SEVERAL CRITICAL ISSUES OF THE GIS ARCHITECTURE FOR CHINESE RAILWAY

Hua QI [1, 2], Deren LI [1], Qing ZHU [1]

[1] The National Laboratory for Information Engineering in Surveying, Mapping and Remote Sensing
Wuhan University, 129 Luoyu Road, Wuhan, P. R. China, 430079
[2] The Surveying Engineering Department, School of Civil Engineering
Southwest Jiaotong University, Jiulidi Road, Chengdu, P. R. China, 610031
qi-3dgis@sohu.com

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ABSTRACT:

The significant function of GIS technology in promoting the railway development in this information era is now attracting great attention from the Ministry of Railway and the State decision-making institutions of the P.R.China. However, until present, the GIS has not been economised on the Chinese Railway. Discussions have been made on the several critical issues in building up the railway GIS. In this paper, the concept of the Basis of Railway Linear Spatial is put forwarded, and the logic model is given on the basis of the analysis on the features of the railway geo-spatial objects. The constitution of the railway spatial database and the features of railway GIS are analysed. The idea for constructing the railway GIS by the means of distributed data models is advanced, and the object-oriented multilevel distributed railway GIS model is presented also. The assumption on the scheme for constructing the Digital Geo-spatial Data Framework of the railway GIS is expounded. It is shown that this paper has a positive influence on the preparation for the "Overall Program of Railway GIS" which is under processing.

1. INTRODUCTION

For the railways of China, the information system technology is mainly applied to equipment management, engineering management and operation management etc. (Li, *et al.*, 1997; Zhang, 1996; Zhou, 1997). On account of the lack of Geo-spatial Data in these systems, the application demands in the railway business is difficult to be satisfied. Along with the rapid development of the integration of economy, the economy at different regions is becoming more and more interrelated and interdependent. The demand for transport, flow of material, is becoming greater and greater, and the market competition regarding the various means of communication will be more than ever dependent on the capacity of information and information processing. GIS technology has its unique significant functions in developing the railway system of the information era (especially the management and control of the transport process). The important function of developing railway GIS (RGIS is named from here on) has caused the great attention from the Ministry of Railway and the State decision-making institutions; the preparation of the "Overall Program of the RGIS" has been taken into the scientific and technological development plan of the Ministry of Railway as well as the 863 Plan of the State. However, until present, GIS has not been economized on the railways of China.

Railway is a spatial object distributed in banded regions, and its features in spatial distribution and habit in railway operation have decided its special characteristics in spatial objects expression of RGIS. Therefore, it is necessary to make the abstraction of taking railway as a linear object and to describe the position of the spatial objects with kilometrage, and at the mean time, the geodetic coordinates would be continued to be adopted so as to give consideration to the description of the objects such as topography and image etc. as well as to maintain the relationship with the State Spatial Locating Datum.

The spatial information of railways is mainly the special-topic information of some business departments besides the geo-spatial information in a general meaning, which comes from the multiple independent and far-reaching institutions of information collection and maintenance. Therefore, there is the inevitability of reality to construct spatial database according to special topics within a period of time. This is one of the reasons why RGIS is eventually a distributed system. Further more, the railway businesses also possess the special character of the basic business distribution and the dispatching unification, thus the management style to concentrate the business data in one single database cannot satisfy the demands in practical application.

Railway is a huge complicated system (Zhang, 1996). The construction of the RGIS must be step by step. The Digital Geo-spatial Data Framework of railway will provide the basic geographical background and mathematical datum for the follow-up construction of the RGIS. It makes the updating of the spatial data more rapid, real and direct, which will facilitate the execution of engineering projects, thus it should be built up first.

The aim of this article is to discuss the architecture of RGIS. The features of the railway spatial objects are introduced firstly, and then the requirements for spatial information at the various segments of construction and operation, the expression of the railway spatial objects, the management and application mode of spatial information, and the construction of RGIS etc. are also stressed.

