

Development and Key Technology of Digital Line Selection System of Urban Rail Transit (URT)

Cunxi Meng¹, Chao Huang² and Yaxin Meng³

¹China Railway First Survey And Design Institute Group LTD., No.2 Of Xiying Road, Xi'an, Shaanxi, China, P.C.710043, PH(86)029-82365214; FAX(86)029-82365258; email: tyymcx@126.com

²China Railway First Survey And Design Institute Group LTD., No.2 Of Xiying Road, Xi'an, Shaanxi, China, P.C.710043, PH(86)029-82365201; FAX(86)029-82365258; email: xyhc@fsdi.com.cn

³The Sino-British Colleague, USST, No.1195 Of Fuxing Road, Xuhui district, Shanghai, China, P.C. 200030, PH(86)18817512339; email: 1037572525@qq.com

ABSTRACT

This paper will introduce the actual development achievements and the key technical problems solving during developing process of the "Digital Line Selection System of Urban Rail Transit (URT)".

Chinese urbanization leads to increases in urban population and transportation demand. The URT construction and design was developed rapidly. However, existed URT design software cannot satisfy the using requirement which causes many problems.

Digital Line Selection System of URT was born to solve the existing problems by China Railway First Survey and Design Institute Group Ltd. The first part of this paper is about the actual achievements of development, the specific functions are mentioned as well, such as rapid construction with triangular grid DTM algorithm, the plane linear model, the interactive design of the "bell mouth" and custom of the grade line entity etc.

The second part will focus on the key technical problems solving during developing process. It began with DTM theory and method, and then made the plane general linear model. Next is management and free combination of line schemes and the mutual drive of geometry graph and the design data of the line. It also researched for the station position design function of multi station type, the auxiliary line design method of unit and module combination, etc.

Finally, this paper will introduce the application of this system. The results show the development of this system is successful, and it will greatly improve the quality, efficiency and level of URT line designing, resulting in significant economic and social benefits.

INTRODUCTION

With the rapid development of national economy, the process of China urbanization speeded up significantly. The urbanization level grew and city scale expanded dramatically. That means the increasing density of the city population and city traffic. Urbanization leads to higher living standard and high quality travel were required. However, there is a big gap between the city and the demand of existing transport facilities, road traffic cannot satisfy people's travel demand, city traffic is bound to cause a series of problems, such as speed dropped, time wasting of transportation, increases of traffic congestion and accidents.

In 20th century, it is believed that URT played an important role in different stages of the process of city development. Development of public transport, especially rail transportation, was helpful to solving the city traffic problem effectively. Nowadays, many cities re-built the city transportation by referencing the experience and lessons of overseas cities and using the concept of sustainable development. After that, it was found that choosing URT as the backbone of the city traffic can satisfy the demand of city traffic development strategy. In addition, it will lead China city traffic to embark on the development of coordination, health, sustainable.

Under this background, the URT construction of China is in a new stage of rapid development, and need to improve the work efficiency by application of advanced computer technology. However, in the survey and design industry of China, the research and development of URT line CAD is not enough. In general, current URT line CAD software is a mainly evolution of the railway or highway design software, it does not fully meet the needs of URT design. There are many problems to be studied deeply, which includes the linear model, interactive function of plane design, the station and auxiliary line design, longitudinal slope dynamic design and illegal tips and so on. Therefore, China Railway First Survey and Design Institute Group LTD. finished the research and development of "URT digital line selection system" project and applied in production.

THE ACTUAL ACHIEVEMENTS OF DEVELOPMENT

Development of "Digital Line Selection System of URT" is mainly adapted to the subway, light rail and other URT, which makes users to completely get rid of the tedious calculation and drawing of previous line design. It can also show designer's creativity and realize the design idea of personal. The development achievements in specific are shown as follows.

First of all, the system realized rapid construction with triangular grid DTM algorithm. Compared with the divided processing method, the algorithm has the features of continuous seamless, fast speed, high precision.

Next is to establish the plane linear model. This model is suitable for URT first line, second line design and calculation. It is used for solving the dynamic interactive design problem of second line. The designer can accomplish tasks such as adding and removing pass around section and S type curve directly on the screen, alternately modifying distance between two lines and changing the side of line. After that, a link between schemes was established by using advanced data structures. It realizes the free combination, automatic and efficient management of multi scheme, and the data of new scheme is the result of the sub-scheme. It is worthwhile to consider the relationship between station and main line linetype. This can be realized by customizing the station entity. Figure 1 shows that the software realizes the design of different types of station position, such as island type, side type station. In addition, it can keep better linkage with the line.



Figure 1. Station design

General algorithm of auxiliary line the design of unit and module method combination is put forward. It can realize various station sidings, which including connecting line, yard line, catch siding and auxiliary line.

