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Design and Realization of the Subway Tunnel Crack Monitoring Data Management Platform

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Abstract: To meet the needs of subway security operation, this study proposed a subway tunnel crack automated detection system on the subway tunnel crack detection and realized the crack monitoring data management platform by Java language. There are three key technologies in this system platform and they are data query, multimedia data alarm and unified management of image coding. The design and realization of the data management platform for the subway tunnel crack monitoring will contribute to improving the detection and maintenance level of urban rail transit infrastructure.

Key words: Crack monitoring, data query, data alarm, image coding

INTRODUCTION

Urban rail transit is an important part of urban traffic in Beijing which is one of the main measures to ease traffic congestion. It has fast operation speed, high traffic density, large passenger traffic and closed environment which needs a safe and reliable operation environment to ensure the safety of its operations. However, tunnel environment often appears different degree of damage due to the influence of geological deformation, near construction and other factors.

In many tunnel diseases (such as cracks, wear, holes and steel corrosion, etc.), it is difficult to detect cracks in a broken state which is the most fundamental problem that endanger the safe operation (Liu and Xie, 2009). Every time we detect the subway cracks, there will be large amounts of crack data and image information. If there is no effective data storage and management, then we will not realize the safe monitoring and timely maintenance of the subway tunnel condition and judge the safe conditions of the tunnel. The system can improve the management efficiency of tunnel crack detection data and realize the scientific management and trend prediction of the crack data. Meanwhile, the strict and scientific management have improved the safety of the subway tunnel and provided a powerful guarantee for the establishment of a safe comprehensive detection system of the urban rail transit.

This article introduces the general scheme of the subway crack detection system and describes the design and realization of the subway crack monitoring data management system in detail.

The rest of the study is organized as follows. Section 2 introduces the general design of this platform. The key technologies are presented in section 3 and a summary of the study is presented in section 4.

SYSTEM GENERALSCHEME DESIG

Structure of the system: Figure 1 is the structure of the automatic detection system for subway tunnel cracks subway tunnel. The system consists of the computer network of subway corporation, system management terminal, data acquisition system, crack application server, crack database group and application terminal group (Lee *et al*., 2007). The administer and users visit the subway crack application server by the computer network of subway corporation, then log in the data management platform for subway crack monitoring.

System function: The subway crack monitoring data management platform divides into five function modules: system management module, system setting module, crack display module, statistical analysis module and alarm platform module. Figure 2 shows its structure as follows:

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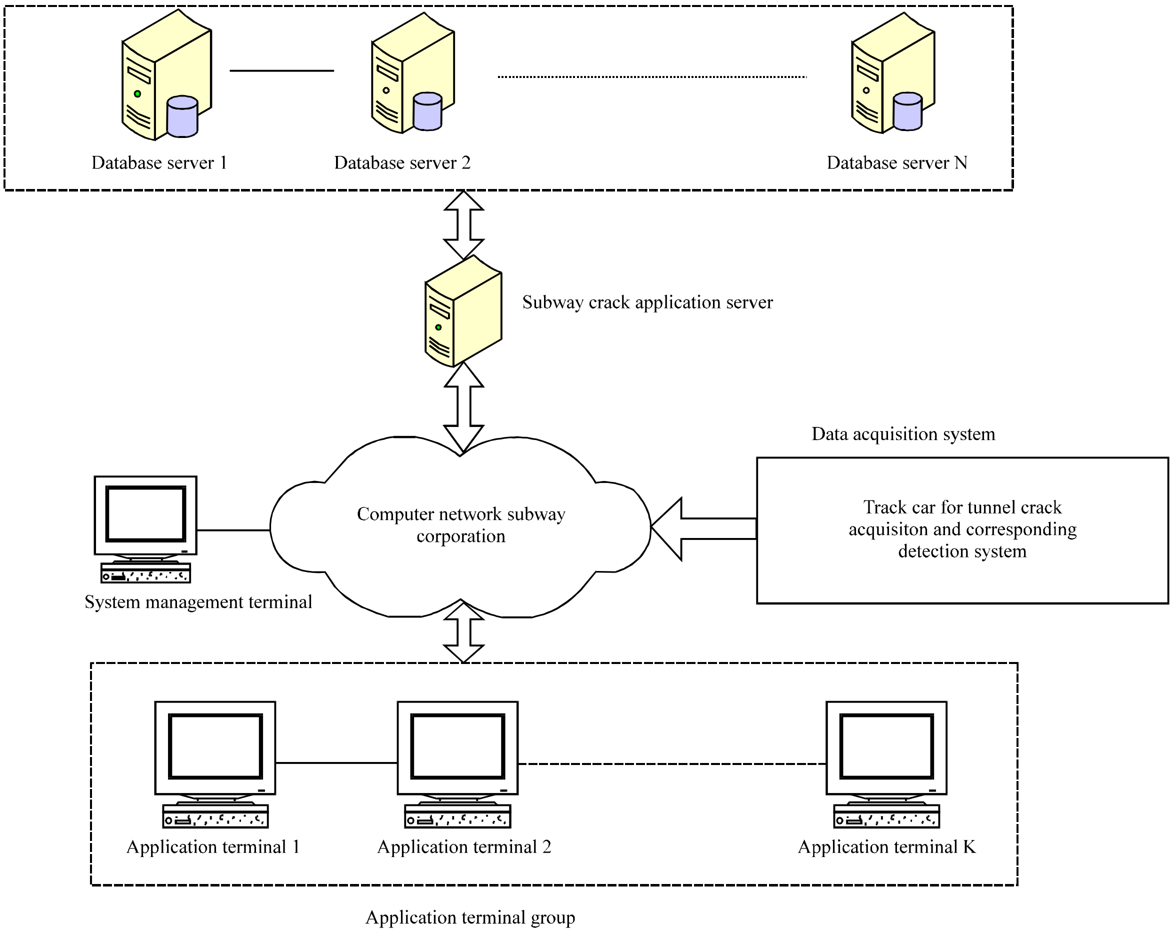

