A Social Network System for Sharing Construction Safety and Health Knowledge

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Abstract

Due to the complicated and complex working environments, construction site still presents high accident rate, which is causing serious project delay and cost overrun. Abundant studies have focused on cause and effect on fatalities or safety training system, and so on. Most of them on this issue have been emphasized the necessity and utilization of information, rather than how to exchange, share and transfer safety data efficiently in the construction industry. With this regard, this paper proposes the Social Network System for Sharing Construction Safety & Health Knowledge (SNSS), which utilizes state-of-the-art semantic wiki web and ontology construction technologies for better communication and representation for construction safety information. The SNSS is developed on the basis of Safety Semantic Wiki Template (SSWT), which consists of the following three modules: 1) Safety Information Module (SIM) to upload and share accident and hazard information; 2) Safety Knowledge Module (SKM) to refine the safety information and to confirm and transfer it to knowledge; 3) Safety Dissemination Module (SDM) to monitor, manage and retrieve safety information and knowledge easily. The SNSS is tested by a scenario of using falling accident information by which the potentials and limitations of the system were addressed. The study emphasizes the potential applicability and benefits of social network system that could be utilized to enhance communication among participants in the construction industry.

Keywords

Social network, semantic wiki, ontology, safety information, safety knowledge.

INTRODUCTION

Construction is a very intricate and complicated environment that causes high accident rates (Carbonari *et al*., 2011). For example, the number of casualties per 1000 workers is 7.5 in Korea, 9.5 in Singapore, 60.6 in Hong Kong, etc in 2006 (Poon *et al.*, 2008). In spite of the attention given to the construction site injuries, the incidence rate of industry is reported to be twice higher than the industrial average (Rowlinson, 2004). This plague causes many problems related with cost overrun and schedule delay in construction project. Therefore, many studies have been performed to reduce the incident rate, such as construction safety and health monitoring system that integrates internet and database systems for a total automated safety and health management (Cheung *et al*., 2004), the game technology based visualizing safety assessment for safety and health training (Li *et al.*, 2011), and so on. According to Fang *et al*. (2010), most of the current researchers have been focused on safety training and education as a main channel to improve construction safety rather than to solve the communication problems in sharing and retrieving construction safety information and knowledge.

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This limitation has required a high demand for online interactive multi-user and information exchange to achieve the sharing and retrieving safety knowledge purpose. The social networking platform allowed its users to connect and communicate with the others, and would help to successfully obtain the construction safety & health sharing purpose. Social network sites is a web-based service that allow individuals to construct profile, articulate a list of other users, view and traverse their list of connections, exchange information, and communicate with other users (Boyd and Ellison, 2007). In the construction industry, the integrated classical project management concepts and social network science theory (Chinowsky *et al*., 2008) or the use of social network as strategic tool for managing construction project (Ling and Li, 2011) could greatly improve efficiency of construction project management. Social networking is a potential and powerful tool to engage, motivate user to share, update, and manage information (Eysenbach, 2008), and plays an important role in exchanging resources among partners which have been applied in many diversified area (Kim *et al*., 2011).

This paper proposes a social network system for sharing construction safety & health knowledge (SNSS) that integrates state-of-the-art of information technologies such as semantic wiki and ontology in order to overcome the communicative barrier of safety knowledge sharing. For efficient representation and effective communication of construction safety knowledge, this paper develops three modules in the system - information module, knowledge module, and dissemination module - based on safety semantic wiki template (SSWT). The SSWT exploits semantic wiki and construction ontology combination as the platform of SNSS, which provides a convenient and easy environment for construction safety and health information sharing and knowledge exchange. In SSWT, semantic wiki application allows users to add, remove, edit, change content of incident and hazard cases in a cooperative manner without any computer science background, while ontology technology plays the role as a tool in accident information arrangement and knowledge retrieval. The safety information module (SIM) allows users to upload and gather safety data through the SSWT. In the SIM module, the safety data (dangerous occurrence or hazard & risk) will be transferred as comprehensive information. The safety information will be conveyed and analysed in the safety knowledge module (SKM). It is noted that the SKM module will mobilize and utilize domain experts to join in knowledge contribution and refinement phases for achieving the best knowledge. The whole safety information and knowledge will be manipulated in safety dissemination module (SDM) on a website. It supports users to construct, participate, as well as explore high-level construction safety and health knowledge easily and conveniently. The proposed SNSS system could be utilized as a beneficial tool for construction safety and health management in the industry.

