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Ontology-based Emergency Plan Management of Metro Operation and its Application in Staff Training

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Abstract

Emergency plans play a key role in the emergency management of metro operation. Well-prepared emergency response supported by plans can greatly mitigate the significant impact of metro incidents. However, most emergency plans remain as plain-text documents, which make it difficult to conduct efficient administrative work such as plan creation, preservation and maintenance. Operational use of plans such as rapid knowledge retrieval and acquisition can't be performed as well, affecting emergency training during preparation process as well as plan review at the scene of the accident. Additionally, the knowledge coded in emergency plans are mostly depicted by texts, which are not vivid and intuitive enough to clearly display the instructions of response procedures and relative information. In this paper, an ontology-based knowledge modeling method has been proposed to improve the knowledge management efficiency, and a unified and formalized knowledge repository of plans can be built based on it to facilitate the efficient administrative and operational use of emergency plans. BIM technology has been introduced to provide a realistic visualization of the plan knowledge for better understanding. A prototype of emergency plan training system for metro staffs, which integrates BIM and the ontology-based knowledge repository, has been developed to demonstrate the feasibility and effectiveness of the method. A case study has illustrated the knowledge management process and shown how staff training can benefit from the system.

Keywords: Emergency plan; Metro operation; Ontology; Training system

1. Introduction

The increasing scale of metro construction as well as the booming passenger flow have set higher demand for the emergency management of metro operation. As the first couple of hours after the incident occurrence play the most crucial role in fighting and mitigating the impacts of the incident on passenger's lives [1], timely and high-quality emergency response are crucial to ensure the public safety. In order to quickly respond to metro incidents, a large amount of emergency plans covering all possible incidents relative to operation areas have been developed by local metro operation companies to prepare for the response process. Emergency plan serves as a manual that describes procedures for dealing with all kinds of emergencies [2], and on-site emergency command and relief work can be greatly supported by it. Also, for better response performance at the scene, the plans will be learnt and memorized during metro staffs' professional training so that they can act quickly after the occurrence of a real emergency.

However, more than 80% emergency plans of metro operation in China are plain-text documents or rigid electronic files without semantic meaning, which make it difficult to conduct efficient administrative work such as plan generation, preservation and maintenance. This inefficient management of emergency plans also cause inconvenience in the use of plans. Large amount of the plan knowledge scattered among various files without organization has made it impossible to conduct rapid knowledge retrieval and acquisition, seriously affecting the advanced emergency training as well as the on-site knowledge support. Thus, it is essential to organize and represent the knowledge in a structured and coherent manner to promote the efficiency in both administrative and operational use of emergency plan.

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Meanwhile, the knowledge coded in emergency plans are mostly depicted by texts, and some descriptions of response procedures are not specific and explicit enough for a good understanding of the information contained in them. The characterization of the emergency conditions like station features and rescue resource availability has not be considered, which leads to the lack of pertinence and effectiveness of emergency plans. Therefore, combining response procedures with its associated contextual information is important to enhance the applicability of the plan knowledge, and a more visualized method of knowledge display is needed to extend the capacity of metro staffs to better understand and memorize them.

In this work, ontology has been introduced for knowledge management support. To overcome the weakness of traditional file management of emergency plans, an ontology-based knowledge modeling method has been proposed to improve the knowledge management efficiency. The vast knowledge of emergency plans can be structured and represented based on a unified and explicit knowledge framework to establish a structured and formalized knowledge repository. Efficient administrative and operational use of emergency plans can easily achieved with technical support.

To enhance the applicability and visualization of the plan knowledge, BIM technology has been exploited to integrate contextual information associated with the response procedures, and specific and intuitive knowledge display of emergency plans has been provided. To demonstrate the feasibility and effectiveness of the method, a prototype system of emergency plan training for metro staffs, which combines the ontology-based knowledge repository and BIM, has been developed to support the efficient emergency plan training process for metro staffs. A case study has illustrated the knowledge management process and shown how staff training can benefit from the system.

The remainder of this paper is organized as follows: In Section 2, we briefly discuss the related work in knowledge management of emergency plans and BIM application in them. Section 3 presents the ontology-based knowledge modeling method of emergency plans for metro operation. Section 4 discusses the establishment of the prototype system of emergency plan training for metro staffs. Section 5 illustrates an example of application. Finally in Section 6 we conclude the work, discuss the prospect of the ontology-based emergency plan training system for metro staffs as well as future study directions.

