EXPLORATORY RESEARCH ON DYNAMIC VISUALIZATION BASED ON SPATIO-TEMPORAL DATABASE

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ABSTRACT:

Visualization plays an important role in the representation of geographic data in GIS. The addition of temporal variable challenged the implementation of it. In the paper, the authors put forward the methodology of dynamic visualization, which is to represent the variation of spatial objects and phenomena dynamically by the utilization of dynamic symbol and dynamic map. The paper discuss mainly about the implementation of geographic data that stored in the spatio-temporal database. Throughout the research, we can conclude that dynamic visualization is a good way to represent the variations of geographic objects and phenomena according to the time process.

1   INTRODUCTION

Visualization can cause people to master essential characters of spatio-temporal data, and it find a best way to convey and receive the spatial information indicated by spatio-temporal data(HUAN Xingyuan,2001). The data stored in spatio-temporal has wide category, abundant content and sophisticated structure, in order to represent, convey and use the geographic data in a systematically and essentially way, it is important for us to master the essential characteristics of spatio-temporal data. The visualization technique becomes a fundamental tool for the acquisition, comprehension and interactive operation on spatial information.

Trace the development of visualization, we can summed up them in the following steps:

1) 2D Visualization
Generally, the common way of visualization of spatial data is 2D visualization, it is the digital implementation of traditional cartology and cartography. Because 2D Visualization has less volume of data and has mature theory, it is widely used by now.
2) 3D Visualization
The true world is a three dimensional space, represent the world into 3D models with computer will give people a live impression of the world.
3) Virtual-Reality technology
By the use of Virtual-Reality technology, people not only get a live impression of the real world, but also can execute interactive operations toward the object in a immerse environment.
However, with the addition of time variable, a key problem should be resolved in this era is multi-dimensional dynamic visualization, which is the visualization of spatial dominated by the temporal variable. At present, one of the weakness is the lack of the efficient valid model, on the other hand, the abrupt increase of information caused by temporal variable challenged the computer technology for the corresponding visualization of spatio-temporal data.
In order to tackle these problems, to introduce a new technology of visualization—dynamic visualization of

sptio-temporal data is necessary besides the establishment of reasonable model.

2   DYNAMIC VISUALIZATION

Dynamic visualization of spatio-temporal data, which bases on the spatio-temporal database system. spatial-temporal database is the database system which stored the temporal, spatial and relevant attribute geographic entities. Before the introduction of temporal variable, 2D, 3D and Virtual-Reality technology have become important methods for the visualization of spatial database. Due to the addition of temporal characteristic, a new challenge is required for the spatial database.

Dynamic visualization employing dynamic symbol, dynamic map and computer graph theory, using computer animation and super display technology, aims to represent the versioned geographic data stored in the sptio-temporal database in a dynamic way on the electronic screen according to time process. By the use of dynamic symbol and dynamic map, the variation of spatial objects can be represented lively.
The dynamic visualization of spatial-temporal database not only employed all classic visualization methods, but was respected to resolve the temporal problems that haven't been solved yet.

2.1   Dynamic Symbol

Cartographic symbols not only display the spatial and mutual relation between spatial objects and phenomena, but also reveal the variation of space and time. The traditional cartography describe many aspects of properties and characters of geographic entities based on the manipulation of 7 visual variables—shape, size, direction, opacity, rotation, structure, density and color(ZHU Guorui,2004).However, the traditional symbol system is limited in representing dynamic characters of spatial objects and phenomena. For better demonstration of dynamic characteristics of geographic entities, we introduce dynamic visual variable—time into the visualization of

geographic data, so that variations according to the temporal variable can be displayed very well.

According to the methodology of demonstration ,we can sum up dynamic symbol into two styles: Object-Oriented dynamic symbol and Effect-Oriented dynamic symbol, which are used in the dynamic visualization of spatio-temporal data.

