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Research on the Model of Railway Yard Plane Design Based on Frog Coordinate the Calculation Model

Anna Hu

Yanbian University Academy of Fine Arts, Yanji 133000, China

Abstract

With the continuous development of social economy in China, inter-regional trade has become more frequent, especially in the rapid development of e-commerce, construction level of transportation facilities can directly affect the economic development level of a region. Thanks to relatively low freight rate of railway and the relatively fierce competitiveness in terms of transportation speed and volume of transport, railway has become one of the most important forms of transport for various cities to compete to build. In the process of railway construction, affected by many subjective or objective factors, there still exist some problems in the design of railway yard, resulting in a long period of design construction, low application level of railway yard. This is unfavorable to the enhancement of urban railway construction level. As an important part of the railway infrastructure construction, the design of railway yard has served as a link between past and future. Therefore, in the plane design of railway yard, computer technology could be used to shorten the design cycle and realize the standardized yard design, in order to effectively reduce the job difficulty of railway yard designers and improve the automation design level of the railway yard. This is of great significance to enhance the construction of railway yard and promote regional transportation and economic development.

Keywords: Frog Coordinate Calculation, Railway Yard, Plane Design.

1. RESEARCH OVERVIEW

1.1 Research background

Computer-aided design has attracted wide attention from academic research community Since the 1960s. Unlike traditional design methods, computer-aided design method has been applied to effectively improve design level by combination of designer' logical judgment, comprehensive analysis and creative thinking and computer's rapid and accurate calculation, storage and data analysis capabilities. In the field of railway, CAD has developed rapidly in recent decades. CAD technology has become an indispensable part of the information construction of railway industry. It has played an important role in a wide range of areas, including railway bridge, tunnel, railway location, railway locomotive and other design. However, even if our country has attached great importance to the construction of railway informatization and made in-depth study on computer-aided technology, there still exist some defects in the plane design of the yard. It is mainly reflected in the computer-aided railway yard plane design system, as the yard plane design is analyzed, without effective means to interactively modify the plane design program, thus compromising the functions of the computer-aided system in actual application, which makes optimal design of railway yard hard to give full play. Therefore, the existing computer-aided system is mainly used for its drawing function rather than for computer-aided design function. As a result, building computer-aided railway yard plane design system is of great significance to promote the development of China's railway industry.

1.2 Review of literature

Railway station is a fundamental unit of railway transportation. It includes all kinds of technical equipment related to railway passenger transportation and freight transportation, such as operation equipment, locomotive equipment, car repair facilities and information management equipment for goods and tourists. In the course of railway construction and transportation, railway yard has played an important role in the transportation and distribution of personnel and goods. During the process of railway basic design construction and transformation, the plane design of railway yard has played a connecting role. Therefore, carrying out the plane design of railway yard through computer-aided technology is of great significance for improving the construction level of railway yard (Li et al., 2015). Nowadays, the construction of informatization in China's railway industry has achieved outstanding results, thus promoting China's social and economic development. However, in the design of railway yard, there still exist some problems in the application of computer aided technology, as the computer-aided function has not yet come into play. Therefore, through the optimal design of computer aided railway yard plane design system, automatic analysis of the connection of layout mode between the line and turnout can be realized, and the corresponding interactive modification function can be provided to complete the computer optimal design of railway yard. In addition, the operation of railway is simulated and predicted according to the plane design of the railway yard, thus effectively reducing job difficulty of designers and improving the design level of the railway yard (Wang et al., 2014). Since the 1980s, China's major survey and design institutes, railway research and design institutes and railway-related institutions have conducted a great deal of researches on computer aided plane design of railway yard and achieved remarkable results. At present, CAD-aided plane design system has been constructed for the railway yard, thus effectively reducing the workload of the plane design of the railway yard in many aspects, reducing the design strength, increasing the plane design speed of the railway yard, and improving the design quality (Pu et al., 2017).

2. FUNCTIONAL DESIGN OF RAILWAY YARD PLANE DESIGN SYSTEM

2.1 Design principles of railway yard plane design system

In order to realize intelligence and standardized plane design of railway yard, computer-aided design system of railway yard layout should follow the following design principles:

The first is the principle of adaptability, to ensure that CAD-aided system can design a railway yard plane design scheme that meets the actual needs of different railways in a more flexible way. At the same time, it also requires some flexibility so that users can use it better (Cao et al., 2017).

