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Context-aware intelligent service system for coal mine industry

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ABSTRACT

In coal mine industry, the context-aware intelligent service system can be used to provide the most appropriate information services to miners according to their real-time situation. As a result, the information resources can be taken full advantage of so as to help miners to improve their safety condition, which are not just accessible to the management staff. However, there is not a detailed discussion or an in-depth research on the implementation of service system at present. In order to bridge the gap between the theory and the practice in the field, three critical problems need to be solved: (1) How to model the served miners' context? (2) How to provide the information services to meet miners' customized demands? (3) How to verify the availability of service invocation? According to the characteristics and practical needs of coal mine, this paper first proposes the Coal Mine Semantic Sensor Network Ontology (CMSSN) to build miner's context model, which can facilitate reusing the context resources in different coal mines. Then, the configuration model connecting context information and business services is constructed to realize the customized service invocation. Thirdly, the method of computational experiment is proposed to verify the availability and validity of service system, i.e. whether the service system can provide the suitable service on time in various virtual accident experiments. A case study is given to explain how to implement the computational experiment on a virtual coal mine simulation platform. Finally, the potential problems in realizing the system are discussed, which will be our research focus in future.

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1. Introduction

Information technology has been widely used in coal mine industry, especially in the fields of disaster prevention and emergency management. The seamless integration between computer technology and production management can effectively promote the operation of coal mine. In the past decade, a considerable progress has been achieved in the informatization of coal mine industry in China. However, there is still a large gap compared with other developed countries, such as the United States, Germany. According to the statistics of literature [1], in the past five years (2007–2011), China's annual coal production is 3 times that of the United States (3 billion tons in China, 1 billion tons in the United States), but its mortality rate (every one million tons) is nearly 30 times that of the United States (China is 0.96, the United States is 0.03). The main causes for coal mine accidents are various. In addition to the natural conditions of the coal mine, mining technology, management level, and personnel quality, the application of information technology is considered to be a very critical factor which account for the accidents in coal mine to a large extent.

However, the development of digital mine has encountered many problems, some of which are as follows: (1) The number of information systems is growing continuously, but each of them is an isolated system with a special purpose. It is difficult to realize the interactions between two or more information systems, which result in data silos. As a result, how to take full advantage of the legacy systems to provide an integrated service has become a barrier to the development of mine industry. (2) The primary mode of delivering information services is PULL rather than PUSH. The management staffs are usually considered as target users who enjoy the information services, while the vast majority of underground miners feel it hard to enjoy the benefits of informatization. Therefore, another problem emerges concerning how to extend the scope of the information service so that they can be available for every miner.

In order to provide an effective solution to the above problems, by inspiration of the idea of "smart planet" [2], the concept of "intelligent mine" [3] is put forward, which is expected to be more thorough perception (Instrumented), more comprehensive interconnected, and more intelligent than the digital mines by means of applying a lot of advanced technologies (such as service computing,

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cloud computing, internet of things, etc.). Context-aware service is a key technology to build "intelligent mine", which is able to bridge the gap between the existing information services and miners' demands. It can provide miners with the real-time services based on their own situation. However, the current research and application in this field are at the initial stage, which has posed a barrier for the implementation and promotion of intelligent mine.

Literature [4] proposes an idea of how to apply context-aware technology in coal mine industry, and also presents the architecture of the context-aware-based service system. The architecture is composed of three layers: perceive the context information of service object (miners) by means of sensors; determine the current status of the served miners based on their context information; select and provide the appropriate business services.

However, there is no an in-depth discussion of the implementation of service system in [4]. In order to promote the research in the field and facilitate the application of context-aware technology in coal mine industry, the following key issues need to be emphasized: (1) How to depict the miner's context to support the subsequent service invocation; (2) How to provide the customized information service to miners in different situations, which can effectively deal with their particular needs and improve their safety condition; (3) How to verify the availability and validity of service system in order to facilitate its implementation and promotion in practical environment.