Object-Oriented Dynamic Symbol

Object-Oriented dynamic symbols are symbols that each of them are regarded as separately objects, each symbol object can be generated into an corresponding instance after the setting of its temporal variables for every visual attribute. Through this method , each changed object in the spatio-temporal database can be represented by one kind of Object-Oriented dynamic symbols. So the variation that occurred in time process will be demonstrated by the dynamic symbols. However, the display efficient is very low because of it is high memory consuming. In order to better the display, we introduced the Effect-Oriented dynamic symbol.
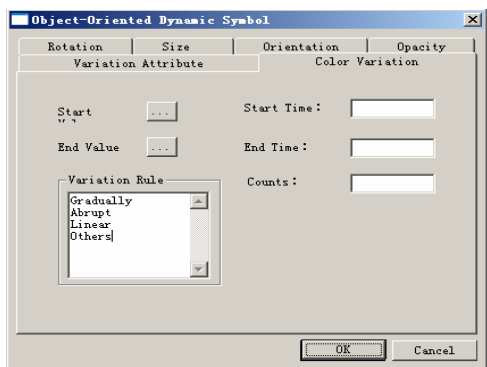

Figure 1   Object-Oriented dynamic symbol

Effect-Oriented Dynamic Symbol

We mentioned above that the display efficiency of Object-Oriented dynamic symbols is very low, then the Effect-Oriented dynamic symbol was introduced aims to resolve the problem. The Effect-Oriented dynamic symbol is a combination representation of Object-Oriented dynamic symbols and snapshots of several time spots. Such as we know, if every changing object is demonstrated by a dynamic symbol, much of the memory of the computer will be concentrated on the display, so the speed of demonstration will definitely slow. If some snapshots are used to accompany the display of dynamic symbols, the numbers of dynamic symbols will be reduced, which can speed the demonstration. But the choice of snapshots will concern generalization of objects, so this method still need to research on.

2.2   Dynamic Map

Map is used as a carrier of information to visualize the geographic information, through the addition of temporal variable in the data structure and its utility in the visualization, a new map—dynamic map was created by the use of dynamic symbol and the implementation functional representation of time(AI Tinghua,1998), the map also called deduction map. The manipulation on several attributes including color, size, opacity etc. according to time improve the function of map. By the use of dynamic map we can implement process

recurrence, live tracing and movement.t simulation and other functions, then we can get the destination of visualization of spatio-temporal data on the way: show the essential and principle of the geographic phenomenon. Figure 2 shows the exploitation process of north –America by dynamic map.
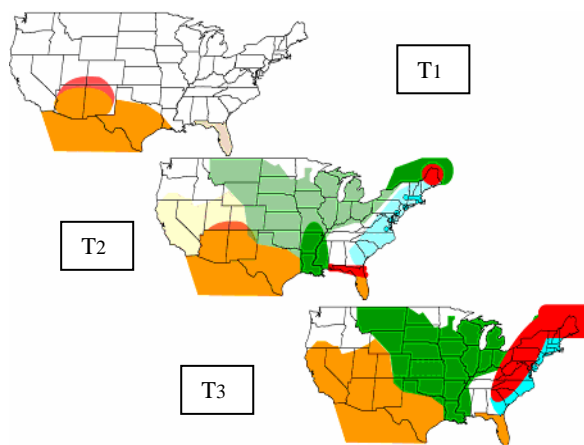

Figure2   The exploitation process in north-America

2.3 Dynamic symbol, Dynamic Map and Dynamic Visualization

For the representation of variations of graphic objects and phenomena, dynamic visualization is adopted. Both dynamic symbol and dynamic map are employed to achieve the destination. The detailed use of them are discussed in the following.

The variation of geographic entities and phenomenon is actually the process of changes in location and properties. According to properties and styles of variation, we divide the movement and variation into following styles (TANG Xinming, 1999):

①To display abrupt variation of property: in this variation, the property of one object changed suddenly, e.g. the annotation of a city was change, by the use of dynamic display of annotation, this phenomenon can be demonstrated;

② To demonstrate gradually variation of property: in this variation, the property of object changed while the location of it preserved, e.g. the continuous observation of weather. Through the dynamic visualization of opacity or color of polygon objects, the phenomenon can be represented very well;

③ To display abrupt variation of location: in this variation, the location of object changed in a specified time while the property of it preserved during the time, e.g. the movement of cloud. Through the dynamic visualization of location of spatial objects, the phenomenon can be displayed;

④ To demonstrate gradually variation of location: in this variation, the location of object changed gradually while the property of it preserved during the time, e.g. the movement of cloud. Through the dynamic visualization of location of spatial objects, the phenomenon can be demonstrated;

⑤ To display abrupt variation of property and location: in this kind of variation, the property and location of spatial object are

suddenly changed in a specified time, it is a combined variation, by the use of dynamic display of dynamic parameter and location of symbol synchronously, we can represent these very well.

