USING GIS TECHNOLOGY FOR RAILWAY DESIGN AND MANAGEMENT

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ABSTRACT:

Railway system is a big business in China. It includes railway line design, build, management and maintance. Railway Ministry is the earlist one of using phogrammetry and remote sensing data for railway design. To select an optimum railway line, keep the best transportation condition, the geologic, hydrologic, vegetative, landform, political and social factors ... etc. are comprehensively investigated with a wide view. The Railway Ministry require using GIS technology to establish a national Railway Geographic Information System (RGIS) in 5 years. Some RGIS model are beginning to study in different railway units.
This paper presents a new development of RGIS. Two spatial analysis model are used:
One is the automatic new railway line selected system. Using CAD technique, selecting the new railway line on the computer monitor screen can save a lot of money and survey time.
The second spatial analysis model is to decide the optimum transportation path. Using Voronoi diagram technique find the shortest transportation path and lowest cost transportation path to save the transportation time and money.
Some suggestions have been made for improving the two spatial analysis systems.

1. Introduction

Compared with the first railway build in the world, China was half a century late in building hers. During the 73 years from 1876 when she started constructing it to 1949 when the People's Republic was founded, only 21000 kilometers of railway were constructed in China, averaging less than 300 kilometers built per year and these were irrationally distributed as concentrating mainly in the northeastern part and the coastal province of the country. By 1949 only 11000 kilometers of them were barely seviceable.
Since 1949 railway construction has developed quickly. Averaging more than 1000 kilometers built annually in the past forty years. A national railway transport network undertaking about 70% percent of freight transportation of the country is formed, playing a vital part in the development of the country's national economy. Now the Railway Ministry plans to use the power of modern computers and associated developments in Railway Geographic Information System (RGIS) to integrate and selected availuable information derived from spatial data acquired in different formats from a wide variety of souces to inprove the transportation and management conditions. Establishing national computer network system connect several thousand railway units. It includes Railway Ministry office, province railwayadministrations, local railway administrations, railway stations, rolling stock plants, brige-girders plants, ... etc. This is a big computer network engineering projects. It will take a long time and much money. The Railway Ministry provide the financial support to establish the computer network in 5 years. This research work is the one of the RGIS program. Two spatial analysis model are present. This project supported by the Railway Ministry of the People's Republic of China.

2. Automatic New Railway Line Selected System

In China, there are more than two thousant kilometers new railway line need to design every year. Almost hundred surveying teams work in the field for reconnaissance surveys. A railway alignment, although narrow in itself, can only be selected after an appraisal has been made of a very large area of land. It spend a lot of time and labours. Using remote sensing data and GIS techniques is ideal for railway design. The RGIS provide spatial informations from different sources. It can decide the accuracy location of railway line. The satellite images can provide rich surface information of the earth. The automatic new railway line selected system is subprogram of the RGIS. It can select the railway line on the screen of the computer to adopt the railway line that closely follows the profile of the ground and to use construction materials that occur near the railway line. This system can quickly find all possible railway line direction. At that time, the factors of influence every new railway direction mainly is the topographic factors. The more smaller the amount of fill earth and cut earth, the lower the construction cost. The more shorter length of railway line, the better transportation conditions. A topographic map drawn on a scale of one to fifty thousand, main national highways, rivers, artificial buildings were entered by digitizer, using as a basic map for railway line selecting. The contour topographic interval, Δh , is 10 m. In the railway design, the maximum slope rate in the mountainous area is 12‰. In the plain area the slope rate is 5‰ or 3‰. The smaller slope rate the better transportation condition. If we know the contoure topographic interval Δh , the maximum slope rate of railway line s. Then it needs the horizontal distance on the map is

$$\Delta d = \frac{\Delta h}{s} \cdot \frac{1}{m}$$

where $\frac{1}{m}$ is the scale of the map. For example, in the one to fifty thousand map, $\Delta h = 10\text{m}$, $s = 12‰$

$$\Delta d_{12} = \frac{\Delta h}{s} \cdot \frac{1}{m} = \frac{10 \cdot 1000}{12‰ \cdot 50000} = 16.7\text{mm}$$

