technique considers the depth line of each height and we can find the feature line is represented as a sequence of edges of triangular mesh.

At first we compute regular shaped TIN data by simply connecting each height field and draws a common shaped triangle. We use the following step to use the simplification technique.

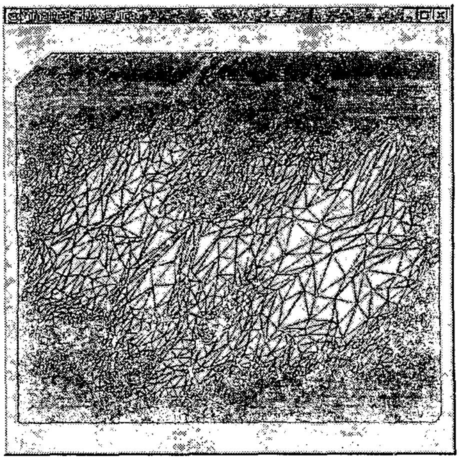


figure 2.3 Simplified TIN of 12000 faces

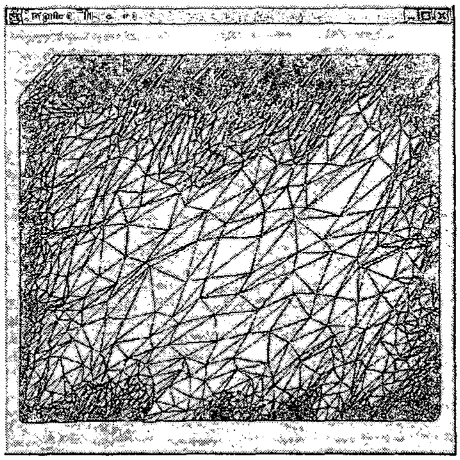


figure 2.4 Simplified TIN of 6000 faces

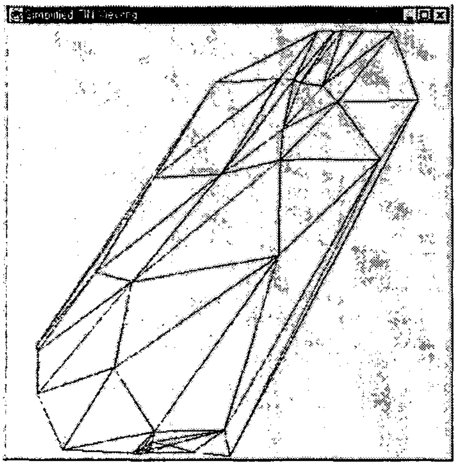


figure 2.5 Simplified TIN of 60 faces

1. *Simple TIN conversion of DEM*

This method is to generate position and connectivity information from DEM. We can compute position on the surface by the real coordinate of each corner and the number of samples and lines. Moreover to represent triangle information, we have to generate connectivity among position data. However, this operation cause the incresement of data size because the position and face information is add as the number of height field is unchanged.

2. Mesh simplification technique.

We can simplify above high-resolution TIN by using mesh simplification technique. This operation can follow user's requirement in the number of faces or vertices or error between original TIN and simplified mesh. The algorithm in this system is deleloped in this critera. The main idea is edge-collapsing operation. This operation is to reduce the number of vertices by collapsing edge of two vertices. These cause 2 vertices become the same vertices. To determine the edge collapse, we chech edge-length, height difference of each vertices of a edge, and the degree of 2 vertices of a edge.

If we remove a edge of small length, the change in the global geometry is not so much influenced. And in comparing the lengths of two edges, removing the edge of which outer joing circle has smaller than the other circle takes effect. As a result of this operation we can remove smaller triangle relatively. This is important that we check the area-geometry for determining collapse rather than edge length only.

The second criterion of collapse is comparing the height difference of 2 vertices of a edge. The smaller difference of height, the less influence the whole shape. The resulting vertex position and height is relavent to preserving geometry shape. The figure 2.3,4,5 show this results

The last criterion is to checking the degree of 2 veritces. The high degree means a lot of adjacent faces. And collapse of the vertices increases the degree of the vertices. This increases complexity of original mesh.

2.4 Local Density Control of TIN

To visualize and control of geographic information through 3D graphcs pipeline, we need a lot of computation and it is time consuming though it is only for visualization. The prior steps like selection area assign and TIN approximation, are for reducing 3D computation loads and time. This methods control the static number of geometric object to be drown to screen. But there is redundant area when uesr naviate the scene or move any special place and zoom in to a certain local area in the scene. Or the area too far from the viewer or hard to be seen for the atmosphere condition need not to be rendered. In this case by reducing the local resolution of geometry or omitting to render, we can save computation time. In this way, we call the series of method LOD(Level of detail) control and has been researched in computer graphics. In GIS, this concept is implemented, feature by feature through composing various layer for each features. And system manages what to display for each level of detail or applications.

LOD methods implementing in this system is computing the local area to be appeared to viewer when user navigate the scene and when user simply views the scene, area of long distance or located at the back of viewer is culled dynamically. This method has merit that they use less data than the method that load all necessary data when user start to view the scene, though it need a computation of viewing direction and viewable area during scene manipulation.

3. Conclusion and future works

In GIS, 3D surface geographic data is measured in a various ways. But the raw state of the data is of the form DEM. To visualize this data effectively and to control them for extracting geographic information useful to users, we manipulated them in a various way for each optimal format. In this paper, we propose 4step manipulation that can deal with large amount of data through user interaction and approximation. By this method, we can implement fast navigaton, response to your interaction.

For the future research, we have to develop more fast mesh simplification algorithm. Especially, approximating DEM data directly is necessary, because regular grid TIN data can occupy system memory too much in a certain times. And developing algorithm that can cope with user interaction or change of views. Various culling and LOD control method have to be innovated. For this result, the system can respond in real time to user's selection and navigation.

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