Fig. 1: Automatic detection system for subway tunnel cracks

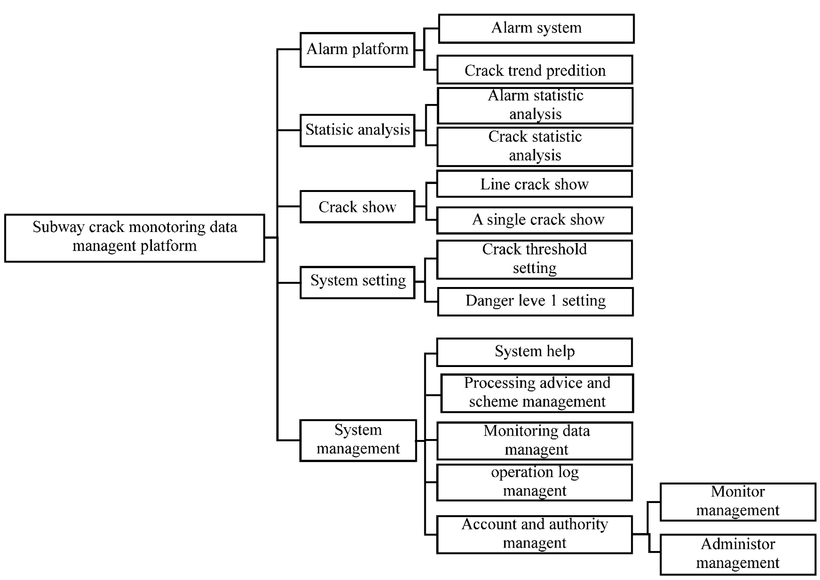

Fig. 2: Function structure of subway tunnel crack monitoring data management platform

System management module: The module can be divided into five function parts: User account distribution and authority management, operation log management, monitoring data management, processing advice and scheme management, system help, respectively.

System setting module: The module includes crack threshold setting and danger level setting. Crack threshold setting provide a division basis for tunnel crack danger level setting. Danger level setting refers that we divide different danger levels on the basis of the different characteristics, importance and criticality of the monitoring objects and come up with a processing scheme of the corresponding danger level.

Crack display module: The module can complete the analysis display function of the specified tunnel crack and the annotation display function of the specified subway line.

Statistical analysis module: The module includes crack statistical analysis and alarm statistical analysis. Crack statistical analysis can do statistical analysis on the subway tunnel crack data according to the crack danger level, the lines including cracks, the time generating cracks etc. Alarm statistical analysis can do some classifications and statistics about several alarm information of the system platform.

Alarm platform module: We predict the variation trend of the tunnel cracks by comparing with the historical data and provide auxiliary decision-making help and send the alarm information automatically. For the dangers that have occurred, the alarm system will automatically send the alarm information and then the monitors will submit the maintenance report and cancel the alarm after the audit succeeds.

KEY TECHNOLOGY REALIZATION

Data query based on skyline: Here, we will show how to select the crucial cracks which are more likely to cause safety accidents in massive crack data. The technique we use is based on skyline query processing. In the following we first introduce the skyline query and then introduce NN(nearest neighbor algorithm) which is one of the mature methods for computing the skyline.

