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Ontology-based Safety Risk Interactions Analysis for Supporting Pre-task Planning

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Abstract: The construction industry remains serious accidents, injuries, and fatalities due to it's unique, dynamic, and temporary nature. On workplace sites, Safety pre-task planning is one of the efforts to minimize injuries and help construction personnel to identify potential hazards. However, the working conditions are complicated. Many activities, including tasks or job steps, are executing at the same time and place. It may lead to an increase in the risks from simultaneous tasks. This paper contributes to addressing this issue by introducing a safety risk interaction analyzing framework. To accomplish this objective, accident reports of the Occupational Safety and Health Administration (OSHA) are investigated. The pairs of task incompatibility, which have time-space conflicts and lead to incidents, are found. Ontology technology is applied to build the risk database, in which the information is acquired, structuralized. The proposed system is expected to improve pre-task planning efficiency and relieve the burdens encountered by safety managers. A user scenario is also discussed to demonstrate how the ontology supports pre-task planning in practice.

Keywords: risk assessment, ontology, pre-task planning, simultaneous tasks

1. INTRODUCTION

Safety is critical for the construction industry. Jobsites are considered as one of the most dangerous places for workers. According to the Occupational Safety and Health Administration (OSHA), 971 of 4674 worker fatalities occurred in the construction industry (20.7%); that is, one in five worker deaths in 2016 occurred at construction sites[1]. The high injury rates and fatalities can plague productivity losses, cost overrun, and schedule. To solve these problems, The Construction Industry Institute funded a study and identified the essential components of an active construction safety program, including Demonstrated management commitment, Staffing for safety, Pre-projects and pre-tasks planning, Safety education and training, Employee involvement, Safety recognition and rewards, Accident/incident investigations, Substance abuse programs, and Subcontractor management [2].

Construction projects are characterized by complexity and a dynamic environment where many activities occur simultaneously. When two activities overlap in time and their workspace, incidents may occur by the risks is higher than considering each activity. For instance, They require adaptive safety measures to be ready in unexpected situations [3]. Practically, safety pre-task planning is demonstrated as an effective method in preventing accidents and injuries by (1) define task sequence, (2) identifying, and (3) controlling potential hazards. Safety pre-task planning is usually applied to analyze every task daily, at the start of each work shift or work condition changes. Specifically, this includes defining a task sequence, identifying hazards and their respective control measures. An assessment of the plan's effectiveness is carried out after the completion of the work package.

Researchers put much effort into improving safety pre-task planning. Assessing potential risks have been studied, which proposed many aspects of levering hazards. For example, Jannadi and Almishari [4] developed a risk assessor model (RAM) to determine risks for significant construction activities, quantifying risks for 19 different construction occupations. Besides, innovative technologies are also applied to analyze hazards. The hazard analysis form is typically read and explained to workers in a pre-task work meeting. It takes time to deliver all contents in safety pre-task planning with vast and complex safety information. Consequently, the worker may start jobs while lacking information.

In order to address these limitations, ontology has offered to structuralize for presenting and reusing knowledge. Project employees can make decisions rapidly. The objective of this study is to consider the interaction among incompatible tasks. This paper proposed a framework for reassessing risks in safety pre-task planning.

2. LITERATURE REVIEW

2.1. Current construction safety pre-task planning

Many construction accidents and injuries occur due not to train in the proper process. A safety pre-task plan of all activities should be provided to measure risk in place. However, current safety pre-task planning requires safety employees to do many manual tasks. For example, the employees must know safety knowledge such as regulation, work sequence, historical accident and injuries data, and checklists. Hence, safety pre-task planning is complicated, time-consuming, and has to update when the schedule adjusts. It is hard to balance work results and safety concerns. On the other side, the information is unstructured, less updated, and complicated. It is challenging to deliver these safety contents with accuracy and efficiency.

2.2. Ontology-based knowledge in construction safety

Ontology can represent information in specific domains in comparison with the database schema and connect to other data sources semantically [5]. Knowledge reasoning and query are efficiently used in the ontology domain based on class, properties, and relationships. It can communicate with semantic web technologies and provide three significant advantages in information modeling [6]: (1) enhance versatility and extensibility of the model; (2) provide robust semantic representation and promote semantic interaction; and (3) promote grammatical inference and retrieval by enhancing concept-level retrieval requests.

The development of ontology in the construction industry aims to improve knowledge management. With explicit definition (concepts, attributes, relations), this technology can facilitate knowledge capture, storage, and query. In construction safety, ontology models usually apply in integrating with BIM. Wang et al.[7] expresses two reasons to adopt the ontology model to hazard analysis concept. (1) The hazard analysis concept has taxonomy similar to the form of class and properties in the ontology. (2) The relationship or non-relationship of each pre-task planning form can be reused.

2.3. Spatial and temporal interactions

In construction, activities have to follow sequences. It guarantees productivity, quality, and safety during the project. To maximize profits, contactors concern about how to improve productivity by optimizing time and space. It means that more activities can be producing. However, crowded job sites, resource constraints, and overlap activities may lead to higher safety risks. To decrease risks, Huang [8] adds safety design considerations into a multiple-stage site layout plan. The model was suggested to consider the influence of crane operations, hazardous materials, and travel routes on safety [9]. Although these proposals could support to minimize risks, very few research contemplates the interactions among tasks [3].