LITERATURE REVIEW

SAFETY DATA, INFORMATION, AND KNOWLEDGE

Before entering more in depth into the discussion about this research, several terminologies, which include construction safety data, information and knowledge need to be understood to make the paper clearer. According to Wikipedia, data are values of qualitative or quantitative variables, belonging to a set of items. Information is a message or collection of messages in an ordered sequence that consists of symbols, or it is the meaning that can be interpreted from such a message or collection of messages, while knowledge is a familiarity with someone or something, which can include information, facts, description, or skills acquired through experience or education (Wikipedia). Data is the lowest level of abstraction, information is the next level, and finally, knowledge is the highest level among all three. From the point of view of three definitions above, construction safety data in this paper is accident, hazard and risk records or reports

while safety information is considered as the description of accident process, which consists of hazard phenomenon, accident result, etc. Construction safety knowledge is acquired by domain experts based on safety information analysis through a social network platform.

COMMUNICATION IN CONSTRUCTION SAFETY & HEALTH

The construction industry is considered to be a distinctly unique and highly fragmented environment where the lack of safety knowledge is a critical reason for high accident rate that caused cost and time overruns (Ulang *et al*., 2010). The effective safety knowledge and information exchange is becoming more important to reduce dangerous occurrence as well as hazard and risk in construction industry (Lin, 2009). However, it is difficult to solve this problem due to nonstandard knowledge, vague, ambiguous, inconsistent safety standard and regulation (Fang *et al*., 2010) or the subjective nature and ad-hoc of construction knowledge (Zhang and El-Diraby, 2012). In order to achieve better safety performance, an enhanced safety and health communication system is necessary to identify and analyze safety hazards and risk, incident information, and to develop proactive accident prevention methods in the construction process.

SEMANTIC WIKI WEBSITE

Unlike some content management systems, semantic wiki websites offer sharable environment that allows visitors to easily add, remove, edit, and change available content in a collaborative manner without using any complex commands or learning programming language (Mill, 2005). West and West (2009) reviewed that Wiki could support the dynamic online communication where wiki customers could write, discuss, comment, edit and evaluate information. Furthermore, wiki systems are used for many different purposes such as database for research and writing, information management, collaborative tool for documents needed to update frequently due to the free expandable collection of interlink web pages or storing and modifying information functions (Pereia and Soares, 2007). Buffa *et al.* (2008) proposed a system, called Sweet Wiki that combines general Wiki advantages and semantic web technology. The Sweet Wiki not only formalizes and reuses information based on semantic searching and navigation but also supports knowledge relationships between searching keywords and the results through semantic tagging. Obviously, semantic wiki technique would be an excellent tool in information sharing and knowledge exchange.

ONTOLOGY APPLICATION

An ontology is a representation model which defines concepts, attributes, and relations with explicit specifications that could solve the problems of ambiguity in knowledge sharing and reuse (Shih *et al*., 2011). According to Rezgui (2006), ontology plays a critical role in proposing knowledge environment and providing a semantic reference to ensure relevance, accuracy, and complete of information. Lima *et al*. (2005) suggested e-COGNOS that applied ontology as the main feature of platform provided a formal representation of knowledge domain with an effective means. Reusable ontology is more important for information integration, knowledge-level interoperation, and knowledge base development (Farquhar *et al.*, 1996). Tudorache and Noy (2007) developed the Protégé system as an open-source platform that provides a growing user community with a suite of tools to construct domain system and knowledge based applications with ontologies. The Protégé system enables users not only to establish and populate hierarchical ontologies but also to build a new ontology class. In summary, ontology is a potential and powerful technology to facilitate knowledge sharing, reusing and also knowledge acquisition.

SOCIAL NETWORK SYSTEM FOR SHARING CONSTRUCTION SAFETY & HEALTH KNOWLEDGE

The main purpose of developing a social network system is to enhance information sharing and knowledge exchange through social communication. The key benefit of social network system does not require the authority expert as intermediary, which allows users to more direct access of data and information. As illustrated in Figure 1, the disintermediation process properties of SNSS mobilizes and utilizes expert domains to take over the role of the intermediary and to help users to attain accurate safety information and knowledge. The SNSS is a broker between user and information, which enables the individual to play an active role in perception rather than just passively receiving impression from surroundings. Through this disintermediation process, the safety data are transferred to information using wiki editing, tagging, browsing, and linking, and the safety information is changed to the safety knowledge using ontology tagging and wiki editing. Then the safety knowledge will be available in the website for the use of specific safety knowledge.