Skyline query: Data Dominant is a basic concept of skyline query. As A and B are two data points in the same m-dimension date set, we call A can dominate B if when compared with B, A is not worse in every dimension and better in at least one dimension. Skyline query is to select the data points not dominated by any other data points in the complete set, the collection of the selected date points are called skyline. Take Table 1 for example, we use three attributes namely width, length and rate of change to describe cracks.

Obviously, cracks we have to focus on are relatively wider, longer or faster change. According to the table, the three attributes value of Crack 3 are all larger than that of Crack 2, so we say Crack 3 dominates Crack 2; The width and length of Crack 1 is relative smaller, but its rate of change is the largest, so Crack 1 is not dominated by any cracks. Through comparing, we can easily get the skyline of complete set: {1, 3, 6, 8, 9}.

In practical applications, cracks data in the database is enormous, thus it is difficult to achieve skyline query by simply using SQL statement, so we must use the appropriate algorithm to compute the skyline.

Data query in our system: There are many algorithms for computing the skyline such as DDC, BNL, D and C, BBS, NN and so on and these methods are not absolutely better or worse. In this study, we use the NN (nearest neighbor algorithm) to find the skyline of cracks database.

As shown in Table 1, we define three attributes to measure the crack which are width (W), length (L) and the rate of change (R). Then Crack C can be indicated as C = {W, L, R}, the specific value of width W and length L can be obtained by image recognition. R(L) and R(W) are rate of change of length and width, respectively, they can be calculated by measuring the width and length for several times. R is the sum of R(L) and R(W), namely R= R(L)+R(W). From above we can map every crack to a point of a three-dimensional space.

Firstly, find out the farthest point Cmax(w,l,r) from the original point O(0,0) which can be easily realized by some existing algorithms. In Fig. 1, the point space can divide the space into eight regions, numbered 1-8 successively. Then, find out the farthest point from original point in the three regions, respectively. Finally, combine the farthest point in each region to get the final collection of skyline.

Obviously, the cracks in the skyline collection are relatively serious ones that easy to cause safety

Crack No.	1	2	3	4	5	6	7	8	9
Width (mm)	0.4	0.7	1.5	0.6	0.6	0.8	1.3	1.7	1.1
Length (mm)	4200	4400	4600	5700	3900	6800	5000	5200	6500
Rate of change (mm month^{-1})	0.15	0	0.1	0.1	0	0	0	0	0.1

accidents. But in reality, when the value of crack width is relatively large that of length is also large, meanwhile the value will not change in a certain time, so it is possible that there're only a few especially serious cracks to dominate the other cracks. If the number of cracks in skyline is too small or even only one, this explains that some serious cracks were not selected, thus the skyline is meaningless in this circumstance. In this study, we use the following method to solve the above problem. First, we distinguish the crack database according to the subway lines, of each line we perform the skyline query to the cracks data, respectively. We set a threshold M to indicate the minimum number of serious cracks found out. When the number of cracks in skyline is less than M after skyline query by the first time, then reject all cracks in skyline from the database and perform skyline query again using the remaining cracks and so on, until the number of chosen cracks is no less than M. This method ensures that the selected cracks are more representative.

The cracks selected by the method aforementioned are what we will focus on, for these cracks are more likely to cause safety accidents. So according to the location of the image display, it is necessary to send professional investigation personnel into the tunnel to perform field observation every two weeks. Once dangerous situation was found, report to the superior timely and adopt corresponding repair measures to avoid the impact of operational safety.

Realization of multimedia data alarm: When the crack data in the database reaches a warning level or a higher level, the platform will warn or alarm and tell administers about the specific location and the property of the alarm point. Meanwhile, it will send messages to the monitors and the monitors find the location of the crack based on the alarm information and take some corresponding maintenance scheme, then submit the maintenance report and cancel the alarm after the audit succeeds.

Structure of the short message platform: The multimedia data alarm can be realized by the short message platform. The platform mainly consists of short message transceiver module, business processing logic module, system interface, data backup statistic module and database (Li, 2007).

Figure 3 shows the system structure of the short message platform. The function of every module is as follows:

- **SMS transceiver module:** It consists of the operator SMS webmaster interface, transceiver control and short message filtering and timely and safely complete sending and receiving legal short message module. The transceiver module connect with the sending and receiving short message buffer table which are set up in the database and the database table acts as an interface between transceiver module and business processing module
- **System interface:** It includes the business interface which connects with other system business processing module and the data

Relationship between SMS platform and SCMD-MIS system: SCMD-MIS is short for subway crack monitoring data management and Figure 4 shows the structural relationship between SMS platform and SCMD-MIS system.