If the Δd_{12} smaller or equeal than the Δd which is the shortest horizontal distance between two adjacent contour line, i.e. $\Delta d_{12} \leqslant \Delta d$. The means the terrain was flate, the railway line direction can use free slope rate. At that given start point, the railway line can choose in the straight line direction between the start point and terminate point. If the $\Delta d_{12} > \Delta d$, the means that the terrain is mountainous area. The railway line have to use the maximum slope rate. The railway line can not choose in the straight line direction between the start point and the terminate point. Then the given start point as a circle center, the Δd_{12} as a radius, drawing a circle intersect a point of the next countour line, linking the two points of start point and the newset point, get a straight line. The slope rate of the straight line is 12‰ along the topographic surface. This means that, a railway line on this straight line direction, the railway line are not need fill earth and cut earth. The constructure cost are the lowest.

Then, with the newly set point as the start point the Δd_{12} as a radius, to make a similar search again. Then, the optimum direstion is decided, and the start point is moved in that direction. Thus, this operation is repeated till the terminate point is reached. Along the optimum direction, matching suitable straight line and curve line, get a optimum new railway line.

In practice, from the start point, the Δd_{12} as a radius may intersecte two points on the next countour line. One point is the correct direction along the straight line between the start point and the terminate point. Other point may be in a different direction leading the railway line in to a wrong direction (see Fig. 1). Thus, the computer have to decide which direction is correct direction. Using a given algorithem, two angle r_1 (between line at and ab_1), r_2 (between line at and ab_2) are computed, compared the r_1 and r_2 , choosing the line of smallest angle r_1 is the optimum direction.

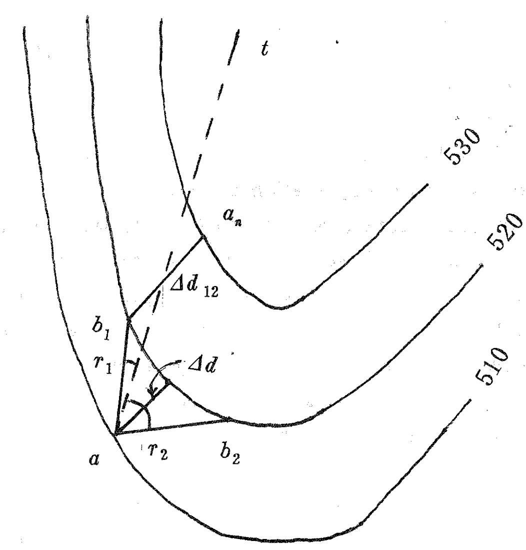

Figure 1. Search Direction

3. The Optimum Transportation Path Selected System

The Railway Transportation Information System (RTMIS) is the main part of the RGIS. It connects with more than six thousand railway stations distributed in the whole country, using computer network techniques organize the railway transportion work in facilitating the transfor of information from one area to another. It is dynamic monitoring the whole national moved train cars in real—time. This optimum transportation path selected system is one program of the RTMIS. It can choose the shortest and lowest cost transportation path. A customer may ask the following queries:

1) How find the shortest transportation path from a given two railway station for saving the transportation time to keep fresh of the cargo (such as vagetable, fruits...)
2) Find the nearest railway station from a given factory for convenience to transport the factory's cargo to the nearest railway station.
3) Find the lowest transportation cost path to save the money.

The transportation management units may ask the following queries:

4) Show the region in which the nearest railway station is with 100 kilometer. This area call the attractive area of cargo and passengers. In different radius can inventory all important transportation information data such as big factories, business, large cities and villages...etc. The railway transportation planner can estimate the volume of the cargo and passengers.
5) Show the region in which the nearest railway station is the railway station at S_i.
6) Find the nearest rolling stock plant from a give railway station. If some train cars break down, it can send to the nearest rolling stock plant to repair.
7) If the shortest transportation path some section of railway line interrupt traffic by nature disaster, find the second shortest transportation path or kth shortest transportation path.