Unlike some knowledge management systems, the SNSS is structured under a semantic Wiki system as a bridge to link the following three modules: safety information module, safety knowledge module, and safety dissemination module, as illustrated in Figure 1. The Safety Semantic Wiki Template (SSWT) is designed for the SNSS and support a flexible environment for information collection, knowledge creation and dissemination on construction safety.

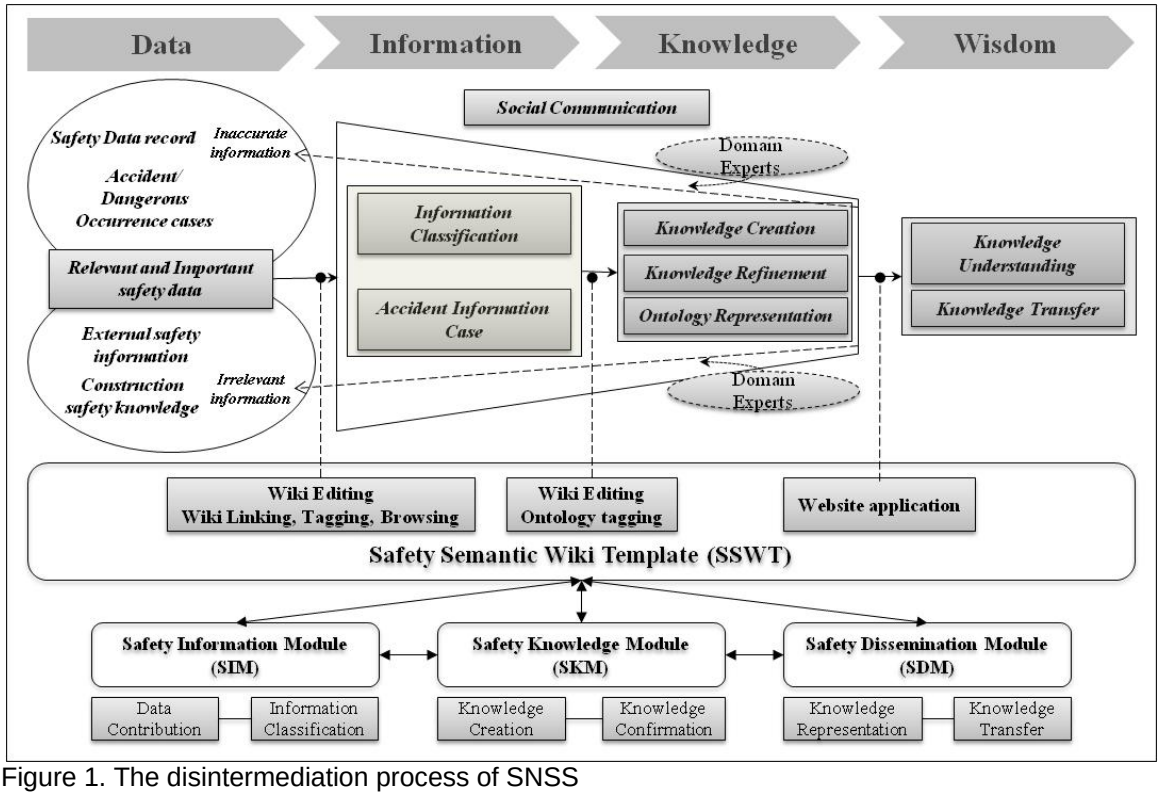

Figure 1. The disintermediation process of SNSS

SAFETY SEMANTIC WIKI TEMPLATE

The Safety Semantic Wiki Template (SSWT), as illustrated in Figure 2, is designed under the collaboration between semantic wiki web and construction safety ontology technologies that allows visitors to share safety information and knowledge as well as to

classify them easily and conveniently without any computer background. Firstly, the semantic Wiki web provides an elegance and flexible form of safety knowledge, which users can add, comment, remove, and edit its content via web browser. The SSWT pages are directly edited by all users, and allow them to create new topic pages as required. Similar to Wikipedia, the SSWT page creates a knowledge network through tagging, linking, and browsing (Bruns, 2008). Secondly, the safety ontology provides the safety classification framework that presents the correlation of safety information and their corresponding significance. The ontology applied in the SSWT constructs conceptual maps of safety information based on Protégé (Tudorache and Noy, 2007) in order to provide an effective safety catalogue for reference to users as they perform information search and contribution. The functions of sharing and reusing of ontology enable users to search, identify and manage text safety information easily and accurately. With taken advantages of semantic Wiki and ontology, the SSWT provides open safety platform for its users to contribute, share, evaluate, and synthesize their safety knowledge.

