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The safety management of urban rail transit based on operation fault log

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ABSTRACT

With the rapid development of China's rail transit, the safety of Metro has roused the society's concern more and more widespread. So deeply mining the massive dispatching log data is of great significance to the safety management of Metro operation. For the purposes of risk early-warning and promoting the safety management level of Metro, a dispatching fault log management and analysis database system (DFLMIS) is designed, which contains almost all kinds of accidents that have occurred in the operation of Metro. Taking the compatibility and safety into consideration, the Visual studio 2010 and SQL-sever 2005 are used to develop the DFLMIS. First, changing operation fault log is regarded as a state machine, which describes the data from three dimensions: time, value of information, frequency, and forms the operation scheduling database with data management as the visual angle. Second, the probability space cut algorithm is presented for pruning strategy of probability space, which is suitable for high frequent update of the environment of grid technology as index structure. Finally, the procedures are demonstrated to how DFLMIS can be used to early-warn and identify the risk sources. The research and design of DFLMIS would be of great help to the Metro operators to identify the risk and promote the safety management level.

1. Introduction

During the Nearly 10 years, China's urban rail transit line operating mileage grows faster. Up to the end of 2015, 33 cities have been approved or been operating metro, and the total amount of operation lines has reached 96, the total operating mileage has reached 4000 km. According to the plan of line network, by 2020, the total operating mileage of urban rail traffic is expected to break through the 7200 km, the network trend is very obvious. The passengers carried by metro continue to increase, and the complexity of operation organization increases. The factors affecting the operation safety and reliability become more, fault rate continues increasing. Therefore, how to improve the reliability of rail transit hardware equipment, passenger service, reduce the occurrence of fault is very important.

The main accidents caused by Metro safety both in domestic and international have become increasingly prominent: The South Korea Daegu subway fire happened on February 18, 2003, which caused 198 peoples' death and 146 peoples' injury, and resulted in property losses up to 4 billion 700 million won (Balducelli and D'Esposito, 2000).

On December 22, 2009, the crash of Shanghai train leads to the surrounding road traffic paralyzed, and it cost 105 buses 6 h to evacuate stagnation passengers; On September 27, 2011, more than 260 people were injured in Shanghai train crash accident (Kyriakidis et al., 2012). These series of accidents in the world caused strong social repercussions, how to efficiently disposal emergencies during the urban rail traffic incidents, has widely aroused the extensive concern of the whole society and universal attention. The safety management of urban rail transit operation has become an urgent problem to be solved. The basic procedure of data mine can be illustrated in Fig. 1.

2. Literature review

2.1. Operation data of rail transit systems

The operating data of subway contains line operating mileage, train interval running time, operation failure, passenger flow, travel OD data, etc., the safety related data of subway is not only less, but also difficult to obtain. After many years' operation, Beijing, Shanghai and other cities, which operate the subway earlier, has accumulated a large number of operational data (Shi, 2004), domestic and foreign scholars have made a more basic research based on these operational data about safety management of subway.

He (2015) the information construction of urban rail transit enterprise is often a single line sorted by professional, and lack of overall planning, coupled with the construction of large span,

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Fig. 1. The basic procedure of data mine.

information standards not unified, which will cause to be lack of an effective linkage between each line, information isolated island is formed, resulted in each subject cannot be timely communication and coordination, which will give the overall efficiency of the operation and management bring negative influence, and even affect the efficiency of the disposal of emergency. Dobbins (2011) designed an information system to support real-time response as well as planning decisions such as risk resource allocation and evaluation of potential response strategies. In the event of an incident, this system enables en route responders to view incident details via an Internet GIS map service. Zhang (2008) the system adopts and integrates the technology of computer vision, digital image processing technology, database technology, communications technology, control technology, image sensor technology and system integration technology to the transportation industry. And using the most advanced technology of union database currently to give the sharing of information resources from different IT application system of transportation industry. The advanced scheme shall become a base for the development of integrated information system for urban transportation (Lu et al., 2011; Reinach and Viale, 2006; Munder and Gavrila, 2006).

Form the above, many information systems have been used to analyze and prevent the fault of operation. So it is of great necessity to do research of information system based on the operation log.

2.2. The analysis of operation data

Zhang (2016) an adaptable metro operation incident database is presented for containing details of all incidents that have occurred in metro operation. Microsoft Access 2010 is used for the comprehensive and thorough design of the MOID. Through the statistical characteristics of incident, such as types, causes, time, and severity, and 24 accident precursors are identified from Shanghai metro. Finally an organizational structure is proposed from the four aspects of supervision, research, implementation, and manufacturer. It would be conducive to safety risk analysis in identifying relevant precursors in safety management. Takeda (2015) an extraction method of experts' operation know-how from historical operation data is proposed, and efficiencies of the proposed method are demonstrated by numerical experiments using a dynamic simulator. Wang (2009) the flight operation control risk assessment index is established (Zhang, 2016). Using the Bayesian network analysis method based on the fault tree and insecurity event analysis reports over the years as a sample; the probability of occurrence of unsafe events by forward reasoning is predicted. Risk inference result is entirely consistent with actual operation situation.

2.3. Information system design and application

Jiao (2013) the design and implementation of the Beijing subway risk management platform is discussed, the risk management status and existing problems are combined. After the investigation and research of the risk management of Beijing subway, and then the demand of performance and data analysis platform is analyzed from the aspects of function, according to the system demand analysis, the risk management platform functional design, interface design and database design (Jianjun and Siji, 2002). Thirdly, the author describes the risk management platform of software and hardware architecture.

3. Operation scheduling data processing and mining

The quantity of original operation scheduling log is up to 110,284, which is from Shanghai Metro 6, 9, 10 line arrange from 2011 to 2015, containing all kinds of faults that encountered in the course of rail transit operations, the normal operation of the record, the construction inspection, night exercises and other production activities related to the subway operation (Peng and Wang, 2001; Xu et al., 2009). The normal log records, fault records, redundant data are all included, so it needs data mine and processing to the basic raw data. The hazard data processing procedures can be illustrated in Fig. 2.

3.1. The original data

Shanghai Shentong Metro Dispatch log is recorded by the control center of each line, the dispatching log reflects the non-normal situation during the process of operation, covering: the name of the line, scheduling date, scheduling time, recording content, starting station, terminal station, site type, scheduling, professional record types, equipment number subordinate units, equipment, equipment type, warranty time, registration number, report, fault repair time, responsibility type, reason, reason segmentation, two minutes late to start, two minutes late to arrive, five minutes late to start, five minutes late to arrive, and clear off the table, through the exchange dropped, one of the core fields "content" is the subjective descriptive content (Jin and Sendhoff, 2008). Because of the confidentiality of the data and the length of the space, only parts of the content are chosen from the traffic scheduling log.

In recent years, Shanghai urban rail transit line traffic continues to increase, the impact of operational safety and reliability of the fault factors continue to increase, resulting in a growing trend of failure frequency (Liu and Sun, 2009). Among them, the fault caused by vehicles, general and objective factors the proportion is particularly prominent. Therefore, it is very important to improve the reliability of rail transit hardware and passenger service and reduce the occurrence of faults.

According to the provided operational data from the operators, main fault includes seven categories: vehicles, power supply, communication, maintenance management, passengers' transportation, and total harmonic, objective causes. It is usually divided the 7 categories into three grades: the first class classification, the second and third classification, the three categories can be subdivided into 81 types of fault.

3.1.1. Fault type 1: Vehicle fault

The fault of the vehicle is divided into: control system, train doors, braking system, traction system, auxiliary system and two