These queries Q2, Q4, Q5, and Q6, can be answered by the Voronoi diagram (Voronoi 1908). For example, in Figure 2, given a set of railway stations located at S_1, S_2, $\ldots S_n$. We define a buffer zone, the region enclosed by the circular arcs. Let S_1, S_2, $\ldots S_n$ be a finite number of distinct points in the 2—dimensional Cartesion Space, F be arbitrary factory location, $d(F, S_i)$ be the Euclidean distance between location F and S_i. If the set of location satisfying the condition that

$$d(F, S_i) \leqslant d(F, S_j)$$

for all j except for $i = j$. The S_i is the nearest railway station from F. Queries Q2, Q4, Q5 are directly given by the Voronoi diagram. For example, in Figure 2, the region in which the nearest railway station is the one at S_2 is given by the shaded region.

To answer Q1 and Q3, we consider a national railway transportation network N. Consisting of connected line segment (called links), and a set of railway stations.

$$S = \{S_1, S_2 \ldots S_n\}$$

on the railway network N, we define the distance $d_{net}(S, S_i)$ from a railway station S to S_i by the length of shortest path from S to S_i called the railway network distance. The Voronoi diagram on a railway network which gives the answer to these queries. The Voronoi diagram is defined by the set $V_{net}(S_i)$ of location on N, from railway station S the network distance to railway station S_i is less than or equal to the network distance to any other points i.e. for $S_i \in N$.

$$V_{net}(S_i) = \{S, S_i \in N, d_{net}(S, S_i) \leqslant d_{net}(S, S_j) \quad j \neq i, j = 1, 2, 3, \ldots, n\} \qquad (1)$$

The first queries is easily answered if the railway network Voronoi diagram is obtained. The computational method for constructing this Voronoi diagram is fairly straightward if we can use a shortest path algorithm (Ford and Fulkerson 1962).

In different railway line, different cargo, the transportation price are different. The unit transportation price is defined price of one ton cargo transported one kilometer, t_i, we can modified (1) as following

$$V_{net}(S_i) = \{S_i, S_j \in N, \quad t_i d_{net}(S, S_i) \leqslant t_j d_{net}(S, S_j)\} \qquad (2)$$

The lowest transportation price on a given two railway stations are obtained by weighted Voronoi diagram.

4. Conclusions

In this study, the automatic railway design system is work. The results of selected railway line by computer is near the results by traditional method. But this system is more efficiency and saving a lot of time. More experiments will be done to meet the different terrain model.

The second spatial analysis model studying work just begin. In practice, basic work is to establish a national railways transportation and environmental information database. It needs to do a lot of field investigation work. In this research, just using a part of railway stations as a model, we hope to extended more the function of Voronoi diagram in the railway transportation.

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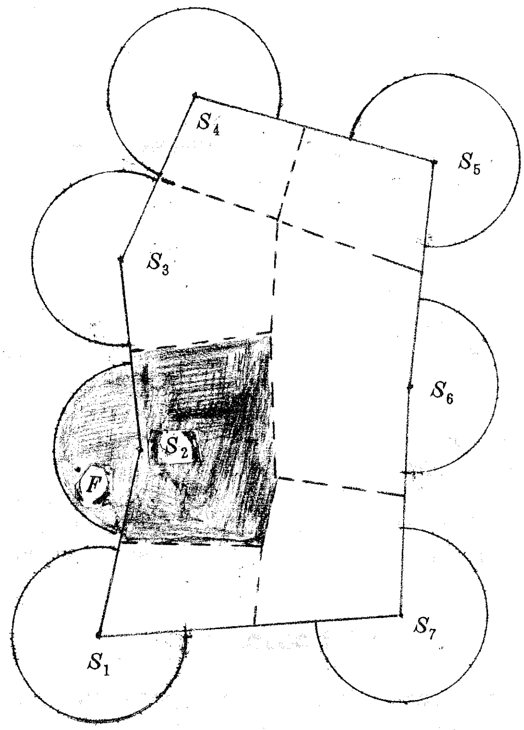

Figure 2. Voronoi diagram