As noticed in Figure 2, there are two main sections that are information and knowledge of construction safety in the SSWT. Firstly, in the section of construction safety information, the visitor will contribute to upload cases of accident, unsafe situation or hazard by describing such as what kind of hazard, how accident happens, and so on. Similar to other social network pages, they can use dynamic editing and semantic resources by tagging in order to create better description of unsafe phenomenon. Secondly, domain experts take part in analyzing the uploaded accident information to suggest accident causes and prevention method in the construction knowledge section. It is noted that this knowledge section of SSWT would support three main functions of bringing the best results: 1) Discussion forum where experts can easily and collaboratively insert their expertise to analysis accident or dangerous cases; 2) Safety voting and confirmation for expert evaluation to attain the best knowledge; 3) Ontology representation to categorize construction safety information and knowledge.

SAFETY INFORMATION MODULE

The safety information module (SIM) is the fundamental module of SNSS that is devised for construction engineers/participants to share accident and dangerous occurrences data. The known accident data and its relative information would be inputted step by step in the SSWT, which include: (1) Accident case type and location; (2) Specific accident data such as work phase, hazard type and case; (3) File attach to upload visual information such as accident case picture or video for better understanding of accident; (4) Description section to depict detail accident process and also level of damage of accident case; (5) Result section to figure out the real situation after the accident happened (refer to the top portion of Fig. 2). With these collaborative safety data contribution and classification of the SSWT, an active user engaged community can be created. It should be noted that the SSWT, similar to wiki pages, would support functions of editing (A) and semantic tagging-browsing-linking (B) to participants for ambiguous terminology explanation and data supplement without any computer science skill (refer to the middle portion of Fig. 2). Through the process of uploading and supplementing data in the SIM, the safety data are transferred into safety information and are ready for information analysis to convert it into safety knowledge.