Connect SMS platform and SCMD-MIS system. When the cracks in MIS reach the warning, alarm or control level, it can be easily prepared and send text messages through the WEB SMS platform automatically.

Realization of mage coding unified management: At the end of each test, the image acquisition device will generate a lot of cracks in images.

Ideas of coding: We take Beijing Subway for the study. Ended May 2013, Beijing underground has 17 lines 270 stations, the total mileage of 456 km, a total of 262 intervals (take the distance between two adjacent stations interval as a unit). Interval number for each line is between 4 and 45 and interval distance is between

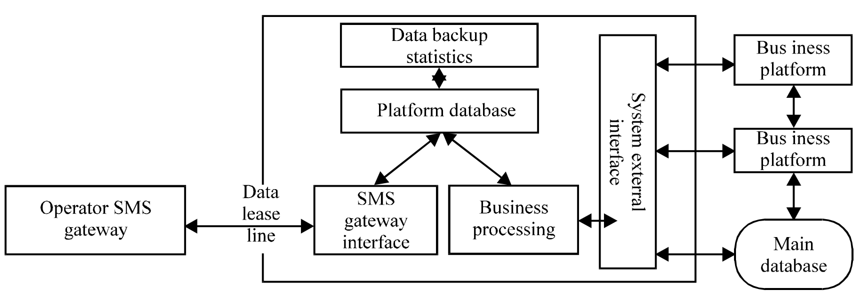

Fig. 3: System structure of the short message platform

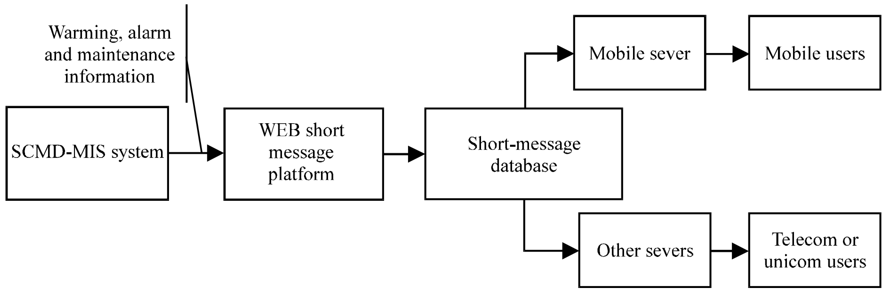

Fig. 4: Embodiment SMS platform

Table1: Structure of image coding system

1-5bit 00000-11111	6bit 0/1	7-12bit 000000-101101	13-25bit 0000000000000-1001110000111
Line No. 01-17	Up/down line	Section No. 01-45	Image No. (01-5000)

1 and 7 km. We sampling the image of each line for each interval, control the number of sampled images in 1000-5000 according to the interval distance. In this way we can calculated the distance in tunnels each image represents and specific location (via., scale), achieving cracks positioning. For Beijing subway, this study presents an image coding scheme SCIC.

Encoding rule: We use the 25 binary coding. The code is divided into four parts, respectively are coding for lines, up/down line, section and images. As shown in Table 1:

- We take 17 sites into consideration. In terms of coding efficiency and optimization, we can combine Line 4 and Da-Xing Line, Line 5 and Yi-Zhuang Line, Line 9 and Fang-Shan Line, namely performing 4 bits binary coding of the line. As the rapid development of Beijing railway and new lines increasing constantly, we use 5 bits binary coding to obligate for the new lines
- 0 indicates the up line and 1 indicates the down line. Beijing subway line is divided into four types: east-west, north-south, mixed direction and inner-outer ring. We define from east to west, south to north and inner ring as the up line and we define the direction which has maximum sites and longest mileage as the direction of a mixed direction
- Take the downlink as the number of interval's codes of conduct, code as interval 1, interval 2,..., interval N (4-45)

Finally, the encoded image data is stored in the 3detection system of a computer, the computer translate the encoded binary data into text information and be stored automatic in the database along with the resulting crack width and other data which is got through the image processing technology and measurement algorithms in order to facilitate the administrators to manage and user queries (Yin, 2006).

CONCLUSION

China's urban rail transit is experiencing rapid development, leading the world in the development of its scale and speed. The construction of urban rail transit emphasis in the future will be from the backbone lines of the megacities and big cities, gradually extended to the city's encryption line, contact lines and backbone lines of low scale level cities. This study designed the subway tunnel crack monitoring data management platform, including system management, system setting, crack show, statistical analysis and alarm platform five functions which can provide support for establishing the complete comprehensive testing system of urban rail transit infrastructure.

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