Research on measurable actual scene geographic information technology for railway factors

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Abstract: Based real-time geographic information technology, the measurable elements of the track maintenance, signals and contact line are analyzed in Beijing National Railway Track Test Center of the Chinese Academy of Railway Sciences. The technology of mobile measurable real image acquisition is studied. A real-time and accurate measurement technique for railway elements spatial location is proposed. Based on the measurable real geographic information technology, the loop railway digital platform is built. The rapid inspection and change detection of railway infrastructure has been realized. The visual comprehensive management and statistical analysis of railway infrastructure have been completed.

1. Introduction

With the development of geographic information technology and mobile measurement technology, measurable real-time geographic information technology combines three-dimensional geographic video real-time data acquisition technology, real-time spatial location acquisition technology, fast video real-time image resolution technology, video real-time geographic information integrated processing and display technology, spatial-temporal integration based on GIS. The combination of statistical analysis technology and other technical means provides a rapid update of spatial information and asset characteristics for intelligent cities, highway transportation, digital municipal, urban safety and emergency and other fields.

With the characteristics of mobile acquisition, rapid updating, on-demand and high visualization, the real-time geographic information technology adds continuous ground measurable images as a new data source on the basis of traditional two-dimensional geographic information, and seamlessly integrates with geographic information industry application software through a special data development platform. And provide a more intuitive and easy-to-use real-world visualization environment, and ultimately achieve rapid collection of railway line environment-related information, rapid inspection and change detection of railway infrastructure, update of current database and maintenance of historical database, and visual integrated management and statistical analysis of railway infrastructure.

2. Railway element analysis of measurable circular test

Beijing National Railway Track Test Center of the Chinese Academy of Railway Sciences includes the large-loop, the small-loop and the newly-built urban rail test lines, and is equipped with various professional railway laboratories. The circular test line can carry out scientific tests of locomotives, rolling stock, railway construction, communication signals, railway electrification facilities, passenger and freight transport, and special transport.

Real-time geographic information technology can provide rapid updating technology means of spatial information and asset characteristics information for ring test railway. The measurable real-time digital image of railway can be used for quantitative comparison and scene investigation of railway maintenance, and for precise geographic image reference of railway emergency, line planning, reconstruction and extension, operation monitoring and maintenance. Three-dimensional real-time high-precision geographic digital image of loop line can reflect the detailed thematic information of loop line and the facilities along the track, especially the infrastructure of loop test railway, such as track, catenary and signal. Including track equipment, track marking, marking, mileage piles, protective fences, sound barriers and other infrastructure; providing accurate measurement, marking the geometric dimensions of railway thematic elements, and integrated rapid database building.

Fig. 1 GPS antenna installation Fig. 2 Actual scene image acquisition

3. Key technologies of measurable actual scene geographic information

In order to obtain high-density continuous measurable images, we collect real-time images at high-density time or distance intervals during the running of test locomotives and scan them along the road with carpet. At the same time, the use of automatic, no human intervention in continuous data acquisition capabilities, to achieve a single technician, independent, easy to complete the data acquisition task. The real-time image acquisition method based on satellite positioning and inertial navigation technology is studied to realize the fusion of real-time image and spatial position. At the same time, the real-time image is combined with the circuit mileage of the loop test line, so that each real-time image has two coordinate systems of platform and linearity. At the same time, the measurement technology based on close-range photogrammetry, real-time positioning and mapping technology is studied to provide technical and basic data support for the spatial information extraction of facilities and equipment in real-time images.

3.1 Loop railway infrastructure spatial data mobile measurable actual scene image acquisition technology

In the course of locomotive traveling on the test line, the real-time images are collected by industrial digital camera (CCD) at high-density time or distance intervals. Carpet scanning is carried out along the line, and multi-photo intersection (multi-baseline measurement) data processing is carried out based on SLAM algorithm to ensure the accurate matching of any image and map spatial position. In order to obtain high-density and continuously measurable actual scene images. At the same time, the use of automatic, no human intervention in continuous data acquisition capabilities, to achieve a single technician, independent, easy to complete the data acquisition task.

3.2 real-time and accurate measurement of railway elements spatial location

The real-time image acquisition method based on satellite positioning and inertial navigation technology is studied to realize the fusion of real-time image and spatial position. Real-time spatial position acquisition technology, relying on high-precision and high-reliability GPS signal receiving chip, achieves the accurate coordinate acquisition of any position on the all-weather road. At the same time, combined with the advanced inertial navigation technology, it guarantees the continuous linear accurate position acquisition under the unstable environment of GPS signal, and finally realizes the fast and accurate spatial coordinate acquisition of any line position.

Virtual reference station VRS refers to GPS network RTK (network real time kinetics, carrier phase dynamic real time differential) technology. GPS reference station network is always connected to the control and data processing center through the data communication link. The computer of the data processing center continuously collects the information of all the receivers on the reference station and establishes a local place. Zone correction database, and then these data and raw data from the mobile station together to create a virtual reference station only a few meters away from the mobile station, the mobile station read and use the data as if from the real reference station data, but to obtain RTK positioning performance can be greatly improved.