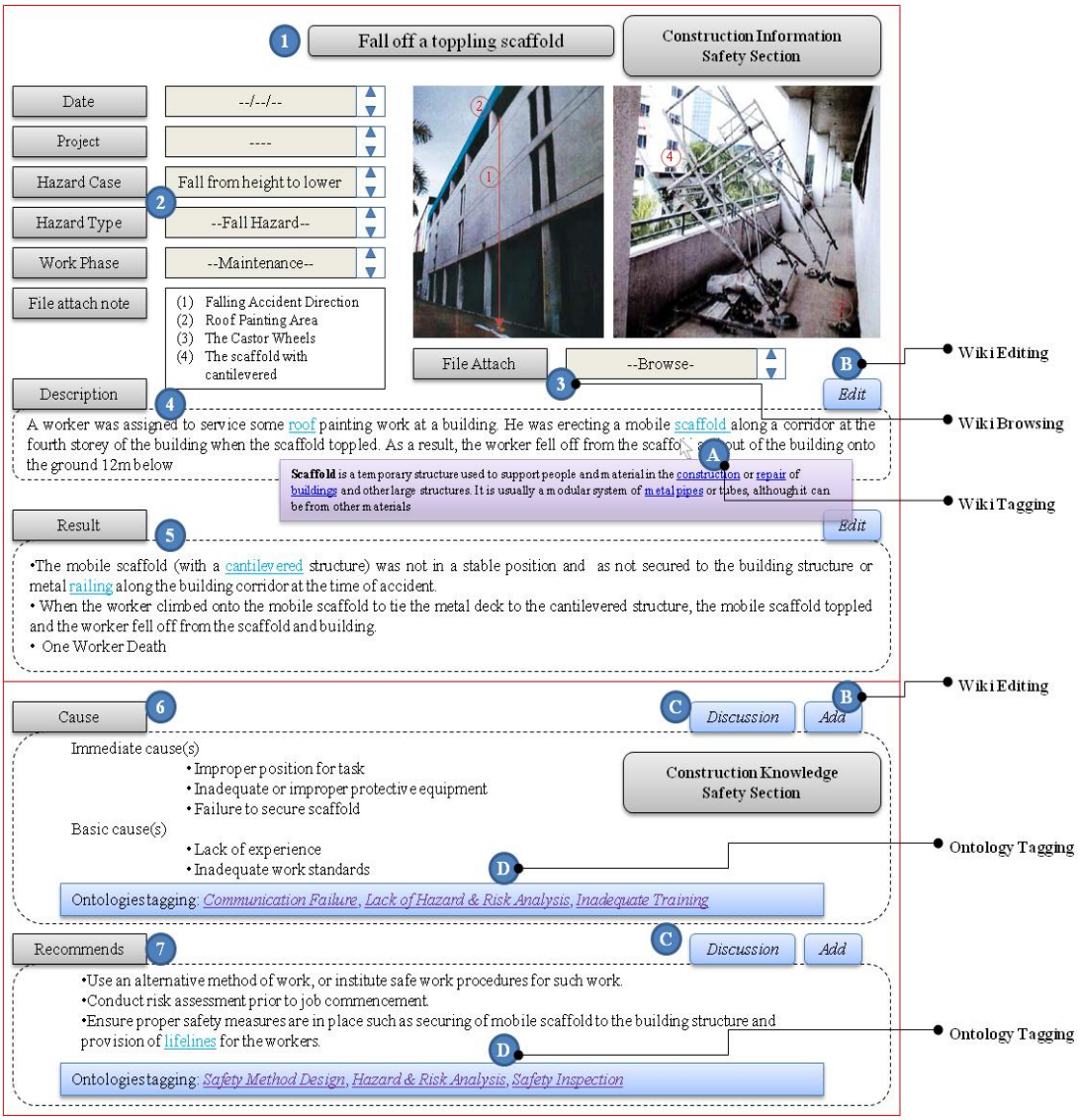

Figure 2. A Sample Case of SSWT
(This case study is extracted from "Falls from Height - Case Studies Construction Industry", Workplace Safety and Health Council, Lee Tzu Yang, 2008)

SAFETY KNOWLEDGE MODULE

In the Safety Knowledge Module (SKM), the accident information are analyzed and refined through the contribution of domain experts, as illustrated in Figure 3. The SSWT provides the knowledge contribution forum for experts to add their expertise by clicking the discussion button icons (C) in cause (6) and recommendation (7) sections (refer to the bottom portion of Figure 2). By leveraging on state-of-the-art of social network system, the SNSS supports users with an easy and convenient environment to share their experiences about the causes and prevention methods of accident phenomenon by commenting ideas and uploading evident documents. After this expertise contribution activity is finished, all analytical accident causes and recommendation ideas would be refined to achieve best results through voting process by domain experts. In the voting process, domain experts give rating points by inserting "like" or "dislike" or "neural" opinions to each idea via the voting tool of SSWT in pre-defined time. At the end of pre-defined time, the idea that acquires the highest score voting is the credible knowledge.

