Theory and Application of Moving GIS

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Abstract: The paper compares Static GIS, Mobile GIS, Dynamic GIS and Moving GIS at first, then puts forward and discusses a description means of mobile objects, a model of spatial relation based on 9-intersection model and the query and analysis operations that Moving GIS should implement. On the above theory basis, the paper designs the function of Moving GIS and implements a prototype system named PNS-I on the basis of PDA, which has integrated GPS, GIS, GSM and GPRS.
Key words: mobile GIS; moving GIS; dynamic GIS

1. Introduction

As far as the traditional topographic map and current GIS data goes, under the error limitation of the research and project it is easily to find that the position and the relation of spatial reality will hold the line for a period of time, except spatial reality changed or destroyed, the map and GIS with this character will be called static state map and static state GIS. To static state GIS, as it will hold steadiness, the relation between the spatial reality can be computed and stored in advance for the convenience of query, search and analysis of the data process. With the development of the computer, the spatial relation of the reality can be calculated by the absolute position of the reality. In theory, once the spatial reality make sure its own absolute position, the spatial relation between the spatial reality is also confirmed. In the digital map and GIS, Dynamic GIS can be defined as the hard and soft system to simulate, express, handle, query, search and analysis the reality static state or dynamic group, in which there will be one or more moving object. From the definition, Dynamic GIS can be classified as Moving GIS and Mobile GIS based on the moving status of the reference background. In Moving GIS, the reality group of the reference background is in relative static state; In Mobile GIS, the reality group of the reference background is in relative dynamic state.

Generally speaking, many impersonality phenomena can't be explained by static state GIS smoothly. Such as airborne Navigate system based on vehicle, plane, ship, handheld navigate system, both of them are with the character that mobile spatial entity (GPS position) lies to the relatively static spatial entities. The most important to research is that the position and relation character of mobile entity to the relatively static spatial entities, only part of the question can be solved by the theory and method of the static GIS. An other example is the planes on the air, ships on the sea, if we take N planes or N ships as the target entities and the rest of them as the reference entities. Then, target entity set with the reference entity set are the function of the time not only in spatial position but also interior relation. Such problem will appear in future GIS application, and it is also not can be resolved by static GIS theory. So the progress of the technology and new application demand will make the research of the Dynamic GIS to be very important. The theory, method and implement of the moving GIS and mobile GIS are discussed in the paper.

2. Basic Theory of Moving GIS

2.1 Description of mobile objects

The basic character of the mobile object is temporality which denotes that its position and attribute are changing along with the time running on. In order to describe mobile objects well and truly, we must import the time into the coordinate system for mobile objects. Thus there will be a three-dimensional reference system that is composed of X, Y and T instead of the two-dimensional system, and the position of a mobile

object can be described by such a expression as (x, y, t).

Like objects in Static GIS, objects in Moving GIS can be also divided into three types: *Point*, *Line* and *Polygon* (temporarily we have not take three-dimensional entities into account). When the mobile object is a point entity, it behaves as a line in the X-Y-T reference system; when the mobile object is a line entity, it behaves as a surf; and when the mobile object is a polygon entity, it behaves as a declining column. The static objects in Mobile GIS can be described as the same of the mobile objects in a certain extent, they behave as a line, a surf and a column which are vertical on the plane confirmed by X and Y. Figure 2 shows the representation of the above objects, and broken line stands for the mobile object, real line stands for the static object.

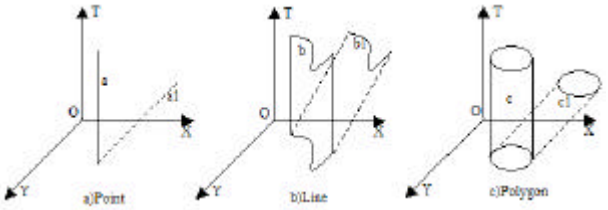

Fig.1 Point, Line and Polygon Object in Spatio-temporal Coordinate System

2.2 Topologic relations among mobile objects

There are lots of models that describe the topologic relations in Static GIS. One relative mature model is the 9-intersection model put forward by Egenhofer which represents the qualitative spatial relation among static objects based on the theory of topology. In the model Egenhofer defines the exterior, the boundary and the interior of each entity, and confirms the topologic relations through the intersection of the three parts. The following Formula shows the form of 9-intersection model.