2. Research review

For better management of emergency plans, IT-enable method has been studied by different researches to improve administrative efficiency and practical application effect. Dong, Li and Xu [3] have developed an information management system to enhance the automatic management of emergency plans such as adding, deleting, modifying and inquiry of plans. Canós et.al [4] introduced SAGA, a framework designed to provide support to the full lifecycle of emergency plan management and use. The information management system proposed by Mejri [5] has introduce ontology for the analysis of information function during the entire workflow of emergency management. Wang, Yang and Dong [6] have built an emergency plan system ontology to promote the communication and sharing between different plan systems. To enhance the applicability of plan knowledge by integrating contextual information, Canos, Alonso and Jaen [2] have proposed the concept of hypermedia plan which integrated the plan information with a 3D model of incident location on one screen. BIM is used to provide geometric information of the emergency scene for evacuation planning by Li et.al [7].

Although ontology has been introduced to solve the semantic lack existed in the traditional information management system of emergency plans, most researches built the ontology from the administrative perspective, which limited its further operational use for knowledge support during a real emergency. Besides, much of the environmental information of the emergency scene presented by BIM are mostly used to refine evacuation routes or support realistic visualization of emergency scenarios. The support for a better understanding of the knowledge contained in emergency plans are seldom studied. In this research, an ontology-based knowledge management of emergency plans for metro operation has been proposed to improve the efficiency both in administrative and operational use. The development of a prototype ontology of emergency plans for metro operation (Ont-EP4MO) will be firstly presented in the next section.

3. Development of Ont-EP4MO

As the most widely recognized definition said by Gruber [8], “Ontology is an explicit specification of a conceptualization.” It provides a way to move from a document-oriented view of knowledge management to a content-oriented view [9]. Another characteristic of ontology is formalization, which was mentioned by Studer et.al [10] to highlight its machine-readable feature. Hence, the ontology-based knowledge management of emergency plans for metro operation will facilitate the organization and standardization of plan knowledge,

improving the efficiency in administrative work and operational use such as knowledge retrieval for emergency training or timely knowledge support at the scene.

3.1. *Knowledge modeling of emergency plans*

In order to achieve the ontology-based knowledge management of emergency plans, a common and standard knowledge framework of emergency plans should be built first, in which a common language is used to conceptualize the necessary information contained in these plans. After a study of national guidance and emergency plans of several cities, key concepts and relations are captured and extracted from these scattered sources for knowledge modeling, and a common knowledge model of emergency plan is built, as shown in Figure-1.

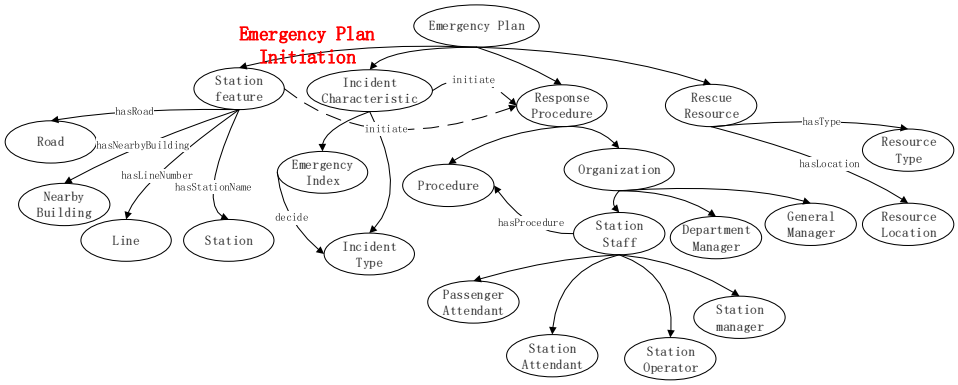

Figure-1 Knowledge model of emergency plans for metro operation

Four core parts of a complete emergency plan have been identified, namely station feature, incident characteristic, response procedure and rescue resource. The former two parts also form the classification standard of vast emergency plans. The most import part of the plan is the response procedure described for each position at the station. Incident characteristic is used to describe the basic information of the emergency such as incident type and emergency index. The information of rescue resources are needed to help with the action performance. The most essential relations between these concepts are constructed based on the initiation mechanism of an emergency plan, as shown in the dotted lines. After the occurrence of a metro incident, the real-time information of incident type and occurrence location shall be gathered immediately to launch the associated emergency plan, and then response procedures can be committed by station staffs respectively.

The knowledge model has provided a unified framework for the organization and standardization of all different kinds of emergency plans. Based on it, the knowledge of emergency plans can be stored in a common way to achieve the construction of a coherent repository. The advantage of information sharing and reuse of ontology has enable the efficient administrative work such as plan generation and maintenance, as well as a collaborative environment for different actor involved in the whole lifecycle management of plans.