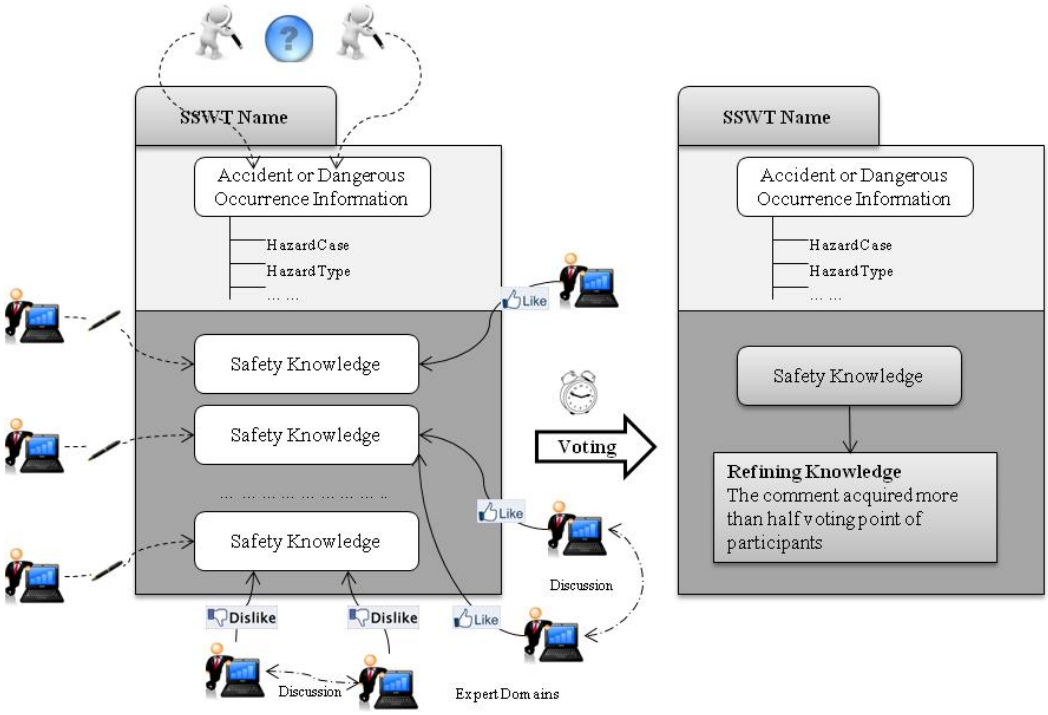

Figure 3. Construction Safety Knowledge Analyzing and Refining

After safety knowledge is confirmed, the whole knowledge in the SSWT would be converted into ontology classes, as illustrated in Figure 4. Via ontology library of SNSS, domain experts would execute ontology tagging and verification for the knowledge sharing and reuse. The ontology library of SNSS has been built based on the theory of Collaborative Protégé (Tudorache and Noy, 2007), that supports collaborative ontology editing and voting to allow expert participants not only to extract ontology class from library but also to contribute to define new ontology classes onto ontology library. Particularly, in case of accident cause and recommendation knowledge, there could be more than one ontology class to be tagged based on the different theories of construction industry. In the SNSS, users can play an active role in establishing safety information and knowledge in the form of systematic and automatic procedures.

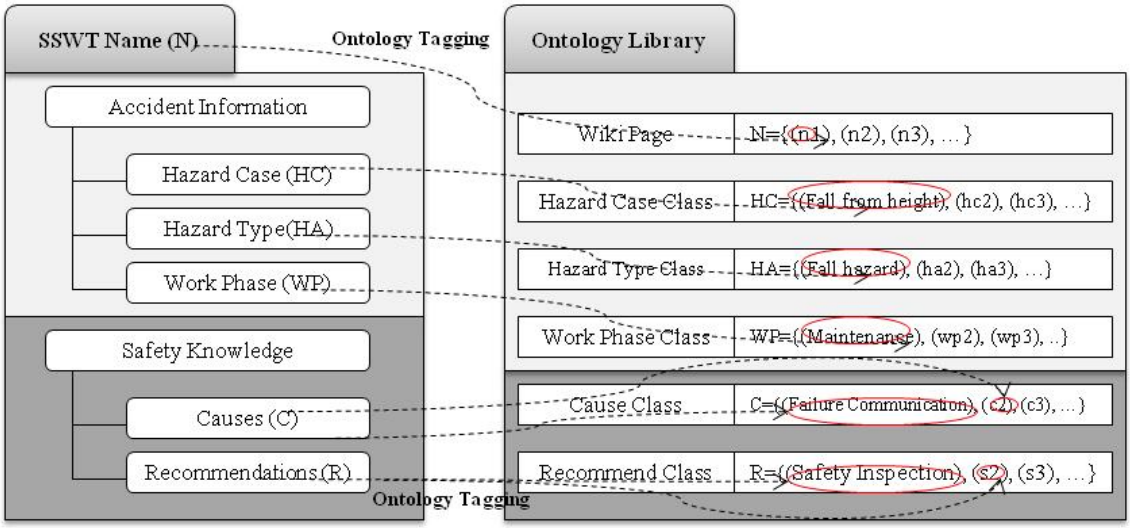

Figure 4. Ontology Converted Information and Knowledge

SAFETY DISSEMINATION MODULE

The safety dissemination module (SDM) of SNSS consists of the following three layers: Interface Layer to implement, Management Layer to create knowledge from user input, and Data Layer to store the input data from users, as illustrated in Figure 5. The Interface Layer allows users to interact with websites to create safety knowledge based on the semantic wiki web and ontology applications. The Management Layer includes three parts to support the system management: 1) SSWT Management creates and modifies the safety knowledge in wiki pages as well as supports domain experts to accumulate knowledge and to construct ontology classes; 2) Ontology Management provides ontology class name list and new ontology class creation; and 3) Refining Engine allows users to discuss and score the knowledge. The score of knowledge is stored in the data layer for knowledge refinement. The Data Layer consists of Database Storage and Safety Ontology Library. Ontology Library is encoded based on Protégé (Tudorache and Noy, 2007) that is the cornerstone to support knowledge classification framework of the Database Storage.