⑥ To demonstrate gradually variation of location and property: the property and location of spatial object are gradually changed during the time, it is a combined variation, by the use of dynamic display of dynamic parameter and location of symbol synchronously, the phenomenon can be demonstrated;

⑦ To display abrupt variation of property while the gradually movement of location: It is also a complicated transformation, not only the abrupt variation of property of objects are expected to be visualized, but also the gradually movement of spatial objects will be displayed.

⑧ To demonstrate abrupt variation in location while the property is gradually changed: It is also a complicated transformation, not only the abrupt movement of spatial object are expected to be visualized, but also the gradually variation of property of objects will be displayed.

Through the employment of computer graph theory, computer animation and super display technology, a good way was provided to represent the changing geographic information by dynamic symbol and dynamic map.

3   IMPLEMENTATION OF DYNAMIC VISUALIZATION

3.1   Schema for Dynamic Visualization

Before the discussion on the schema, we firstly talk about the term of versioned data. Such as we knew,the geographical data stored in spatial-temporal database have complex relations and gigantic volume, however, we can use temporal variables to relate them in a organic system. After the utilization of time dimension, versioned spatial data came into being, versioned spatial data is a systematic collection of data which marked with temporal character. To represent the versioned spatial data according to the time process with visualization technique, which we name it the dynamic visualization of spatial-temporal database.

In the paper, a schema is put forward for the dynamic visualization: import all the versioned data of the spatio-temporal database into computer at once, then begin the process of association, afterwards, dividing the displaying time into several segments, then represent the changing information with dynamic symbol and dynamic map based on temporal variable. A figure was drawn for it(see Figure 3):
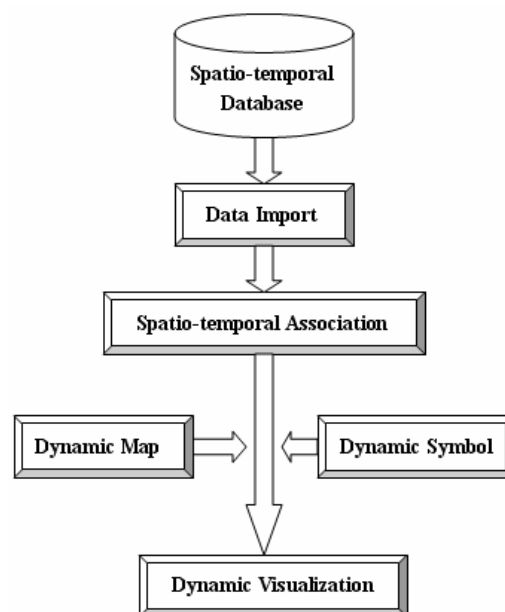

Figure3 Schema for the dynamic visualization

The Schema for the dynamic visualization have the following steps:

Firstly, Read the versioned data: the Spatio-temporal data are stored in the form of versioned data, in this step, all the versioned data are read into the memory of computer at once.

Secondly, the spatio-temporal association are implemented, such as we know, the spatio-temporal variation include variation in space, topology and property. The space relation, topology and property of geographic objects are different in the different time, one item or two or all of the space relation, topology and property of geographic objects will change during the process. The topological relations, space state and property characteristics of the spatial objects at the following time are affected by the previous time(WU Lixin,2003). Based on their location relation, topological relation and property of spatial objects, spatio-temporal association aims to find out and mark the corresponding objects which state have changed during the process in the versioned data. In the procedure, raster matching, node matching, property matching, delaunay matching and other methods are used. the selected objects after assocition will be represented in the dynamic way.

Thirdly, the implementation of dynamic visualization is put in practice, which include two aspects, one is to represent the objects after spatio-temporal association with dynamic symbols, the other is to   display the objects that has no variation (or the degree of variation is so low that it couldn't be detected) as the static background of the dynamic symbols.

### 3.2   Application of Dynamic Visualization

In the paper, using Visual C++ 6.0 Integrate Development Environment, OpenGL technology, in a computer environment of Dell/ PIV/2.4G/512M, a application for dynamic visualization was carried out successfully. Some key technology which concerned in the application are as followed:

Computer animation: by the use of computer animation, we can map the real time for the variation of the objects into the

computer time, and trigger the display event in the different time, So that the dynamic visualization can be represented in a continuous way.