3.2. *Knowledge representation*

After the unified knowledge model was built, a representation schema is needed to represent the knowledge in a formalized and explicit way with machine-readable language to facilitate computer-aided information retrieval and acquisition. OWL, as a common ontology language, has been used to define and describe the ontology elements. Moreover, the ontology model is implemented using protégé, which is a software that provides an easy and flexible interface to create an ontology. Based on the proposed knowledge model above, the basic elements such as classes and properties of the ontology can be constructed. Then, the specific information of different emergency plans can be stored as the instances of the corresponding classes, and a structured and formalized knowledge repository can be represented.

4. Emergency plan training system

As one of the most promising development in AEC industry, BIM can provide accurate virtual models in a digital way to support the management activities through the whole lifecycle of the building [11]. Semantically rich information including all geometric and functional properties related to the facility can be integrated into the BIM model, improving visualization as well as the understanding of the relevant management work. Considering

the weakness of text-based knowledge display of emergency plans, BIM has been exploited to provide a realistic visualization of the plan knowledge for better understanding.

In this research, a prototype of emergency plan training system for metro staffs has been developed to demonstrate the effectiveness and feasibility of the ontology-based knowledge management. The architecture of the system are shown in Figure-2. Different emergency plans are collected to build the ontology-based knowledge repository, while 2D drawings of metro stations are used to construct a BIM database by Revit. The information retrieval and acquisition can be quickly performed based on the knowledge repository, while realistic visualization of the related plan knowledge can be presented based on the BIM database. Four function modules are built to perform the plan knowledge learning from four aspects mentioned in the knowledge model above.

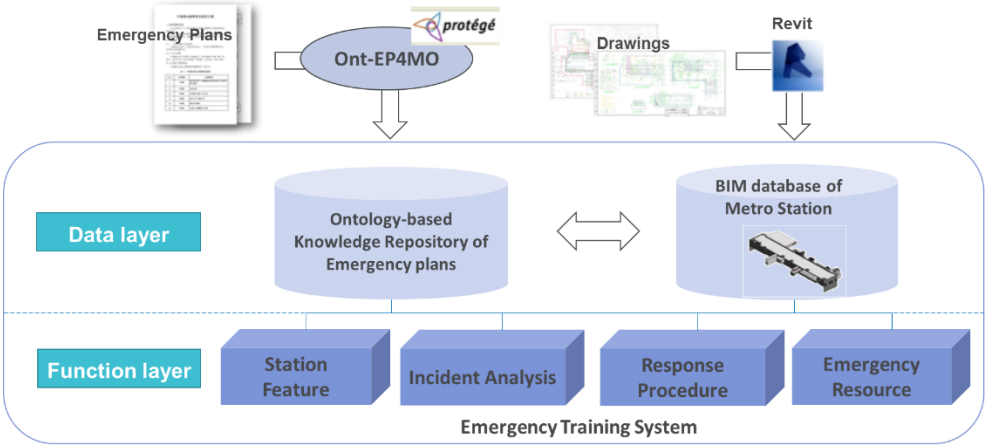

Figure-2 System architecture

5. Case study

To demonstrate the effectiveness of the system proposed above, emergency plans for the incident type of passenger flow surge in Wuhan ZhongNan Road Station has been stored as instances of Ont-EP4MO in the construction of the knowledge repository, and the BIM model of the station was built to provide visualization of the plan knowledge. Based on the emergency plan, the severity of passenger flow surge has been classified into three levels. The higher the level, the severer the situation is, and various response procedures will be inferred based on the level and the staff position previously set. The passenger flow thresholds of each level for both station hall and platform have been set up. A partial exemplified illustration of how the knowledge can be used to populate the corresponding concepts and the relations of Ont-EP4MO is given below, as Figure-3 shows.

