Ontology modeling and case database construction of subway emergency plan knowledge

Li Hongliang¹,a, Zhang Zhenhai²

¹School of Automation and Electrical Engineering Lanzhou Jiaotong University
Lanzhou China
²School of Automation and Electrical Engineering Lanzhou Jiaotong University
Lanzhou China
*1150336725@qq.com

Abstract—In order to improve the effectiveness and timeliness of the subway emergency plan knowledge, it is necessary to standardize and semantically express the emergency plan knowledge and promote the emergency response work to play a more efficient and timely role. Firstly, an ontology-based emergency planning knowledge modeling is proposed, and a unified and standardized metrology database for the emergency planning ontology is constructed. Secondly, drawing on the case reasoning method MyCBR, combined with the established subway operation accident case knowledge base, a case retrieval method based on semantic similarity is proposed to achieve efficient retrieval of subway emergency accident cases. Finally, Protégé software and MyCBR are used to realize the emergency reasoning knowledge reasoning and case retrieval function, which significantly improves the application efficiency of emergency response knowledge.

1. INTRODUCTION

As an urban rapid rail transit system, the subway bears the important task of urban passenger transportation and plays an increasingly important role in people's social life. However, due to the complex construction environment and the huge tasks undertaken by the subway, its safety issues have become increasingly prominent. The safety issues of subway operation should arouse great attention from relevant departments, and also put forward higher requirements for the emergency response plan and management of subway emergencies in my country.

In terms of plan information research, in order to promote the structured management and expression of emergency plan knowledge, the method proposed by Penadés et al. [1] abroad is to use structured knowledge modules to realize the preparation and generation of emergency plans. Domestic research on the informationization of emergency plans started late, so there is little research in this area, and the main focus is on the knowledge management system. For example, Zhang et al.[2]developed a database query system based on the construction of emergency plans, and then implemented knowledge retrieval of response plans.
It can be seen from numerous studies in the field of emergency response at home and abroad that introducing ontology into pre-planning knowledge modeling and achieving efficient knowledge query and case retrieval is a major focus of current research. This paper models emergency plan knowledge based on ontology-related knowledge, and implements emergency plan knowledge reasoning and case retrieval, which significantly improves the application efficiency of emergency plan knowledge.

2. THEORETICAL KNOWLEDGE

2.1. Subway Emergency Plane

Our country defines the emergency plan for emergency response plans to effectively respond to various types of emergency events [3], the purpose of which is to strengthen the professionalism and pertinence of emergency response plans. The emergency plan system can be composed of four-level emergency plans based on the "Preparation Rules". Taking Lanzhou Rail Transit Emergency Plan as an example, the system diagram shown in Figure 1.

![Figure 1. Rail transit emergency plan system](image)

2.2. Subway emergency plan management

The emergency plan of the subway contains emergency personnel. The responsibilities and division of labor of the emergency personnel should be clearly specified in the plan, and there must be a high degree of coordination when handling incidents. Staff in various departments should take measures in accordance with the operation in training in emergencies to minimize the negative impact of the accident and ensure the safety of passengers' lives and property [4]. The subway emergency plan management process is shown in Figure 2 below.

![Figure 2. High-speed rail emergency plan management process](image)
2.3. Ontology modeling of emergency plan knowledge
Ontology originates from the philosophy concept [5], which is a description and description of the abstract essence of objective reality. This article uses the ontology to construct a subway emergency plan knowledge model, which intuitively expresses the characteristics of events, the relationship and rules between response plans and later disposal, which is conducive to integrating various types of subway emergency information, and at the same time lays the foundation for the future development of subway emergency intelligent systems. The modeling process is shown in Figure 3.

![Figure 3. Knowledge modeling process of subway emergency plan](image)

2.4. Knowledge Framework of Subway Emergency Plan
The emergency plan knowledge framework is an objective, hierarchical description. By understanding this framework, there is a framework and systematic understanding and understanding of the plan knowledge, which lays the foundation for efficient and correct emergency decision-making for emergency workers. The foundation provides help to further reduce the harm caused by the accident. This article sorts out and constructs the subway emergency plan knowledge framework shown in Figure 4.

First, the accident characteristics include three major parts: fault characterization, type of accident, and location of the accident. It is the basic characteristic information of high-speed rail accidents. Among them, the core element of accident characteristics is fault characterization.

![Figure 4. Block diagram of subway emergency plan knowledge](image)
Second, the emergency response plan is the core key to quickly respond to emergencies. Emergency response measures are measures taken by staff to minimize the hazards of accidents, eliminate faults as soon as possible, and restore the normal operation of high-speed rail after an emergency. While emergency personnel take emergency measures, they also need the support of emergency materials, so the emergency response plan consists of response measures, emergency personnel and emergency materials.

