3D MODELING AND DATA ORGANIZATION OF POWER TRANSMISSION BASED ON DIGITAL EARTH

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ABSTRACT:

Since the moment Google Earth launched by Google company, the subject of geographic information system (GIS in short) has made great progress. While, the traditional two-dimensional and three-dimensional power transmission lines GIS can no longer satisfy people's requirement to understand the real world. This paper is based on GeoGlobe digital terrestrial platform.It requires some fast scheduling data method. Because the data organization and management methods in the traditional 3D transmission lines GIS are no longer suitable according to the requirement of data scheduling in the digital earth theory, it is necessary to put forward a more reasonable and conformable data structure to implement clipping data scheduling.This paper aims to discuss and resolve the problems mentioned above, and then establish a modal database for the use of Digital Earth.

1 INTRODUCTION

Since the moment Google Earth launched by Google company, the subject of geographic information system (GIS in short) has made great progress. While, the traditional two-dimensional and three-dimensional power transmission lines GIS can no longer satisfy people's requirement to understand the real world. So, the new three-dimensional digital terrestrial transmission lines GIS based on digital earth has been developed, which can give users more intuitive information. Further more, in a more realistic manner, the new three-dimensional digital terrestrial transmission lines GIS can indicate the variety, the quantity and the quality of spatial objects, the spatial location of these objects and the spatial and temporal distribution of the phenomena.

To be simply, the meaning of Digital Earth is to collect the information of the earth, the activities on earth and the changes of the entire environment on earth, and then put them into computer and implement the circulation of that information on the internet through some digital methods. Now, with the efforts of the scientific workers, there have been a great deal of digital terrestrial platforms, such as google earth, world wind, geofusion, GeoGlobe and so on. Typically, this paper is based on GeoGlobe digital terrestrial platform.

The new three-dimensional digital terrestrial transmission lines GIS based on digital earth confronts more special technical requirements: In the first place, it needs virtual reality technology by which we can show more details of the multi-level objects. Taking the performance of 3D photorealistic visualization and computational efficiency into consideration, it is necessary to adopt the Level of Detail Model (LOD in short) Technology for the establishment of a group of different levels of models describing the same object to make a realistic reproduction of "responsive" virtual transmission line system. So, when the view point is far away from the object, the window shows the low level model. On the opposite, when the view point has a closer distance from the object, the window will show a higher degree of precision model. In the second place, it requires some fast scheduling data method. Because the data organization and management methods in the traditional 3D transmission lines GIS are no longer suitable for the requirement of data scheduling in the digital earth theory, it is necessary to put forward a more reasonable and conformable data structure to implement clipping data scheduling.

This paper aims to discuss and resolve the two problems mentioned above, and then establish a modal database for the use of Digital Earth.

2 CONSTRUCT LOD MODEL

2.1 Introduction and classification of LOD

The basic concept of LOD is protracting smaller and far-away parts or not very important parts of the scenes with smaller details, in order to balance the fidelity and frame frequency [1]. LOD technology deals with rendering quality and rendering speed eclectically and is viewed as the main method to accelerate graphics rendering [2].

There are discrete LOD and continuous LOD in categories according to the continuity of detail levels. In discrete LOD, a number of different accuracy detail levels are pre-established for the modeling object. Then we just choose the appropriate level in the actual applications. Discrete LOD can simplify the real-time processing and the detail Levels can be obtained through either artificial modeling or computer automatically generation. The drawback of discrete LOD is that the detail levels is not continuous, which may cause visual mutation when switching between levels. In order to reduce the visual discomfort, some appropriate LOD switching technology is needed [3]. Continuous LOD is proposed against the shortcomings of discrete LOD. In continuous LOD, it will generate appropriate detail levels real-time according to the actual situation. So it has a more sophisticated level granularity and can avoid visual mutation due to large-span changes. View-Dependent continuous LOD, which is evolved from continuous LOD, takes simplified view relevant standards and attempt to choose the most appropriate level of detail model for current view.

In the 3D scene of power transmission lines, the main 3D models are the pole model and the transmission line model. Pole model with the same type is reused in high frequency [4], while the transmission lines are different with each other. According to the realistic effect and computational efficiency of 3D visualization, Prof. Zhu Qing classified 3D models into three categories [5], according to which, we use different levels of detail methods to simplify different types of models.