The second is the principle of advancement. In the construction process of computer-aided design system, it is necessary to extensively learn and absorb the advanced experience and methods in the design and development of other systems in order to maximize the development level of computer-aided design system;

The third is the standardization of construction. A unified computer-aided technical standard for railway yard should be established. Therefore, computer-aided design system will become more flexible and advanced through the same format and transmission mode to adapt to the rapid development of modern information technology (Wen and Hu, 2012);

The fourth is the principle of maintainability and scalability. With the development of the railway yard, the functional requirements for the CAD-aided design system will inevitably change. This also requires the CAD-aided design system to be maintainable and scalable. Flexible adjustment is conducted according to the actual situation of the development of railway yard to avoid function of computer-aided design system being eliminated;

Fifth is the principle of simplicity. In order to make computer-aided design system easy to use, its interface should be designed to have clear hierarchy, be simple and easy to manage.

2.2 Function module design of railway yard plane design system

According to the above proposed five principles for the development of computer-aided design system, the overall architecture of the system was shown in Figure 1.

Among it, external functional framework mainly included an engineering database and a master control program, while the internal functional framework included a schema generating module, a automatic coordinate calculation module, a signal/fouling post automatic computing module, an AutoCAD application software, a program map editing module, a schematic generating module, operational simulation module, etc. (Liu et al., 2013). The data flow chart was shown in Figure 2.