$$R_9(A,B)=\begin{bmatrix} \partial A\cap\partial B & \partial A\cap B^0 & \partial A\cap B^- \\ A^0\cap\partial B & A^0\cap B^0 & A^0\cap B^- \\ A^-\cap\partial B & A^-\cap B^0 & A^-\cap B^- \end{bmatrix}$$

To the topologic relations among mobile objects, we can transplant the mobile objects in three-dimensional coordinate system which are represented as the form *X-Y-T* to a two-dimensional system represented as *X-Y*, thus we can also use the 9-intersection model to describe the topologic relations. Although the position of a mobile object always changes, at a certain time instant t_i we can regard it as a static one too. So if we draw a plane at t_i which is parallel to the *X-Y* plane, we can get the analysis plane on which we could study the topologic relations among static and mobile objects through the 9-intersection model. Figure 3 shows the process how to acquire the analysis plane.

2.4 Spatial operations in Moving GIS

Querying and analyzing mobile objects is the actual matters that Moving GIS should implement. But there is still no uniform cognition on how many spatial operations Moving GIS would cover. Many researchers distributed all over the world put forward their own opinion, for an example, QIN generalized six kinds of mobile spatial operation. On the basis of formers' work, we think that Moving GIS should cover the following operations at least.

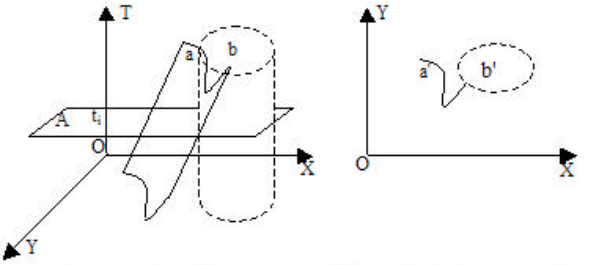

Fig.2 Analysis Surface Acquisition in Spatial Relations Description

2.4.1spatio-temporal position query of mobile objects

It is the most basal operation in Moving GIS. According to the different cases when the mobile object is *Point*, *Line* and *Polygon*, we take different actions, but the common ground is that we can all focus on a certain snapshot t_i at last. And if t_i is sampling instant we could directly get the result, or if t_i is not we need to do interpolation using the methods stated above.

2.4.2attibute query of mobile objects

The great difference between static objects and mobile objects in attribute is that the velocity is an important character of mobile objects. For the object that has changeless shape such as the car, the plane, the ship and etc, we can abstract it as a *Point* entity in the *X-Y-T* coordinate system, and think the velocity of the entity is equal to the mobile object's. And for the mobile object whose outline is changing such as the expansible desert extent, we need to calculate the average velocity of the boundary of the object.

2.4.3 spatial relation query between mobile objects and static objects

The distance between a mobile object and a static object at a certain instant, the area that a mobile object overlaps a static region, whether a mobile object is in a determinate region, and whether a mobile object intersects with a determinate line are some examples. We can implement such kind of query by acquiring a analysis plane at a snapshot t_i to simplify *X-Y-T* system into *X-Y* system. And since the spatial relation among static objects is changeless, we can deduce some results from the known relations.

2.4.4 spatial relation query among mobile objects

Compare to the spatial relation between mobile objects and static objects, relations among mobile objects are more complicated. Similar to the above, we can also solve such query by simplifying the reference system through analysis planes, but here we have to consider the moving state of all studied objects at the same time.

2.4.5 historic track analysis of mobile objects

On the basis of finite sampling data and using interpolation and fitting methods, we can acquire the exact track curve of a mobile object. So users can query the historic positions of mobile objects at every snapshots.

2.4.6 intending trend analysis of mobile objects

The final purpose of Moving GIS application is to forecast and control the moving trend of mobile objects. Based on the historic track curve of studied objects, we can discover the moving discipline, and further control the moving trend, such as commanding two cars to encounter at a determinate station.