2.2 Construct Pole' LOD model

Pole model has invariant geometric shape, similar surface materials and textures and important features of the shape and location. Such models are usually built in software tools (such as 3D MAX) in advance, and then exported as specific document format. Then in applications, we import the document into overall 3D scene according to the special information of position and stance relative to the origin of the local coordinate system in the model.

There are more or less ten types of pole models in the power transmission GIS based on Digital Earth Virtual World GIS platform. Further more, most poles are just different from their coordinate. So we can use software tools to manually construct LOD model for poles. The simplest Pole model is a cylinder with a bar on top. According to the reduced grade, we produce five different detail levels from the most sophisticated model to the basic model. The higher the level, the more sophisticated the model is and the greater the data volume is. This series of models is called as multi-resolution model. When a pole model is displayed, we usually send a basic model at first and then gradually display a more sophisticated model.

3 CONSTRUCT POWER TRANSMISSION LINES' LOD MODEL

3.1 Principles of constructing the model

The arc sag is the basic feature of the transmission line. Calculation, adjustment and observation of the arc sag are extremely important in the construction of transmission lines. In order to describe power transmission lines realistically, we should establish 3D model of the arc sag rather than simply using a two point straight line [6]. The power transmission lines hang with poles as the support and insulators as the hoisting points. So for a soft (not under bending stress) and weight equidistribution along rope, which hangs with two fixed points A and B, it presents the shape of a "catenary".

In power transmission lines, (1)the span is usually very bog, (2)the rigid impact of the transmission line material can be ignored, (3)weight equidistribution along, so the shape of transmission line hang can be viewed as a "catenary" shown in Figure 1. The catenary formula is as follows:

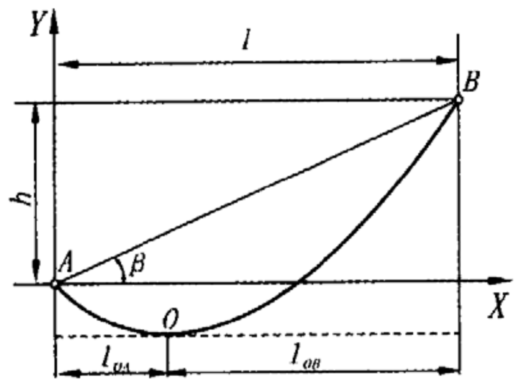

Figure 1 Power transmission line

The original catenary formula is very complex and inconvenient in the actual calculation. So we usually simplify it as the sideling parabola or flat parabola formula. In order to minimize the booboo of arc sag as far as possible, in normal circumstance, when $h / l \leq 0.15$, we choose flat parabola formula and when $h / l > 0.15$, we choose sideling parabola formula.

3.2 Construct level of detail model

The contents of the original 2D power transmission line information are: (1)3D coordinates of the initiative pole, (2)3D coordinates of the terminal pole, (3)the serial number of the initiative pole, (4)the serial number of the terminal pole. And space Cartesian coordinate system is used. The 3S model generated presents a electric line with "line out" for a record and each transmission line is formed by a series of line segments. The two endpoints of each segment are generated through the formula above. When the points are ample, the display effect will be similar to a smooth arc, which demonstrating the real form of power transmission lines.

In term of the display requirement of the Digital Earth Virtual World platform, this paper divided the power transmission line model into six different detail levels (0-5). The divided principle is: (1)the most simple model is presented with only a segment between the endpoint of a line; (2)the other models are formed by a number of segments. The formation process of model is shown in Figure 2.

The fineness of the model is decided by the number of lines, which is decided by the number of points formed the arc meanwhile. The most sophisticated model in the paper adopt the following formula to get interpolation points: interpolation points = (current level / 6) * sqrt (dx * dx + dy * dy)。dx and dy are the horizontal and vertical distance between the two endpoints of the power transmission line.