In addition, interactive design of the “bell mouth” is realized. It can easily increase, delete, modify “bell mouth” according to requirements. (see figure 2)

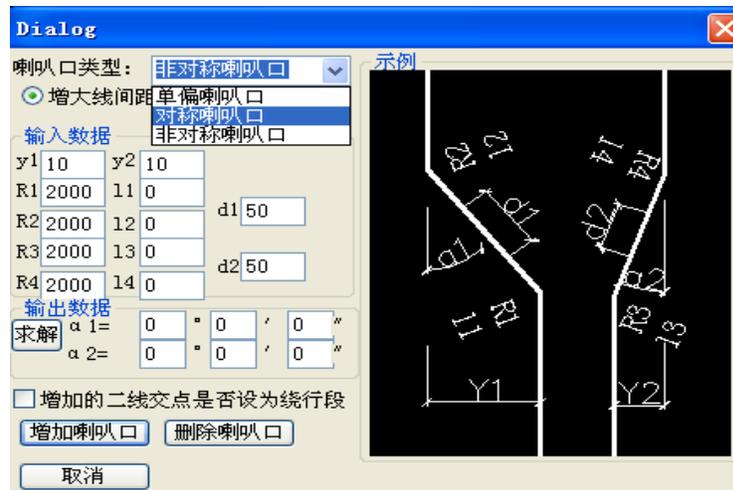


Figure 2. "Bell mouth" design

The system can also make custom of the grade line design entity. It realizes irregular dynamic prompt of slope design line and makes data entry and collection be more convenient by adopting drag correlation technology.

Finally, function of graph and form output improved to easier. It can output plane, longitudinal section, related forms and "WYSIWYG" tools of inserting bridge and tunnel, etc.

SOLVE THE KEY TECHNOLOGY PROBLEM

Research of DTM theory and method

Construct scheme of digital terrain model totally. So far, in organizing and processing the massive terrain data, the existing algorithms of domestic and foreign usually use the methods of pre-separating block, namely to individually construct triangulation net. Although this method is of high efficiency in the data management and processing, it is not appropriate to solving the model edge processing. Determining the method and parameter of separating the data is also difficult. In view of above, this project proposes and implements a whole network method. No matter how much data is, this method can deal with all the data points once and build continuous seamless DTM, without losing execution efficiency based on separating the data method.

Theory and algorithm of the rapid construction DTM. Triangulation terrain point algorithm is the core of the establishment of DTM. This project studies a kind of point by point insertion algorithm, basic idea is: first establishing initial triangulation in a polygonal of including all data points, and then the remaining points are inserted one by one. It uses the Watson empty circumcircle optimization algorithm to become Delaunay triangulation network. In this way can finish a large number of optimization and improvement in the key process of the algorithm, such as

fast positioning of triangle, rapid determination and reconstruction of triangular effect domain. Lots of practice shows this algorithm has higher efficiency.

Processing of the terrain feature line. In the construction DTM, in order to make the model better fit the ground, also need to consider the constraint relations between points, namely the influence of terrain feature line. the project based on the theory of constrained Delaunay triangulation and study the "two step" algorithm which first without considering the influence of terrain feature lines, the rapidly construct the initial standard Delaunay triangulation, then adjust the constrained Delaunay triangulation according to the terrain characteristic lines, not only greatly simplifying the processing process, but also has higher execution efficiency.

The research and establishment of URT plane general linear model. The existing system mainly orient to single track of the URT plane linear model and describe the line type by using absolute relationship. It can only satisfy the demand of the alignment design of the URT single line and the first line of double line, relative relation in the alignment design was ignored. The paper researched the URT line model and put forward two line models according to the characteristic and demand of URT line design. The first one is the boundary line model oriented to URT base line design. Another one is reference linear model which is oriented to second line design. These linear models solved a variety of line type design problem of the URT. Two line models will be introduced specifically as following.

Boundary constraint model. Through the analysis of the line design process, the design process of line plane is the combination process of line element under the constraint condition, and it may arrange one, two, three or n line elements, which is determined according to the specific engineering requirements and technical standards. The paper puts forward the plane center line design model by making the boundary constraints as the driver, so the calculating hierarchy is clear and the solving process is also simple.

Reference linear model. Based on the systematic analysis of the various relative relationships between second line and the baseline, the paper establishes a reference relation matrix of line and intersection point reference relation matrix, and puts forward a reference linear model.

The input parameters of the linear model are with the designing habit, and not only can complete to locate the position of line and calculate mileage rapidly, but also whole line is joined up without segmenting.

The second line position depends on the first line position. When first line position is determined, in accordance with the intention of designer, the second line position needs to parallel first line or change the distance of two lines or change side of second line or pass around. In order to describe accurately second line linetype, the relationship between the first line and second line intersecting point is divided into parallel intersection, the start intersecting point of passing around, middle intersecting

point and end intersecting point, etc. because of researching universal plane linear model, it solves the problem of dynamic interactive design of second line.

Management and free combination of line schemes. In URT line design, the relationship between the lines often exist, such as line starting point or destination is linked with another scheme or lead and access several scheme from the middle of the line. In the selection process, the designer must combines scheme in according to the relationship between schemes. Most of existing domestic and foreign URT line selection software system only consider single line, and does not take into account the relationship between multiple schemes.