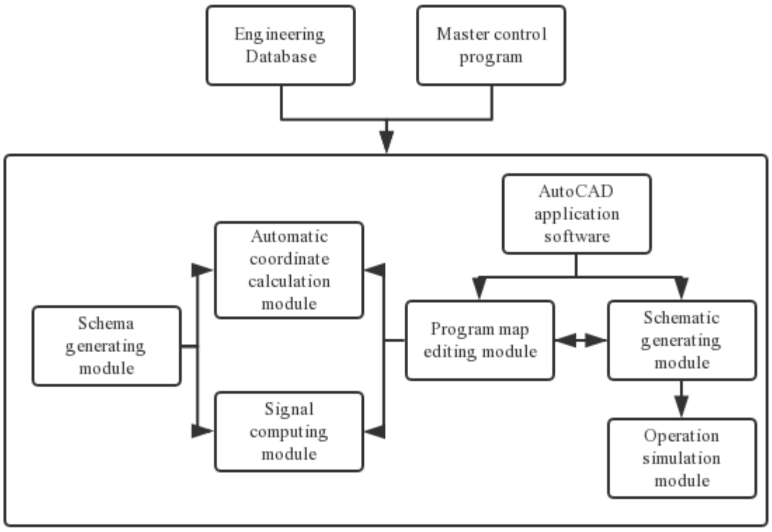

Figure 1. Overall Architecture of a CAD System

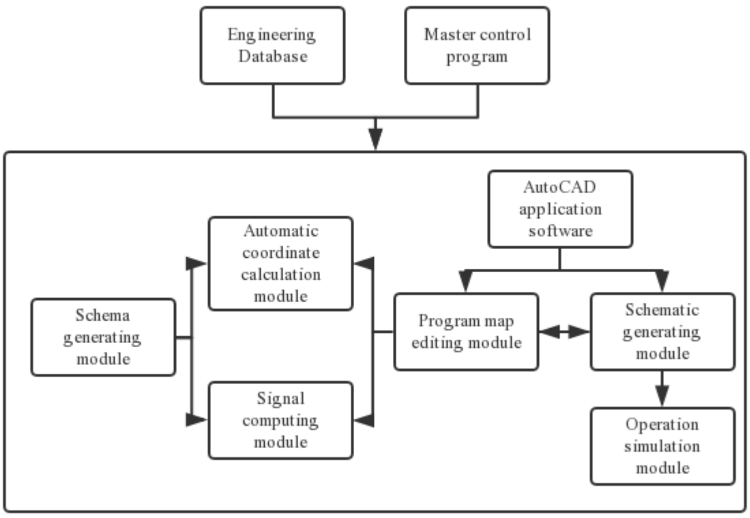

Figure 2. A Data Flow Chart of a Computer Aided Design System

3. RAILWAY YARD PLANE STRUCTURAL DESIGN BASED ON FROG COORDINATE CALCULATION MODEL

The throat area is the core area in the railway yard, which has important significance for ensuring the necessary parallel route. As throat area contains a large number of facilities and operations, connection and conflicts will arise. Therefore, throat area is the design point and of difficulty in the railway station plane design. As a result, strengthening the level of plane structural design in the railway yard throat area is of great importance to enhance the construction of railway yard (Li and Ma, 2014). At present, there are mainly two methods to be adopted in the plane structure design of the throat area of the railway yard. One is that the throat area should be classified into route area and harness area. The adjacency matrix can be used to identify the connection relationship of turnouts in the throat route area so as to use linear programming model to get the distance between the frogs. The other method is that existing constraint reasoning mechanism can be used to study the computer-aided plane design system and corresponding automatic recognition system of turnout connection relationship for the station throat structure is put forward, and optimal frog coordinate is obtained by optimizing the model (Chen, 2017). In this study, quadrant-based inference method was mainly used to establish the connection relationship of turnouts in the structure pattern of throat area of the railway station, and automatic optimization calculation and topology transformation was conducted so as to obtain the optimal coordinate of the throat area of the railway station, and to build a complete plan of plane structure of throat area.

3.1 Drawing of primitive for throat area

At present, the drawing method of primitive in the throat area of railway yard is mainly divided into scribing method and fuzzy method. The scribing method means the center line of the line is used to represent the core region of the throat area. Among it, center of turnout and top of curvilinear angle are the intersections of the center lines of track. The turnout of the throat area can be determined according to these focal points and lines, thus final throat area plan will be drawn. The fuzzy method means the throat area of railway yard is regarded as modules made up of turnouts. The lines of throat area of railway station will be determined by connecting the different linking modules into lines, thus structure pattern of the throat area of the railway station can be formed (Zeng et al, 2013). From the perspective of graph theory, the throat area of the railway yard can be transformed into a central point. Its network topology is *N= (V, A)*, where V represents the focal point of turnout and crossover, and A is the isolated set made up of connection lines between adjacent points. On this basis, the structure pattern of the throat area of railway station was drawn, as shown in Figure 3:

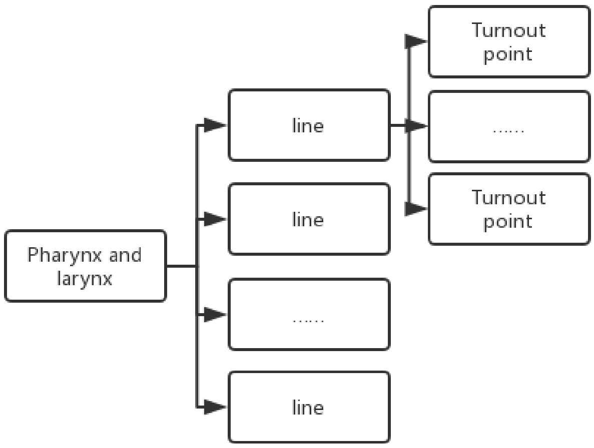

Figure 3. The Structure Pattern of the Throat Area of the Railway Station

It was assumed that in the line j, the first turnout point was P_{ij}, and the distance between the line j and the adjacent line was d_j, the property of leak track j was q_j. If the turnout point was marked as $P_{ij}(x_{ij}, y_{ij}, q_{ij}, s_{ij})$, which meant the x-coordinate, y-coordinate, quadrant, and the turnout in place, the relationship was as follows:

$$T_{ij} = g(P_{ij}, P_{i,j+1}) \tag{1}$$

3.2 Judgment condition for docking of turnout points

For docking of turnout points $P_{ij}, P_{i,j+1}$, following formulas should be met:

$$x_{ij} + (-1)^w d_i s_{ij} = x_{i,j+1} \tag{2}$$

$$y_{ij} + (-1)^h d_i s_{ij} = y_{i,j+1} \tag{3}$$

$$|q_{ij} - q_{i,j+1}| = 2 \tag{4}$$

$$s_{ij} = s_{i,j+1} \tag{5}$$

$$q_{ij} = \begin{cases} 1, 0^\circ \le \alpha + \beta \le 90^\circ \\ 2, 90^\circ \le \alpha + \beta \le 180^\circ \\ 3, 180^\circ \le \alpha + \beta \le 270^\circ \\ 4, 270^\circ \le \alpha + \beta \le 360^\circ \end{cases} \tag{6}$$

$$w = \begin{cases} 2k, q_{ij} \in \{1,2\} \\ 2k+1, q_{ij} \in \{3,4\} \end{cases} \tag{7}$$

$$h = \begin{cases} 2k, q_{ij} \in \{1,2\} \\ 2k+1, q_{ij} \in \{3,4\} \end{cases} \tag{8}$$

$$i, i' \in \{1,2,\dots,m\}, j \in \{1,2,\dots,n\}, k \in \{0,1,2,\dots,m\}, \beta \in \{-180°, 180°\} \tag{9}$$