Third, post-processing includes three parts: analysis of the impact of the accident, analysis of the cause of the accident, and analysis of post-corrective measures. Among them, according to the impact of the accident and the degree of the accident itself, the judgment of the accident level can be made. After analyzing the cause of the accident, you can use this as a basis to arrive at a plan for the subsequent rectification measures.

Based on the knowledge system of the high-speed rail emergency plan constructed above, ontology modeling software Protégé is used as the carrier to build the ontology knowledge model Onto-EPMO. This article uses three modeling primitives of class-C, relationship-R and instance-I to express, expressed as \[ \text{Onto EPMO} = \{ \text{Cs, Rs, Is} \} \].

Cs represents the composition of the subway emergency plan knowledge concept. This article establishes three major categories, namely emergency plan, post-disposal and accident characteristics. This is based on the concept of plan knowledge and can be formalized as \( C_s := \{ C_{s1}, C_{s2}, C_{s3} \} \). Afterwards, further sub-categories, such as the location of the incident under the characteristics of the accident, can be further divided into stations, section lines, and train sub-categories, which can be formalized as \( C_s := \{ C_{s1}, C_{s2}, C_{s3} \} \).

In addition, Is represents various types of instances. "Turnout failure", "axle counting equipment failure", "switch machine failure", etc. all belong to the signal failure category, and they can all be formalized as \( I_s := \{ I_{s1}, I_{s2}, I_{s3} \} \). The knowledge attribute classification table of subway emergency plan is shown in Table 1.

### Table I  ATTRIBUTE CLASSIFICATION TABLE

| Classification         | Attribute name     | Types   |
|------------------------|--------------------|---------|
| Accident characteristics| Line of operation  | integer |
|                        | station            | symbol  |
|                        | Interval           | symbol  |
|                        | Fault characterization | symbol  |
|                        | Emergency staff    | symbol  |
3. CONCEPT TREE

After comprehensively considering the advantages and disadvantages of various semantic similarity calculation methods, combined with the ontology knowledge structure of fault characterization in the subway emergency plan knowledge system, the similarity of "concept tree" based on semantic information proposed by Xiang Dong et al. [6] The calculation method is the best choice for this article. The concept tree is a hierarchical view [7]. This article uses this method to calculate the following semantic similarity. Taking part of the ontology knowledge structure characterized by signal failure as an example, a semantic concept tree structure is constructed, as shown in FIG. 8. The method includes three parts: tree similarity calculation, descendant similarity calculation and comprehensive similarity calculation.

This article uses this method to calculate the following semantic similarity. Taking part of the ontology knowledge structure characterized by signal failure as an example, a semantic concept tree structure is constructed, as shown in Figure 5. The method includes three parts: tree similarity calculation, descendant similarity calculation and comprehensive similarity calculation.

3.1. Calculation of tree similarity

The calculation basis of tree similarity is the level of concepts and the conceptual distance between concepts. The direct similarity between concepts can be calculated and reflected by it. The calculation formula of the tree similarity is shown in the following formula (1), and the similarity between the concept and the tree can be calculated by this formula.

\[
S_{tc}(c_1,c_2) = \begin{cases} 
\frac{k(f(c_1) + f(c_2))}{(d(c_1,c_2) + k)2m \times \max(f(c_1) - f(c_2))} & \text{if } k > 0, c_1 \neq c_2 \\
1 & \text{if } c_1 = c_2
\end{cases}
\]

In the formula, the depth of the concept tree is the maximum value of the concept hierarchy, denoted by m; f represents the hierarchical position of the concept in the concept tree, and d is called the concept hierarchy; it represents the shortest path connecting the two concepts. Where k is an adjustment parameter and k>0. \(S_{tc}(c_1,c_2) = 1\), it means that the concepts \(c_1\) and \(c_2\) have an equivalent relationship.

According to the above definition, taking the concept tree in fig.8 as an example, the similarity of the semantic concept tree of signal failure is calculated. Comparing tree similarity between signal failure and relay failure \(S_{rt1}\), Tree similarity between STC equipment failure and TMS failure \(S_{rt2}\). The calculation process is as follows:

- Depth of concept tree \(m = 5\); The conceptual level of signal failure in the conceptual level \(f_1 = 4\); Concept level of relay failure \(f_2 = 4\); STC equipment failure concept level \(f_3 = 3\); The conceptual level of TMS failure \(f_4 = 4\); \(k = 2\) (k usually take 2)

- Conceptual distance. The conceptual distance between signal failure and relay failure \(d_1 = 2\); STC equipment failure and TMS failure \(d_2 = 5\).
• Calculate the conceptual similarity in the tree, namely:

\[ S_{t1} = \frac{k(4+4)}{(2+k) \times 2 \times 5 \times 1} = 0.4 \]
\[ S_{t2} = \frac{k(3+4)}{(5+k) \times 2 \times 5 \times 1} = 0.2 \]

3.2. Descendant similarity calculation

• The upper concept is called the parent concept in the concept tree. Therefore, the degree of similarity of the lineage also refers to the similarity between the concepts of the father, written as. You can still use formula (1) to calculate the degree of similarity.