OpenGL: OpenGL displaying technology is widely used in the Information Technology because of it's high efficiency, powerful functions, OpenGL technology provide a easy way for the implementation of the dynamic visualization. In our application, OpenGL was use to draw both the dynamic features and the background. It is also used to smooth the screen and get rid of the glitter phenomenon in the displaying.

The application on the dynamic symbol: Adding temporal variables to the traditional symbol, by the use of different variables in different time, utilize the computer animation, we can get the dynamic symbol in the electronic screen. See figure 4, the variation in the property of same line object, can be visualized very well.
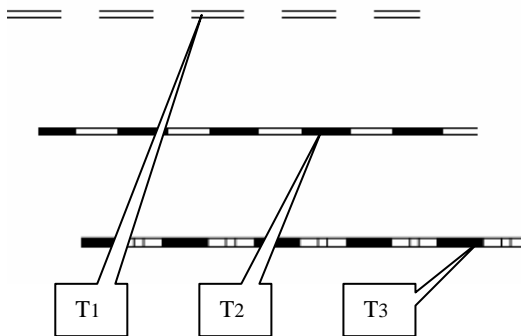
Figure 4: Dynamic Line Symbol
T1: Building Railway
T2: Mongline Railway
T3: Eletronic Railway

The schema mentioned above was used to the research on the dynamic visualization for the versioned data which stored in the spatio-temporal database(see Figure3).In the experiment, we select the National geographic information vector database as our test database, and choose two version of the topographical maps as our test data. Figure 5 shows the variation in city zone of Beijing city (as a example of implementation of Dynamic Polygon Symbol) in four different time(T1,T2,T3,T4) , from that we can get a lively impression of the development in Beijing.

T1

T2

T3

T4
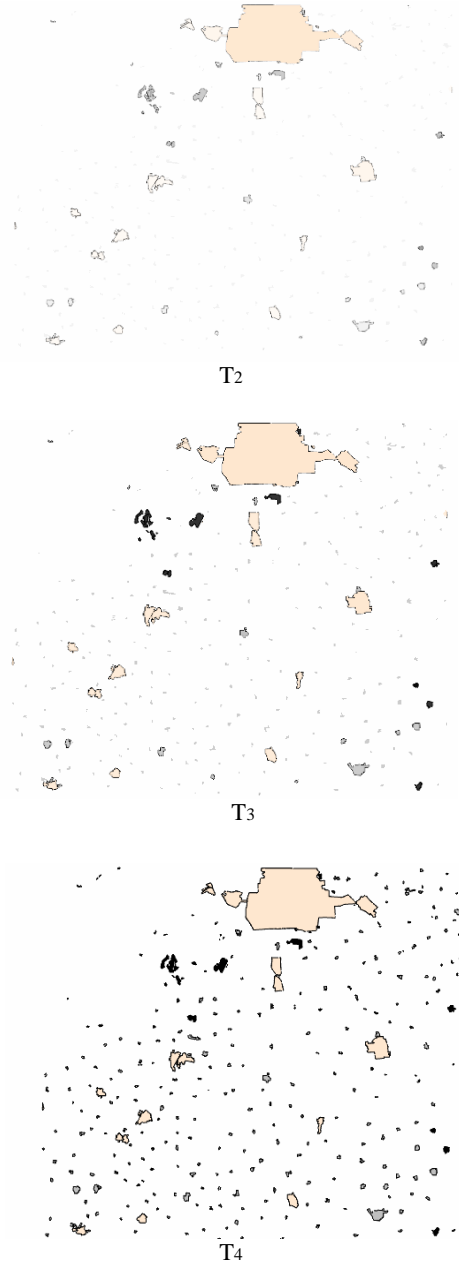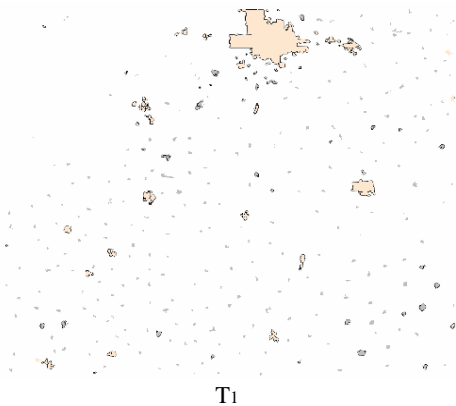
Figure 5   Implementation of Dynamic Polygon Symbol