It was assumed that in a railway yard, the set of all turnout points in the throat area was A, and $P_{ij}, P_{ij} \in A$. When the above conditions were met, the docking connection existed. Under the condition of $Z_{ij} = 1$, there was no docking relationship between the two. Under the condition of $Z_{ij} = 0$, any turnout point was docked with a turnout point, and following several judgment conditions should be satisfied:

$$\sum Z_{ij} \leq 1, i \in \{1,2,\dots,m\} \tag{10}$$

$$\sum Z_{ji} \leq 1, i \in \{1,2,\dots,m\} \tag{11}$$

$$Z_{ij} = Z_{ji}, P_{ij} \in A \tag{12}$$

$$Z_{ij} = 0, 1, P_{ij} \in A \tag{13}$$

In order to ensure the normal operation of the throat area of the railway yard, it was inevitable to determine a minimum frog distance between different turnout points. At this moment, if a certain turnout in the throat area was moved, a series of turnouts would inevitably be moved, and the amount of movement was related to the amount of movement of the previous switch moved (Hao, 2013).

3.3 Optimization scheme for plane structural design of throat area of railway yard

After designing the initial plane structural design of the throat area of the railway yard, it was necessary to make corresponding changes to the original design scheme according to the actual situation of the railway yard, so as to make the design scheme consistent with the actual situation of the railway yard, which could effectively improve the design level of the throat area of railway yard. In the throat area, there were close topological relations and set relations among various facilities and turnouts, which constituted throat area. Any change of one point would cause the change of other parts (Huang et al , 2013). Therefore, while the plane structural design of the throat area of railway yard was revised, it was insufficient to change a certain point, a series of parts connected with the point required to be changed to change the plane structure of the entire throat area. However, the structure design of the throat area was modified mainly in the aspects of turnout and station track (Zhu and Ye, 2015).

3.3.1 Change of turnout

The change of turnout was mainly realized through the following method:

The first was to modify turnout number. According to the characteristics of turnout in the throat area, every single turnout had two turnout points. For example, symmetrical turnout, three-throw turnout and slip turnout could be disassembled into several single turnouts. Therefore, the change of turnout number would in turn lead to the change of various properties of the turnout. Therefore, it is a change of turnout point. During drawing of throat area plan, parameter data of each turnout number was saved. When a certain turnout number was changed, the corresponding turnout point was found, and the property of the turnout point was modified, the property of the turnout number was changed accordingly.

The second was the translation of the turnout. When a certain turnout was translated, the corresponding turnouts in the rear area also required to be moved. In general, the movement distance of turnout in the rear area was kept the same as that of turnout to be translated. Therefore, the translation operation was conducted if corresponding value of turnout coordinate was modified.

The third was the addition and deletion of turnout. When a plane design model in the throat area was constructed, addition of turnout means turnout point was inserted at the corresponding location, as the turnout point that constituted the turnout in the throat area was included in the various lines in the throat area. Therefore, whether the turnout point was placed at the corresponding position in the line was to be determined. When the location of turnout point was found, the change of turnout was completed only if the turnout point was inserted in a reasonable way. However, for the deletion of turnout, turnout point that constituted the turnout in the lines was removed. After the turnout point was deleted, the plane design scheme of the entire throat area was required to be re-planned to complete the modification of the turnout.

3.3.2 Modification of line

Line of railway yard could be divided into main track, station track, section line, branch line and special line. These lines were important scenarios for railway yard to carry out train coupling, un-marshalling and loading and unloading work under normal status, and also indispensable important facilities for railway yard. In the plane structure design of railway yard, station line was typically expressed in a straight line or curve. It was modified according to the following methods:

The first was to modify the distance between centers of tracks. Similar to the above-mentioned translation of turnout, the modification of distance between centers of tracks was realized when UnitRoad node was found in the graphic data file in the established line and corresponding value was modified (Yang et al., 2013).

The second was to increase the line, which means that in the plane structure design of entire throat area, an empty line node was selected from the data file under the premise that no child node was included, and then value of distence attribute obtained by using interactive method was added in the line (Yang and Tao, 2014).

The third was the deletion of line. Similar to the method of addition of line, the method means designated line node was selected from the data file for deletion in the plane structure design of entire throat area. In the process of deletion, there were some precautions to be followed, namely, corresponding child node was deleted from the file, and turnout point of corresponding upper or lower adjacent line that was relevant to the deleted turnout point in the line was deleted, so as to ensure a high degree of consistency of data and avoid the problem of the plane structure design due to the inconsistency of turnout point (Yu, 2010).

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