2. THE BASIS OF RAILWAY LINEAR SPATIAL

2.1 Features of the Railway Spatial Object

Viewed from the Transport Management Information System (TMIS) and the Dispatching Management Information System (DMIS) that are presently under construction and execution, the description on railway spatial objects is very limited (Li, *et al.*, 1997; Zhang, 1996; Zhou, 1997). It is necessary to make an effective description on the railway spatial objects for the future RGIS.

The railway project is a kind of linear one. In the railway projects, "Permanent Ways" usually consist of subgrades and tracks. They, together with bridges, tunnels, stations and yards, constitute the several principal parts of the railway projects. However, "Permanent Ways" still have another meaning, i.e., the central line indicating the directions and the spatial locations of railways. The permanent ways compose the various kinds of architectures and buildings along the railways into an entity according to the requirement of traffic. The projection of the central line on the horizontal surface is called the track plan, and the projection of the central line outspreaded on the vertical surface is called the track profile. The track plan and the track profile are the two important elements in deciding the positions of the ways. For the purpose of making the trains ride steadily from the tangent section into the circular curve or from the circular curve to the tangent section, generally a transitional curve is set up between the tangent section and the circular curve line. The track profile is composed of the segments at various grades. In order to make the train ride steadily, the neighboring segments are connected with curves which are called vertical curve (Wang, *et al*., 1986).

The spatial distribution of the central line can be solely determined by using the curve object and grade sections object, while the spatial location of other railway engineering objects can be solely determined by the means of kilometrage and their relative location to the central line (Qi, 1993).

- [Circular Curve Objects] ∧ [Grade Section Objects] → [Spatial Location of Permanent Way]
- [Spatial Location of Permanent Way] ∧ [Topological Relationship Between the Engineering Objects and Permanent Way] → [The Spatial Location of the Engineering Objects]

However, the spatial objects such as topography and image etc. in relation to railway are hard to be described in terms of kilometrage, and in this case geodetic coordinates would be more convenient.

2.2 The Basis of Railway Linear Spatial

The Basis of Railway Linear Spatial is an assembly of the minimal ordered spatial objects introduced for the purpose of making the descriptions of the spatial features of railways. The assembly of circular curve objects and the assembly of the grade section objects have constituted the Basis of Railway Linear Spatial, which is also the mathematical basis in connecting the kilometrage location system of the linear space with the geodetic coordinates system (Qi, 1993). Figure 1 is the logic model of the Basis of Railway Linear Spatial.

The geodetic coordinates for an arbitrary point located by the means of kilometrage can be calculated with the related algorithm (Li, 2001a; Li and Li, 1999). The ground point indicated by geodetic coordinates can be confirmed by the kilometrage against the way, distance between the point and the central lines of the way and the topological relationship between the point and the way. The conversion of coordinates with the above three quota can be realised through relevant algorithm also (Li, 2001b).

The actual condition and status of railway is far more complicated than the Basis of Railway Linear Spatial description. However, on this basis, the description for the railway spatial objects can be established on the object relation models.

VIEW : The Basis of Railway Linear Spatial	
SCHEMA	
TABLES	**ATTRIBUTE**
CURVE	Sub-bureau ID, Section ID, Track ID, Curve ID, Direction, TS Kilometrag, TS X, TS Y, Transition Curve Ⅰ *l*, SC X, SC Y, Circular Curve L, CS X, CS Y, ST X, ST Y, Transition Curve Ⅱ *l*, R
GRADE SECTION	Sub-bureau ID, Section ID, Track ID, Grade Section ID, Direction, Kilometrag Ⅰ, Kilometrag Ⅱ, Rail Top H, Grade, Grade Section L, Vertical Curve Type, Vertical Curve R, Vertical Curve L, ⊿h, Broken Chain Kilometrag
TYPE	Omit
CONSTRAINTS	
CURVE	Sub-bureau ID, Section ID, Track ID, Curve ID, Direction → TS Kilometrag, TS X, TS Y, Transition Curve Ⅰ *l*, SC X, SC Y, Circular Curve L, CS X, CS Y, ST X, ST Y, Transition Curve Ⅱ *l*, R
GRADE SECTION	Sub-bureau ID, Section ID, Track ID, Grade Section ID, Direction →Kilometrag Ⅰ, Kilometrag Ⅱ, Rail Top H, Grade, Grade Section L, Vertical Curve Type, Vertical Curve R, Vertical Curve L, ⊿h, Broken Chain Kilometrag