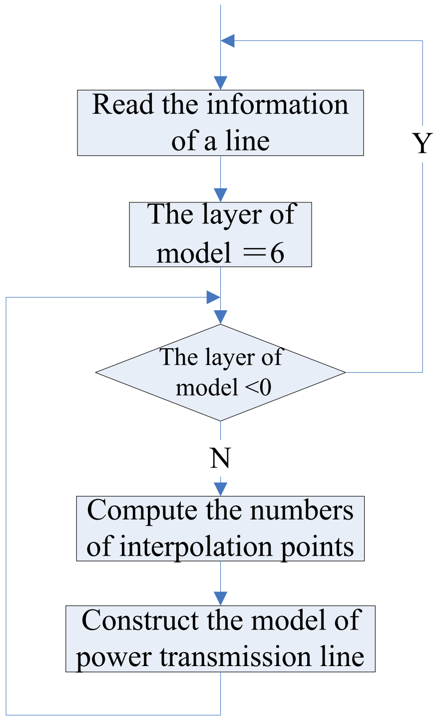

Figure 2 formation process of power transmission line model

4 DATA ORGANIZATION OF THREE-DIMENSIONAL POWER TRANSMISSION LINE MODEL GIS

4.1 The global model data Quadtree index in a unified reference system

In the study of global 3D visualization system, there should be a unified spatial reference for the convenience of data analysis use. In WGS-84 coordinate system, the origin is the core of the Earth and the coordinates is spherical, which has no cross-projection problems. WGS-84 coordinate system can describe the whole Earth sphere unifyingly, perfectly and seamlessly and is suitable for the study of the global 3D visualization. The system in the paper is just under WGS-84 coordinate system.

Quadtree index, which is based on space recursive breakdown mechanism, divides the known scope of the space into four equal subspaces. If necessary, each subspace can be sub-divided sequentially and you can get a space division based on quadtree, see Figure 3. If dividing the Global space will Quadtree method, you can establish the global model data Quadtree index in a unified reference system.

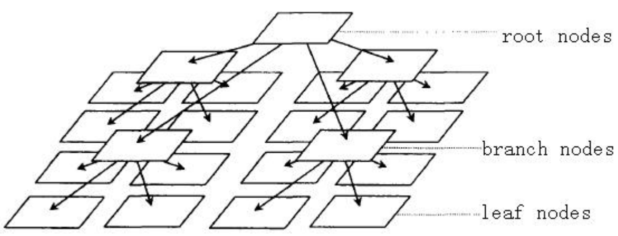

Figure 3 Quadtree chart

4.2 Construct pyramid tile convenient for rapid quadtree index

Pyramid model is a multi-resolution hierarchy model. To be accurate, pyramid model is continuous, while it is difficult and meaningless to make resolution change continuously when building the pyramid. Therefore, we often use ratio method in the pyramid construction to obtain a number of levels with different resolutions or scales. From the bottom to the top of the pyramid, resolution or scale becomes lower, while the scope each level presents is the same. There is a formula to show resolution or scale of each level.

If resolution of the original data is r, the ratio is m, the resolution of the l level is rl, then we have:

$$rl=r*ml \qquad (1)$$

We build pyramid 0 from the original data. Ratio m can be any integer greater than 1, here we use 2, which means one 2*2 data block in current level to generate one data block in the upper level. If the original resolution is 1 meter, the resolution of the first layer is 2 meters and the resolution of the lth level is 2l meters, as shown in Figure 4.

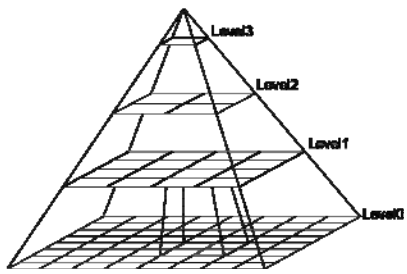

Figure 4 schematic illustration of pyramid structure

The pyramid data sets of the global 3D model are prodigiously different with other pyramid data sets. Take image pyramid for example: assuming that we have a 20-levels pyramid and each level contains different image data. While according to the visibility of 3D model, the model pyramid only builds six levels from the bottom, with the highest precision model at the bottom and the lowest precision model on the top. The specific storage location is calculated in accordance with the resolution based on space coordinates of objects. In term of the feature that different level of the data sets has different resolution, we can do LOD visualization for 3D model according to the resolution of current level when browsing data.

In this paper, the definition of longitude scope is [-180,180] and latitude scope is [-90, 90]. In WGS-84 coordinate system, I process the global data by means of the regular grid block index mechanism. The geographical space is divided into a number of small pieces using uniform-size grid square. Then each small piece is regarded as a barrel and we put the space object which falls on the small piece into the corresponding barrels for storage. When doing retrieval for space objects, we only retrieve the barrels which contains space object. To meet the requirements of precision, the barrels can also be broken down into smaller barrels and can be divided into a number of classes for retrieval. This index is very suitable for the whole block index management, whose coding and algorithm is in the literature [7].