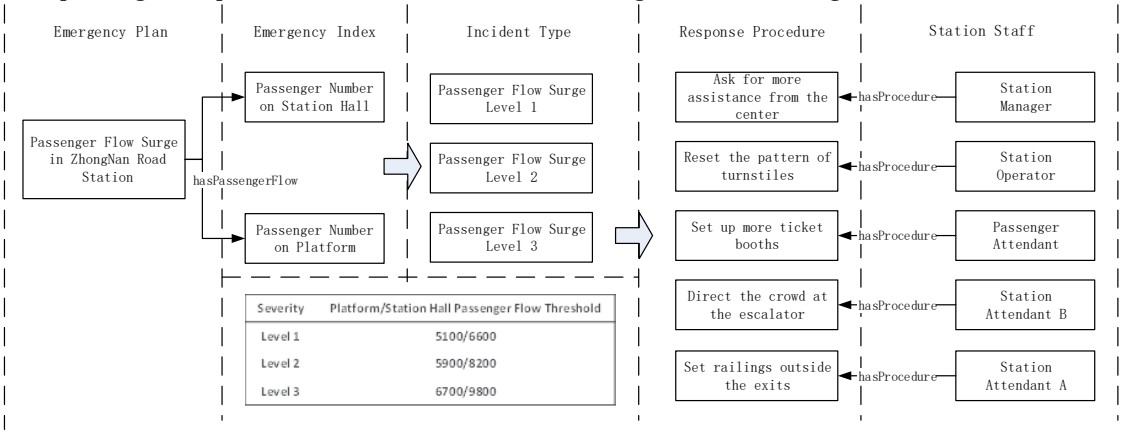

Figure-3 Knowledge repository construction

5.1. *Knowledge reasoning and acquisition*

The ontology-based reasoning can be efficient for knowledge retrieval and acquisition based on the constructed knowledge repository. The rules of level identification and procedures acquisition are presented by SWRL (Semantic Web Rule Language), as shown in Figure-4. If the number of the passengers stay on the platform exceeds the threshold of level 3, the incident type will be reasoned as “Passenger_Flow_Surge_Level3”. The

response procedure “direct the crowd at the escalator” will be acquired according to the station position set as “Station_Attendant_B”.

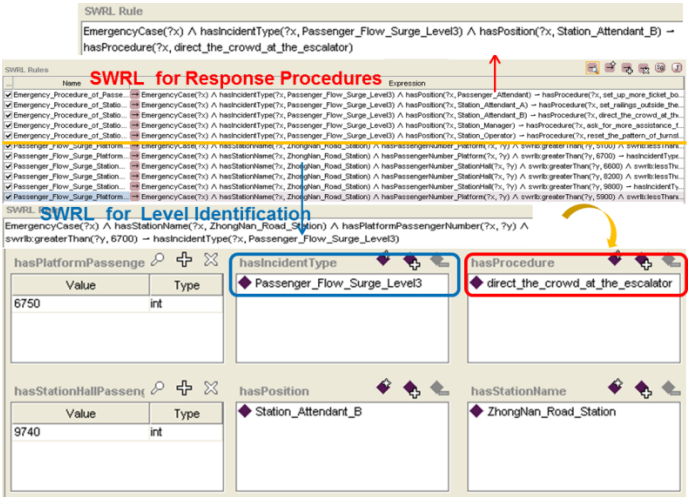

Figure-4 Knowledge retrieval of response procedures for passenger flow surge

5.2. *BIM-based knowledge display*

The BIM model of ZhongNan Road station has been built based on the drawings, as shown in Figure-5. The geometric and functional information are integrated in the BIM database, and the visualization of related plan knowledge can be obtained. According to the knowledge retrieval before, the station attendant should perform the emergency procedure of directing the crowd at the escalator. Hence, in the function module of “Response Procedure” of the system, the knowledge can be display in BIM-based simulation, shown in Figure-6.

Figure-5 BIM model of ZhongNan Road Station

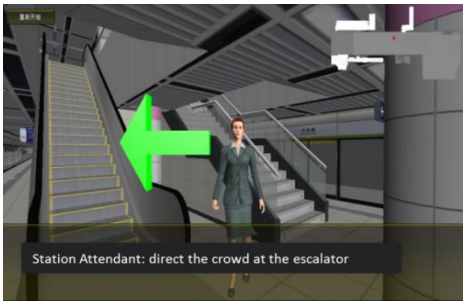

Figure-6 Visualization of response procedures

6. Conclusion and future work

Considering the inefficient management of paper-based emergency plans and the follow-up problems produced in emergency plan training for station staffs and knowledge support at the scene, an ontology-based knowledge management of emergency plans has been proposed to organize and represent the plan information in a standard and semantic way, enhancing the efficiency in both administrative and operational use. A prototype system of emergency plan training for metro staffs, which integrates the ontology-based knowledge repository and BIM technology, has been developed to demonstrate the feasibility and effectiveness of the method. The case study has shown the implementation of efficient knowledge reasoning, acquisition and intuitive training process.

However, two limitations are identified below: since the ontology was constructed only based on existed emergency plans, other important knowledge that haven’t been concluded in the plan may be missed. Interviews of professionals in the field of emergency management should be conducted for continuous refinement and evaluation of the ontology. The proposed training system should be testified by more station staffs to ensure its operability in practical applications. Further development of the emergency training system is the research direction.

Acknowledgement

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