Figure 1. The Logic Model of The Basis of Railway Linear Spatial

3. THE MANAGEMENT AND APPLICATION MODE OF SPATIAL INFORMATION

3.1 Sources and Composition of the Geo-Spatial Database of the RGIS

Railways are integrated engineering projects composed of subgrades, tracks, bridges, culverts, tunnels, stations and yards etc. Besides these, there are the affiliated equipment and housing, such as: power supply facilities, traffic signals, platform inside the stations, foot bridges, underbridges, water towers and freight platforms etc. Rail crossings must be set up at the crossings between the railways with other ways. All these architectures and buildings are interrelated, thus constituted the general railway-engineering project (Wang, *et al*., 1986).

Railways, from the period of construction to operation, mainly consists of the railway networks programming, scheme comparison, surveying and design, civil construction, and operational management etc. The geo-spatial information mainly comes from the surveying units such as the elementary information departments of the State, various design institutes and engineering bureaus. The form of the geo-spatial information includes digital line drawings, digital elevation model (DEM), digital orthophotograph, electronic data and other different types of data collected in the field and actual survey.

Subject to the demand in practical application, the geo-spatial database of the RGIS will mainly consist of the Basic Geo-spatial Database, newly-built railway survey and design database, existing railway track engineering database, train operation equipment database (including signals, communication, power supply and water supply etc.). The databases assemblage of all the above may be called the Railway Engineering Database System (see Figure 2), though at present they can not support all the application demands, they have contained the principal content of the railway system application. In addition, there are some professional dynamic database supported by basic spatial databases, such as: passenger traffic database, freight traffic database, train dynamic database, locomotive and vehicle dynamic database, and containers dynamic database, which are expected to play a better role.

3.2 Distributed RGIS Model

It is a problem worth of consideration as how to manage the spatial information so as to realize the sharing of information and sharing of methods as well. The building up of the RGIS has the following features：

⑴ RGIS is a professional GIS at a large scope. The businesses of railway have a distinctive transregional feature, and therefore the data management of the RGIS is mainly distributed to the many stations at a very large scope;

⑵The collection of data is not to be completed at a single time, but at different segments of time. On the other hand, the collection of some information has dynamic features;

⑶As many departments of information acquisition and the departments of information processing are distributed at separate points with long interval distances, thus many information retrievals, drawings, summarizing and analyses have to be done on this natural distributed network data models;

⑷The sources of railway information are diversified, and the data has isomeric characteristics, which has produced great difficulties for the sharing of information;

⑸From the utilization of information, the businesses of railway have the feature of the basic business distribution and the dispatching unification.

The management style of concentrating the business data and the spatial data in a certain single database neither can efficiently solve the above problem nor satisfy the demands in practical applications. The distributed database is a shared data assemblage distributed physically but concentrated logically, and it is tailed to the special demands of the transregional businesses of railway, and it will facilitate to the integration with the existing system to form a comprehensive utilisation so as to achieve the sharing of information. The object-oriented multilevel distributed GIS model, which combines distributed object technique, distributed component object model (DCOM), and object request broker technique (ORB), is a multilevel C/S model (Li, 2001). It would be propitious for constructing the distributed RGIS. The model of the distributed RGIS is given as Figure 3.