3 Development of the integrated GPS, GIS, GSM, GRRS and PDA system

Comparing with static GIS, research object of moving GIS is no longer the entity set with no change of the relation, but a little of the mobile entity set, with the relatively static entity set as the reference object. Meanwhile, hardware setting is also changed obviously, so it is very necessary to have the portability, agility, graceful appearance and intelligence for mobile device. Because of the predigest of the intelligence terminal and weakness of the computing and storing ability, it is unpractical to put all the static spatial data on the terminal. So it is necessary to update the spatial data in the terminal with server by wired or wireless technology. So, the hardware of mobile GIS consist of four parts: server-side device, wireless communication device, intelligence terminal, mobile object positioning device. Figure 3 shows the hardware structure of moving GIS.

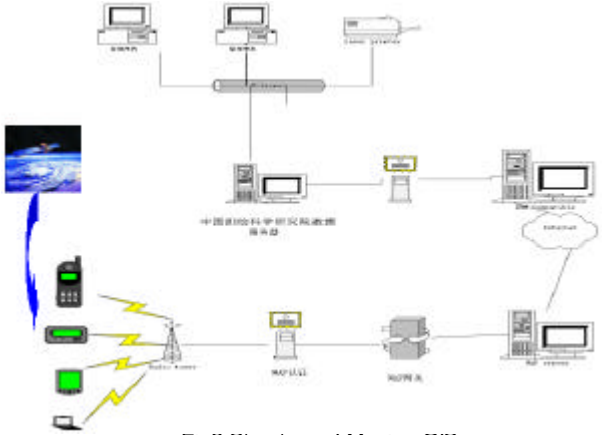

Fig3 Structure of Moving GIS

Corresponding to the hardware, software of the mobile GIS should include spatial service and distribute system on server-side, wireless communication system, intelligence terminal software and navigation system.

1) spatial service and distribute system on server-side

There are a lot of multi-level spatial data on the server-side, query, search and transform for data format are the part of the spatial data management. Otherwise, the software on the server-side should respond the request form the different terminal at one time, launch the spatial data management engine, finish the task of cut, connect and transfer automatically by the request, and update the intelligence terminal of the client with the necessary data in time.

2) wireless communication system

Server will send data and exchange information with intelligence terminal by wireless manner. In general, data from the terminal to server is rather small, but spatial data from the server is rather big to the wireless communication speed. In theory, it is will last 3-5 minute to transfer the spatial data of a middle city. It is too long to wait. So compression data for server and decompress data for terminal is very important.

3) intelligence terminal software

In intelligence terminal, to capture position and query the mobile object are the important parts of the software system on the intelligence terminal. Moreover, raster or vector data structure is also very important for the system. Because of the low efficiency to display, zoom, query and analysis on the intelligence terminal such as handheld computer, higher efficient data structure for the lower performance is present for the system.

4) navigation system

The system will get the GPS information from the infrared or serial port, and transform the data to the coordinate system of the navigate map.

On the basis of the above theory and method, we implemented a moving GIS system named PNS-I, which has integrated GPS, GIS, GSM, PDA and GPRS.

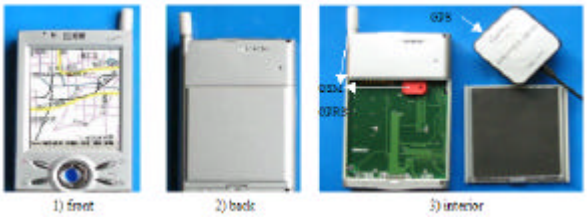

Fig3 Structure of PNS-I

3. Conclusion

When the traditional GIS can not meet users' application demands, Moving GIS emerges and becomes an important developing field of GIS. In this paper, we established the X-Y-T coordinate system, analyze the spatial relation model and generalized six kinds spatial operations which Moving GIS should cover. And we also implemented an application system. Moving GIS is much more complicated than Static GIS, and we has only done some primary researches. With the development of related theory and technique, Moving GIS will achieve new flights in the future.

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