4   CONCLUSION

Adopt the dynamic visualization of spatio-temporal data, the geographic data which stored in the spatial database with temporal dimension was demonstrated through an efficient map and symbol system. From the visualization effect, the sophisticated relations among time, space and property were represented geographically. We can mine the relationship and detect the tendency and find out the objective principles from the data, which help us to make scientific and timely decision to resolve the problem. In the paper, a research on the dynamic visualization was carried out based on the spatio-temporal vector database, the outcome of the research proved that it is a efficient way to represent the changing feature by dynamic symbol and dynamic map .the next research will be carried on

the visualization of raster based spatio-temporal database and Dynamic 4D database.

REFERENCES

Huang Xingyuan, HU Peng, 2001, Tutorial of GIS. *Wuhan University Press*, pp.204- 206.

Koussoulakou, A., Kraak M J., 1992. Spatio-temporal Maps and Cartographic Communication.*The Cartographic Journal* 29 (2), pp.101-108

Masuoka P, Acevedo W. , Fifer S. , Foresman T. 1996 .Tuttle M. Techniques for visualizing urban growth using a temporal GIS database .*Presentation at the ASPRS/ACSMAnnual Convention and Exhibtion*, Baltimore, MD, pp.22- 25.

ZHU Guorui, 2004. Cartography. *Wuhan University Press*, pp.34- 35.

AI Tinghua,1998. Dynamic symbol and dynamic map. *Journal of Wuhan Technical University of Surveying and Mapping*. 23(1),pp.47-51

TANG Xinming, WU lan 1999.Spatio-Temporal data model and Geographic Information System Frame. *Remote Sensing Information* 01,pp.4-8

WU Lixin, SHI WenZhong. 2003, *Principles and Algorithms of GIS*, Science Press ,Beijing, pp.154-156

Alan M. MacEachren, D.R.Fraser Taylor, 1994. *Visualization in Modern Cartography*, New York: Pergamon.

MacEachren.Time as a Cartographic Variable. In:Hilary M H, David J U,eds. *Visualization in GIS*. WILEY, 1994.

Bertin, J. (1967). *Semiologie Graphique*, Paris/Den Haag: Mouton.

Kraak, M.J. 1999 Cartography and the use of animation. Chapter 17 in: Cartwright, W., M. Peterson & G. Gartner (editors) *Multimedia Cartography*. Berlin: Springer Verlag, pp. 173-180.

MacEachren A M , Kraak M J, 2001. Research Challenges in Geovisualizaion. *Cartography & Geographic Information System* , 28(1), pp.:3-12.

Taylor & Francis, 2001.*Web cartography :developments and prospects.* London ;New York.

MIAO lei, LI Lin, 2004. The combination and development of map and animation. *Science of Surveying and Mapping*, 29(3),pp. 42-44.

AI Tinghua,1998. Dynamic symbol and dynamic map. *Journal of Wuhan Technical University of Surveying and Mapping*. 23(1),pp. 47-51.

ZHANG Junhai, HU Wenliang, ZHANG Yiwen, 2001. Study on the dynamic graphic symbols in quantitative map. *Geo-Information science*, (1),pp. 77-80.

Koussoulakou, A. M.J. Kraak (1992). Spatio-temporal maps and cartographic communication. *The Cartographic Journal*, 29 (2), pp. 101-108.

Alan M. MacEachren, D.R.Fraser Taylor, 1994. *Visualization in Modern Cartography,* New York: Pergamon.

MacEachren.Time as a Cartographic Variable. In:Hilary M H, David J U,eds. *Visualization in GIS*. WILEY, 1994.

Chen YueLi, 2005. Study of Visual Variable and Dynamic Expression Method of Three Dimensional Animation Map, *Master's thesis*, Wuhan university.

http://www.macromedia.com/cfusion/knowledgebase/index.cfm?id=tn_15568

http://www.dbxgeomatics.com/svgmapmaker/doc/svgMM_UserInterface-04-2-6_EN.HTML