4. ASSUMPTIONS REGARDING THE RGIS CONSTRUCTION PROGRAM

4.1 Digital Geo-spatial Data Framework of the RGIS

The RGIS is a huge system. It is necessary to construct at the first place the Digital Geo-spatial Data Framework so as to achieve the purpose of improving investment income. It will provide the follow-up construction of the RGIS the basic geographic background and mathematical datum. When taking the geo-spatial information at various proportion scales as the basic information resource unified mathematical base reference and uniform standard and norm are necessary to achieve the purpose of data sharing.

The content for Digital Geo-spatial Data Framework of the RGIS consists of the Basis of Railway Linear Spatial, the railway engineering objects, digital elevation model (DEM), digital orthophotomap (DOM), and digital line graph (DLG) etc.

Information	Basic Spatial Inf. DB	Newly-built Railway Survey and Design DB	Existing Railway Track Eng. DB	Operation Equip. DB
National Basic Spatial Inf. Etc.				
DEM, DOM, DLG Inf. Etc.				
E. Geologic Inf. Etc.				
Track Eng. Inf. Etc.				
Operation Equip. Inf. Etc.				

Figure 2. Compositions of the Geo-spatial Database of the RGIS

The railway engineering is composed of the main part projects, the affiliated projects and the stations and yards projects.

- Main Part Projects (Permanent Way): Superstructure (Tracks); Infrastructure (Subgrade); Bridges and Tunnels Projects (Bridges, Tunnels, and Open Drains);
- Affiliated Projects： Permanent Way Signs, Crossings (Lever Crossings and Grade Separations), Survey and Mapping Signs etc.;
- Railway Stations and Yards：Stations and Terminals.

To all the objects in the railway projects, abstractions of the connotation of their similarity and generality must be sort out and the relationship between them must be expressed and presented. To express one type of object, it is necessary to reflect in abstraction the connotation of the similarity or generality of this type of object. The detailed description and expression of the different aspects of the object need the consultation from experts at various departments. Which aspects may be selected and used when setting up the database is determined by the actual purpose of application and the economic factors as well, for economic conditions usually have decided the scale of database (Qi, 1996). Please see the document (Qi, 2001) for the detailed description for the logic model of the railway engineering objects.

4.2 Basic Functions of the Spatial Database

For the purpose of a better application and distribution of railway spatial data, it is necessary to establish the grid-vector integrated geo-spatial database. The data can be divided into segments by the means of kilometrage and also can be stored and preserved entirely. However, no matter what kind of method is adopted, it should be designed into a seamless spatial database in terms of logic. And indexes should be set up with the stations, terminals, sections and segments as the logic units. And the spatial database of the corresponding software provided should have the following functions (Li, *et al.*, 1998)：

⑴Retrieving, wandering and inquiring can be executed to the whole spatial database;

⑵ The graphic data in vector form should be covered semitransparent on the image, and can be updated with the new image data, which includes the editing work such as modification, supplementation and deletion etc. ;

⑶ The self-adaptability and mutilevel resolution ratio display based on the image pyramid may be realised, i.e., the image data can be fetched automatically from the corresponding layers at the image pyramids according to the proportion scale selected;

⑷ To realise 2.5-dimension displaying, inquiring and wandering and analysing functions for the image and DEM;

⑸ All the spatial data are supposed to able to transferred to other information system supported by GIS hardware and software subject to the requirements of the customers;

⑹ To output visualised products according to actual requirement by means of kilometrage, stations, sections, segments or the coordinate scope given by the customers.

5. CONLUSION

In this paper, several critical issues in respect of the RGIS architecture are discussed, which deal with the features of railway spatial objects, the model of spatial information management and application, and the Digital Geo-spatial Data Framework of Chinese railway etc. The following conclusions can be drawn:

⑴For the first time the concept of the Basis of Railway Linear Spatial is put forwarded. It is the spatial datum in describing other railway spatial objects and is also the mathematical basis in realizing the mutual conversion between the kilometrage-based locating system and the geodetic-coordinate-based location system. On this basis, the description for the railway spatial objects can be built on the object relationship models.