I considered the following points synthetically in the data blocking:

1. favorable for distribution storage.
2. favorable for building the pyramids.
3. favorable for constructing the index.
4. favorable for rendering on the client.
5. disk read / write and network transmission.

Based on the above five points, the blocking rules are proposed as follows:

1. each data block has the same width and height.
2. The size of the grid is integral power of 2.
3. The size of cell grid is generally $2^n \times 2^n$.

The reason for taking such blocking strategy is that the constructions of the pyramids and Quadtree index have the same request for equal block size. And choosing 2 integer power as the data block size can simplify the complexity of building the pyramids and Quadtree index.

4.3 Design pyramid tile data for power transmission line model library GIS

In this experimental system, the most sophisticated model data is put into the bottom level of the pyramid, and then from the bottom to the top, lower fineness model data is stored in turn. For example, regarding a power transmission line, we have constructed six levels of data with different fineness and put the most sophisticated model data on the pyramid level 0, the less sophisticated model data on the pyramid level 1,..., the most crude model data on the pyramid Level 5.

In the power transmission GIS, a common situation is that models of power transmission lines or buildings can not be fully consistent with the tiles scope of the pyramid model, in other words, a line used to be across more then one tiles. In order to make assurance of the integrity of the model during visualization processing, we calculate which tiles the model belongs to from the center coordinates of the model and save the model file into the tile associated directly other than segment the model data. Once a tile contains this model, the other tiles intersecting with the model will no longer include this model again. Toward the power transmission line model, we use the midpoint coordinates of the power transmission lines.

Because there are only a few types of pole model in the power transmission GIS and the same type of pole model is usually reused for many times, if we store the pole model in accordance with the transmission lines and other models, it will result in too large blocks of data and long time scheduling and data redundancy when scheduling by block.

In consideration of those characteristics, we build modules of Pole model separately, and then save various types of LOD Pole models into the pole model library and create indexes files for pole retrieval. The file name of the pole model library is PoleModelInf.dat and the index file name is PoleModelInf.apd. In the document PoleModelInf.apd, there are records of each pole model. The record structure is:

```
typedef struct tagModelFileItem
{
    char strFileName[64];       //pole name
    long nItemOffest;           //pole model Storage location offset
    long nSize;                 //pole model size
}ModelFileItem;
```

In this system, the naming rule of Pole model is: Pole name_level ID. Take a kind of pole called "sea towers" for example, the name of the LOD models are: sea towers_1 , Sea towers_2, sea towers_3, sea towers_4, sea towers_5. And the sea towers_1 is the most sophisticated model, then the other models are gradually simplified and the sea towers_5 is the simplest model.

Similarly, when generating GIS pyramid model of the power transmission through the pole information, we create five Pole documents for each pole model, and the naming rule is "Pole ID_level ID.Pod". So for a pole whose ID is 1528, the five pole documents are 1528_1, 1528_2, 1528_3, 1528_4 and 1528_5. The specific format of the document is:

```
typedef struct tagPoleInf
{
    int poleoid;            //pole id
    double dLatitude;       // Longitude coordinates
    double dLongitude;      // Latitude coordinates
    double dAltitude;       //pole altitude
    double dHeight;         //pole height
    double dAngle;          //pole angle
    int nPoleSerial;   //Pole serial
    char PoleName[64];      // Pole name
    long PoleOffset;        //pole model offset，Value is -1, said the model does not exist
    long nSize;             //pole model size
}PoleInf;
```

When constructing the pyramid, we save the pole document into the corresponding tile level according to the level ID contained in the document name and the specific coordinates of Pole just determine in which pyramid tile and which level the pole model should be saved. In Digital Earth Virtual World platform, Pole model is read from the library according to the offset of Pole model in the Pole document.

5 SUMMARY AND OUTLOOK

In allusion to the 3D transmission line GIS based on Digital Earth, this paper puts forward a basic solution which has been certificated by the Fujian province Electric Power Transmission Line GIS. It has proved that these 3D models can display real-time, fluently on the Digital Earth, and perform the effect of different levels of detail according to the distance between the viewpoint and the object. That's to say, the practicability and scientific significance of the method is undoubtable. While, it needs more thorough research in aspect of more effective modeling methods and fault analysis for the layout of complex circuits.

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