Differential GPS provides 10 Hz sampling frequency data for ground mobile measurement. The sampling frequency relative to network RTKlhz can also better reflect the motion characteristics of mobile platform. The following (3-1) is the mathematical expression of the speed of the differential GPS computing station:

$$\begin{cases} \overset{*}{X}_i = \left[\left(X_i - X_{i-1}\right) \cdot t_2/t_1 + \left(X_{i+1} - X_i\right)t_1/t_2\right]/\left(t_1 + t_2\right) \\ \overset{*}{Y}_i = \left[\left(Y_i - Y_{i-1}\right) \cdot t_2/t_1 + \left(Y_{i+1} - Y_i\right)t_1/t_2\right]/\left(t_1 + t_2\right) \\ \overset{*}{Z}_i = \left[\left(Z_i - Z_{i-1}\right) \cdot t_2/t_1 + \left(Z_{i+1} - Z_i\right)t_1/t_2\right]/\left(t_1 + t_2\right) \end{cases} \tag{1}$$

Among them, the adjacent points before $\left(X_{i+1}, Y_{i+1}, Z_{i+1}\right)$ and after $\left(X_{i-1}, Y_{i-1}, Z_{i-1}\right)$ the measured positions $\left(X_i, Y_i, Z_i\right)$ are corresponding intervals.

Differential GPS data and VRS data are synchronized according to the same time label, so the velocity obtained by reference Doppler measurement is recorded relative to the VRS data. It is found that the part of VRS data which is not consistent with the motion condition is filtered out. The mathematical expression (3-2) of the specific filtration analysis is as follows:

$$\begin{cases} X_i^{'} = X_0 + \sum_{j=1}^{n} \overset{*}{X}_j \cdot t_j, \left|X_i - Y_i^{'}\right| \le \alpha \cdot T_x \\ Y_i^{'} = Y_0 + \sum_{j=1}^{n} \overset{*}{Y}_j \cdot t_j, \left|Y_i - Y_i^{'}\right| \le \beta \cdot T_y \\ Z_i^{'} = Z_0 + \sum_{j=1}^{n} \overset{*}{Z}_j \cdot t_j, \left|Z_i - Z_i^{'}\right| \le \gamma \cdot T_z \end{cases} \tag{2}$$

The linear transformation coefficients of the desired three-dimensional position $\left(X_i^{'}, Y_i^{'}, Z_i^{'}\right)$ and $\left(X_i, Y_i, Z_i\right)$ obtained by integrating the three-dimensional velocity $\left(T_x, T_y, T_z\right)$ with the time interval at the same time, for the given threshold $\left(\alpha, \beta, \gamma\right)$ according to experience, and for the given transformation coefficients from the initial position to the current position, are transformed from the three-dimensional distance between the checkpoint and the initial point on the trajectory to the predicted transformation.

3.3 linear mileage acquisition and linear reference system (LRS) construction technology

In this paper, the real-time image is combined with the circuit mileage of the loop test line, so that each real-time image has two coordinate systems, plane and linear. Linear Range Reference System (LRS) is an advanced model for linear spatial data organization and construction in the world. Based on the linear mileage reference system, the precise mileage calculation between any two points in the linear facility network can be realized, and the precise location and query of any mileage position can be carried out by specifying any position and direction in the network.

Fig. 3 Real-time image with the circuit mileage

4. Railway spatial information service platform based on measurable actual scene technology

In order to realize the rapid collection and management of the spatial information of the loop railway infrastructure, based on the real-time geographic information technology, this paper studies the measurable mobile photogrammetry technology which meets the field conditions of the loop railway infrastructure, and puts forward the technical scheme of the collection and management of the spatial information of the loop railway infrastructure.

The software prototype of the two-dimensional and three-dimensional integrated digital Ring Rail Geographic Information System is designed to realize the visual retrieval and inquiry of the Ring Rail assets and equipment. It has the function of retrieving the history of the surrounding environment and equipment status. At the same time, it realizes the spatial analysis and measurement based on the real-time image so as to achieve the alignment status of the Ring Rail Line. Surveying and mapping, realizing the management of test equipment based on GIS platform, and providing data basis for the health maintenance and efficient use of loop railway equipment and facilities.

5. Conclusion

As one of the basic platforms of Railway Informationization in the Ring Railway Test Center, the achievements of digital Ring Railway Platform are mainly shown in the following aspects.

To realize the digital and visual information integration and visual expression of loop railway infrastructure, the measurable elements of loop railway basic data are analyzed firstly to realize the rapid collection and automatic processing of loop railway and its surrounding information.

(1) Supported by geographic information data, the design, construction, completion and acceptance information of loop line infrastructure are integrated, and the dynamic and static detection information, monitoring information and maintenance operation information are collected, transmitted, stored and analyzed in real time, to realize the design and management of railway infrastructure. The unified management of inspection and maintenance process, and the intelligent

comprehensive analysis of various information, put forward scientific suggestions for equipment maintenance, and provide comprehensive information services for all levels of maintenance decision-making of engineering, catenary and signal equipment.

(2) To achieve unified management of the geographic information resources of the circular line and improve the utilization ratio of resources. Through centralized system structure, the loop line information resources are managed in a unified and comprehensive way, which makes up for the deficiencies of independent business systems, resource division, information integration difficulties and incomplete functions, and provides geographic information resources protection for the future planning and design, engineering construction, operation and management and public service of the loop line.

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