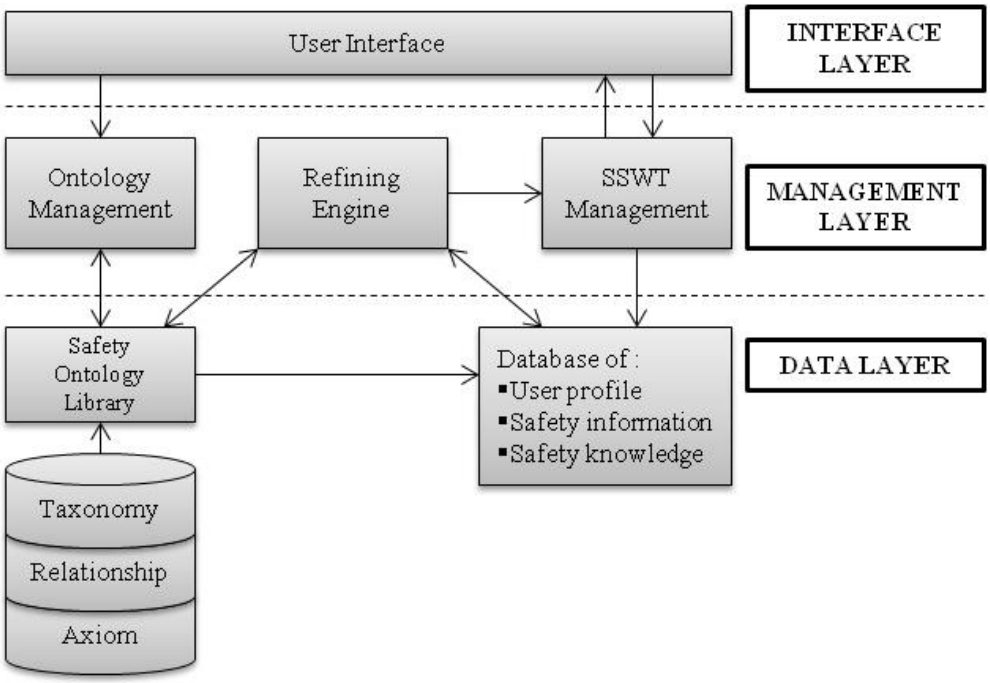

Figure 5. Dissemination Module Technical Architecture

In the dissemination module, like general social network websites, a navigation tool is used for ontology tree as safety categorization and for searching safety knowledge. Typical website interfaces are provided for managing information sharing and knowledge exchange. This feature of SDM would attract many people to take part in the creation of qualitative and quantitative safety knowledge in the SNSS.

SYSTEM EVALUATION

The system has been tested with a real accident scenario in order to figure out the potential applicability and limitations of the SNSS. The system practicability has been appraised and evaluated through interviews with field safety managers. At the current stage of the study, authors found that the proposed SNSS has a great potential to create a good environment for construction safety knowledge retrieval in the construction industry. However, it should be noted that some limitations of the system were found:

1) the pre-defined time for knowledge voting creates some difficulties for users to join in the safety contribution and confirmation process; and 2) the knowledge transfer procedure sometimes met problems due to the abuse of semantic resources tagging, linking and ontology tagging for knowledge sharing and reusing.

CONCLUSION

This paper presents a social network system for coordinating and sharing construction safety and health information and knowledge in construction industry, which are focused on combining unique features of semantic wiki web and ontology to create more effective and efficient representation and communication tools. The core of the proposed SNSS is the SSWT that allows users conveniently and cooperatively contribute, refine, and retrieve knowledge linking three modules - information, knowledge and dissemination. A prototype system was developed and tested with a real accident case scenario. Through the recommendation via interviews with some field safety managers, it is confirmed that the SNSS could greatly enhance the current practices and communication problems of construction safety knowledge. However, there are still some limitations such as the pre-defined time or the abuse of semantic tagging and ontology tagging that will be further examined in the future research. Finally, some research efforts would be directed toward the combination of social network and virtual technique for establishing the good knowledge sharing environment as well as developing the construction safety training or education tool.

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