This paper focuses on the above three problems, which is organized as follows: Section 2 represents the related research work on the above three key issues; in Section 3, the first issue is discussed, and the ontology-based modeling method is proposed to describe miner's context information; in Section 4, the second issue is discussed, and the service configuration model is constructed to connect the context information with the information services; in Section 5, the third issue is discussed, and the computational experiment method is presented to verify whether the service system can play its due role in various accident scenarios; The last part gives the conclusion and future research priorities.

2. Background and motivation

2.1. The context-aware technology

With the emergence of various sensors and the related perceptive software, the context-aware technology comes into being. The concept of the context-aware application is first proposed by Schilit et al. [5] in 1994. Its core is that the system can dig out more useful information about the served customers by means of sensors and then provide the most suitable services to them. By using the context-aware technology, the customer service experience can be improved a lot. Generally, context-aware service has the following four main features [6]:

- Automation. Context-aware services are triggered by the data collected from sensors automatically, which can save the operators' time and energy. It is especially suitable for miners working underground, which is dark, dangerous, and hard to predict.
- 24 h/7 d availability. Context-aware services are not restricted by manual working schedule. The served object can be monitored for 7 × 24 h.
- Real-time response (Perceptiveness). The efficiency of context-aware services is only affected by the frequency of data acquisition, the speed of data transmission and the consumption time of service invocation. Generally, the instant service is very important to the emergency management in coal mine industry. In addition, through analyzing the historical data of the environment, the context-aware service can predict its trend and provide some proactive or preventive services for miners.
- Personalized customization. Because the context-aware service is based on each served object's context information, it is completely personalized. In addition, the data collection and the service strategy can also be configured according to the served object's customized demands.

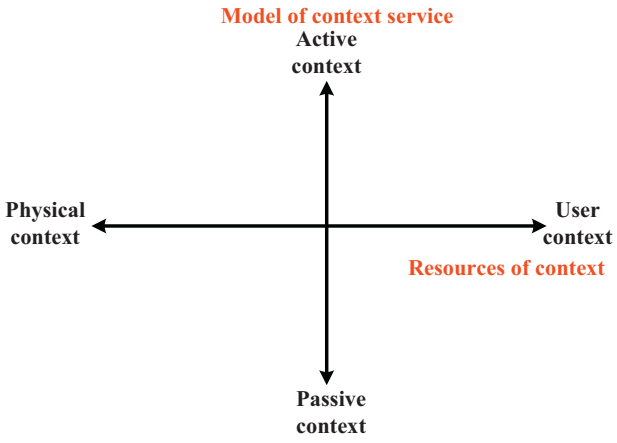

Fig. 1. The types of context-aware services.

As shown in Fig. 1, the context-aware services can be classified into four types based on context information sources as well as service models. According to Schmidt et al. [7], the context information can be categorized into User context and Physical context. Taking a miner as an example, the information about User context refers to his age, mood, habit, preference, ability, etc., while the information about Physical context includes time, location, temperature, light, facilities, etc. In accordance with the definition of Chen and Kotz [8], the service models can be categorized into active service mode (Active context) and passive mode (Passive context). When operating in the active service mode, the service system will change its behavior pattern in accordance with the received contextual information. For example, in a meeting, the phone will be switched into a silent mode according to the pre-set order. When operating in the passive service mode, the service system will change its service content in accordance with the received context information. For example: some goods can be recommended to a customer in accordance with his preferences when he is shopping online.

At present, the context-aware technology has been used in many fields gradually, such as home environment, tourism, mobile computing, healthy care, etc. The Olivetti Active Badge Project [9] is the first application of the context-awareness technology, by means of which the automatic call forwarding service is realized in an office building. Bardram and Nørskov [10] presented a Context-Aware Patient Safety and Information System (CAPSIS), which could monitor the surgical procedure in the operating room by using RFID tags on items and personnel. Wood et al. acquired the real-time data of the residents through integrating various sensors, such as environmental sensors, physiological sensors, and activity sensors etc. By learning their behavior patterns, the system can be used to assist the residential living [11]. Literature [12] and [13] emphasized the importance of users' data and their context information in the recommendation system. Taking the mobile business model as an example, Reuver and Haaker [14] gave a detailed description on how to design a context-aware service and pointed out some problems in building a context-aware business model. Sridevi et al. [15] proposed a context-aware healthcare