This paper has studied the management technology of line scheme deeply. first of all, in the development of interactive alignment function, the relationship between line schemes is fully considered. based on associated graph, the paper not only proposed and achieved the data structure of the storage and management of each line scheme, but also associated graph is dynamically created and maintained in the alignment process. In scheme comparison and selection process, based on the stored information in the associated graph and the path search technology, it rapid combined into a new line scheme and calculated the engineering cost of whole scheme.

A rich and flexible and convenient graphic screen alignment tool. The line plane is composed of some curves. If each curve is defined as a unit, a unit makes up the five line units(particularly there is only a straight line), which includes front straight line, front transition curve, circle curve, behind transition curve and behind straight line. Then each unit can form a complete custom entity. The graphic screen alignment line tools mainly carry out linear unit (referred to as the line element) design and linear unit connection.

Development alignment line tools including: the transfer dynamic design line tool(when designers choose a polyline, transfer dynamic design line tool can configure the curve parameters and produce the line plane unit set according to the longitude and latitude of polyline vertices) and curve board (after designers input a reference value of the curve radius and specify midpoint and direction of circular curve, computer can configure the length of transition curve and generates the line plane unit according to the technical standard).

Unit connection method is each operate of designer can produce a unit, and this unit not only can be directly added to a line entity unit set but also exist independently. the independent unit can be added to entities by connect command. The way of connection unit has two basic ways: through two straight lines of two units to connect them and through their common tangent of circular curve of two units to connect them, thereby to form a new plane unit set.

Mutual drive of geometry graph and the design data of the line. In the graphic platform, existing URT line design software usually describes geometry graph by straight line, circular, polyline and text. These graphic elements are independent of each other. The computer only can recognize and operate a single element. However, URT design line is a whole, designers hope to be able to edit graphics object directly, and then the system automatically updates design data real time according to the graphics changes, namely the graphics driving data. The existing software mostly failed to achieve this function.

In view of the above shortcomings, this paper makes custom of line entity describe all elements of design line and the association between them. The computer can communicate with the design of the line entity. When designing data is changed, the computer will inform the design line entity to update graphics; when the design line entity is changed, the entity can update other element in the domain, meanwhile the design information corresponding to entity also will be updated, thereby to realize the mutual drive of geometry graph and the design data.

Station position design function of multi station type. The relationship of URT stations (points) and lines are very close, the station often determines line. In general, the design way of URT is "first set point, and then set line, combine line with point". Therefore, it is especially important to provide station position CAD tools. The platform of URT can be divided into the island type platform, side type platform and mixed type platform.

Implementation of station position CAD is firstly data structure design of station. All stations are mutually independent and interrelated. Independence refers to independent of space position, and interrelation refers to that calculation of distance between stations is solved by calculating projection mileage of two stations. Meet the requirement of drawing station, calculating the distance between stations by making custom of the multiple station entity.

Auxiliary line design method of unit and module combination. Because the unit and module method uses the universal line element data structure, they can complement each other. Based on modular method, the unit method can be used for local modification, and module method can also be used to add quickly some common modules after using unit method to design some unusual linetype. Using the general auxiliary line design algorithm of the unit and module method combination, the modularizing process is done for plane structure layout of some auxiliary line, and can quickly realize the auxiliary line design, such as the double back line, parking line and shortened transition line, etc. Meanwhile adopts unit method based on line element structure to enhance the universal property of auxiliary line design and meet requirements of URT auxiliary line design.

APPLICATION OF THE ACHIEVEMENT

This system has been widely applied in production. It has finished URT design of more than 200 kilometers in China. Software applications greatly improve the quality, efficiency and level of URT line designing, and reduce the labor intensity, resulting in significant economic and social benefits.

CONCLUSIONS

According to the characteristics of URT line design, this paper introduced the actual development achievements and the key technology problems during developing process of the "Digital Line Selection System of Urban Rail Transit (URT)", such as the DTM theory and method, the plane general linear model, the management and free combination of line schemes, the mutual drive of geometry graph and the design data of the line, the station position design function of multi station type, the auxiliary line design method of unit and module combination etc. The actual application shows it achieved the expected goal.

Because URT 3D visual simulation is of many advantages, such as high security, good reproducibility and strong exploration, etc. It has become an important research direction on international in recent years. therefore the further research direction of this paper is research of URT 3D visual simulation based on the existing results.

REFERENCES

- Xiafei Ye(1999). *The planning and designing of Urban Rail Transit*, China Railway publisher, China
- ZhongHen Shi(2001). *The design and construction of Metro*, Shaanxi Science Publisher, China.
- Zengliang lin(2007). "The design and research of Metro auxiliary line". *Urban rapid rail transit*, 2007(20), China.
- Cunxi Meng(2012). *Development report of Urban Rail Transit(URT) digital line selection system*, Xi'an, Shaanxi, China.