• According to the above definition, calculate the degree of similarity of the descendants in the tree, namely:

\[ S_{tt} = \frac{k(2+3)}{(k+3) \times 2 \times 5 \times 1} = 0.2 \]

3.3. Calculation of comprehensive similarity

• The comprehensive similarity can be calculated by combining the tree similarity and the descendant similarity, which is denoted \( Sc \), the conceptual similarity between \( c_1 \) and \( c_2 \) and two non-equivalent concepts is:

\[ S(c_1, c_2) = \frac{S_t(c_1, c_2) + S_{tt}(c_1, c_2)}{2} \quad (2) \]

• According to the above definition, calculate the comprehensive similarity between signal failure and relay failure. Comprehensive similarity between STC equipment failure and TMS failure, which is:

\[ S_1 = \frac{4k}{2 + 5k} + 1 = 0.7 \]
\[ S_2 = \frac{7k}{2 + 5k} + \frac{5k}{30 + 10k} = 0.2 \]

The local similarity and global similarity constitute a complete case similarity. The semantic similarity of the fault characterization attribute is equivalent to the local similarity of a characteristic attribute in the case, and has been calculated above. After the similarity of each attribute in the case is obtained, the global similarity is calculated, which is the overall similarity of the case.

4. CASE RETRIEVAL RESULTS

MyCBR[8] is a convenient case inference tool developed by the German Artificial Intelligence Research Center, supporting inference framework design, strong scalability, and adaptability, and can be used as a plug-in for Protégé. This article is based on MyCBR to retrieve the case of the original system.

![Case retrieval results](image)
Since most operating accidents are caused by equipment failures rather than other reasons such as passenger injuries, the case knowledge index retrieved in this paper selects the failure characteristics of signal failures. When the feature of the input fault is "cut off", a case similarity calculation program is set in the computer in advance, and the case retrieval result is finally obtained through system calculation. After an accident characterized by a "disconnected" signal failure occurs, it is necessary to complete the failure treatment as soon as possible and restore the normal operation of the high-speed rail. Analysis of statistical data shows that when dealing with such emergencies, the train will be delayed by about 4 minutes. In this case, the on-duty personnel should report the emergency and situation to the command center in time for auxiliary work; at the same time, the platform personnel should communicate with the passengers in time to alleviate the passengers' emotions during the train delay. In this way, the emergency response in an emergency can be further improved to improve the response efficiency.

5. CONCLUSION

Subway emergency rescue and emergency plan management are important pillars to maintain the normal operation of subway transportation, which can effectively reduce casualties and property losses in emergencies or safety accidents, and are extremely important for maintaining safe operations. This paper builds a conceptual tree of fault feature information. Based on the concept tree, the local similarity of various types of fault feature information and the comprehensive similarity between cases are calculated. The subway emergency plan knowledge retrieval system realizes the efficiency of case knowledge query. At the same time, the retrieval system has also fully demonstrated the development potential of semantic technology in subway emergency plan knowledge management.

ACKNOWLEDGMENT

National Natural Science Foundation of China (No.61763025)
Natural Science Foundation of Gansu (No.18JR3RA124)
China Postdoctoral Science Foundation funded project (No.167306)

REFERENCES

[1] Ma C, Penadés, Borges MRS, et al. A Product Line Approach to the Development of Advanced Emergency Plans [J]. Organization, 2011, 5:1-10.
[2] Zhang M, Li P, Wang F. The emergency decision support platform of urban rail transit based on information sharing and digitalized plan [C]. Proceedings of the Tenth International Conference of Chinese Transportation Professionals. 2010. 287-294.
[3] Ministry of Transport of the People's Republic of China. Standards for the preparation of emergency plans for urban rail transit operations (JT/T 1051-2016) [S]. Beijing: China Standard Press, 2016.
[4] Liu Xiaoqin. Research on Auxiliary Decision Method of Railway Emergency Management [D]. Beijing: China Academy of Railway Sciences, 2017.
[5] Bong-Jae Kim; Seok-Won Lee. Understanding and recommending security requirements from problem domain ontology: A cognitive three-layered approach [J]. The Journal of Systems & Software, 2020.169:1-19.
[6] Xiang Dong, Zhao Yong, Chen Yang. Research on semantic knowledge-oriented case knowledge expression and similarity calculation method [J]. Computer Engineering and Science, 2011, 33(12): 159-166.
[7] Zhou Xianhu. Research on emergency decision-making of railway emergencies based on CBR [D]. Chengdu: Xinan Jiaotong University, 2018.ence and Technology, 2017.
[8] Jiang Xiaoyan, Wang Sai, Wang Jie, et al. A Decision Method for Construction Safety Risk Management Based on Ontology and Improved CBR: Example of a Subway Project [J]. Int J Environ Res Public Health. 2020 Jun 1;17(11):3928.