⑵The features of the railway business have determined that it is preferable to adopt the distributed data model for the RGIS. The object-oriented multilevel distributed RGIS model given in this paper has certain value of reference for the establishment of distributed RGIS.

⑶The Digital Geo-spatial Data Framework of the RGIS is put forward, which possesses the features such as fast updating capability, strong reality, object content and advantageous to engineering construction. Evaluating and considering the construction of the Digital Geo-spatial Data Framework of railway with top priority will not only facilitate the improvement of economic returns of investment but also accumulate the experience for the follow-up large-scale construction of spatial databases.

In a word, the establishment the Chinese RGIS still requires the deep researches on many problems and aspects. It is believed that the result contained in this paper will produce a positive influence on the preparation of the overall program of the RGIS of China.

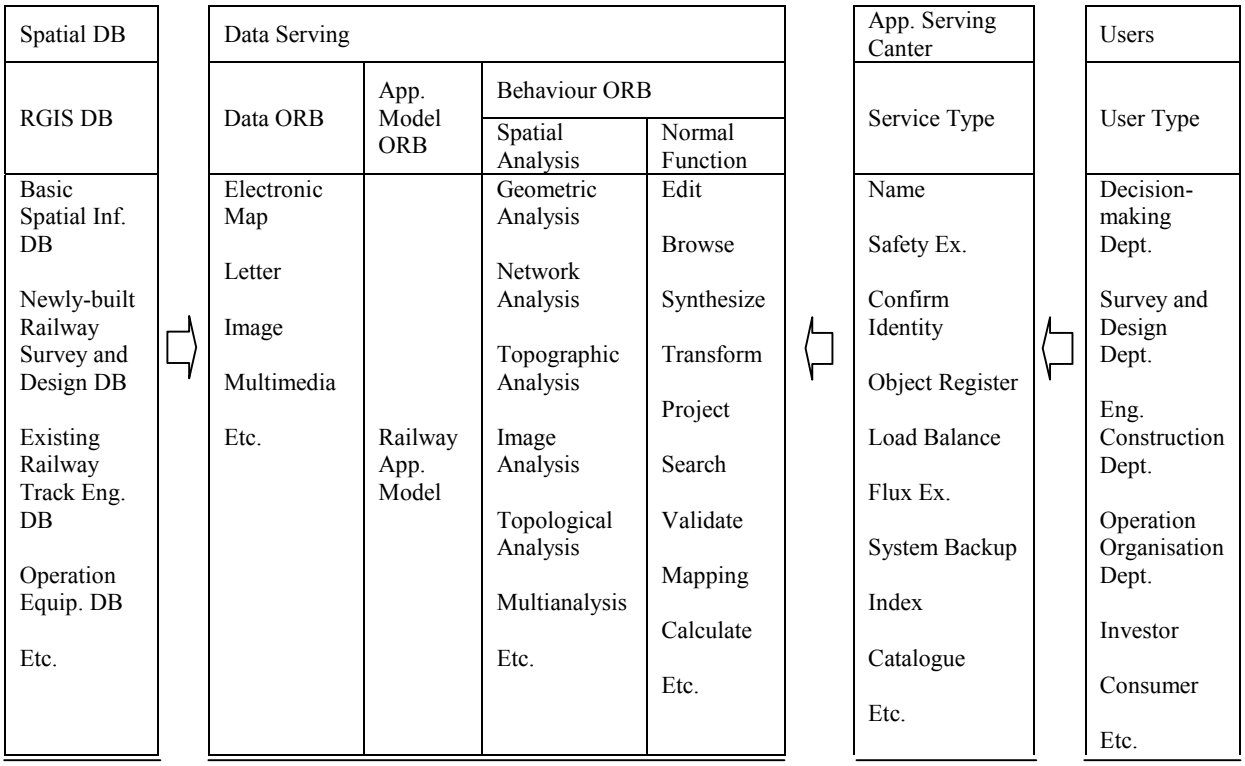

Figure 3. Object-oriented Multilevel Distributed RGIS Model

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