Traditionally, despite the fact that temporal safety management has needed to involve schedule control, these are managed separately [10]. Recently, numerous other studies have put effort to link safety information and work schedule. Chau et al. [11] revealed that linking model between geometrical models with CPM or Bar-Chart, which supports predicting potential hazards. Especially, BIM 4D is a new emergence technology to implement in construction successfully. The integration of the 3D model and schedule brings to improve safety performance. Sulankivi et al. [12] linked falling accidents with a safety guard and railing installation schedule. Sloot et al. [13] demonstrated that 4D BIM could support the process of risk mitigation. However, few studies determine the hazards of simultaneous activities.

3. A FRAMEWORK FOR MUTUAL TASKS RISK REASSESSMENT

The primary purpose of this study is to propose a methodology that can support safety employees defines the potential hazards of mutual task conducting at the same time and place. The overall process is illustrated in Fig. 1. The first step is to collect safety incident cases. The database is usually stored through national data of each country. The pair of tasks incompatibility is extracted manually from the accident context description. Next, with the accident report and risk knowledge category, risk ontology is proposed and generated using the Protégé v5.5.0 tool. The main types include Task, Space, resource, risks. Accident cases are stored as an individual in the ontology. Lastly, it is converted to the RDF file for using the SPARQL tool. The query can show the pair of task incompatibility automatically and support safety employees to determine potential hazards.

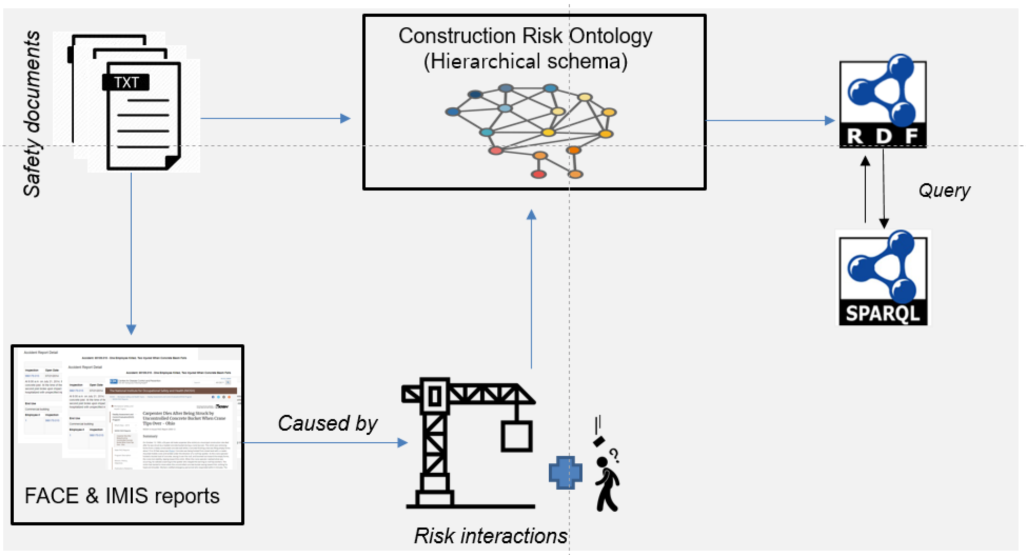

Figure 1. A framework for analyzing task compatibility or incompatibility

3.1. Information processing

To understand the scope and preparation for research, the author chooses two kinds of the database from Fatality Assessment and Control Evaluation (FACE) Program and The Integrated Management Information System (IMIS) from Occupational Safety and Health Administration (OSHA). Both FACE and IMIS databases have been categorized for the construction accident domain. Through the search engine of OSHA and NIOSH, each incident is determined by inspection or report number, and the group of accident cases can be found by keyword search. Fig. 2 shows the result of searching accident cases with detailed information, including description, type of accident, and inspection number.

Accident: 110937.015 - Employee Is Struck By Crane Outrigger That Fell Off Trailer

Accident: 110937.015 -- Report ID: 0626700 -- Event Date: 11/12/2018						
Inspection	**Open Date**	**SIC**	**Establishment Name**			
1359918.015	11/13/2018		Red Hook Conro Terminals Llc			
At 3:45 p.m. on November 12, 2018, Employee #1 was loading a flatbed trailer with crane outriggers. As Employee #1 was attempting to strap down the outrigger, the outrigger rolled off the trailer striking Employee #1. The load was not secured. The employee was struck by the crane outrigger and was killed from head injuries.						
Keywords: struck by, unstable load, crane outrigger, falling object, head, crane, unsecured						
Employee #	**Inspection**	**Age**	**Sex**	**Degree**	**Nature**	**Occupation**
1	1359918.015	69	M	Fatality	Other	Laborers, except construction

Figure 2. OSHA example for searching incident database

3.2. Safety Risk ontology

The safety risk ontology has been built using the Protégé v5.5.0 tool. Context information plays a vital role in construction safety. Based on previous research of Lee et al. [14], the underlying structure of the ontology consists of Task, Space, Resource, and Risk. Following four main classes, there are several sub-classes; for instance, *humane_resource* is a part of *Resource*, *Risk* class has a *degree*, *risk_factor*, *risk_prevention*. Fig. 3 describes the proposal schema of safety risk ontology.

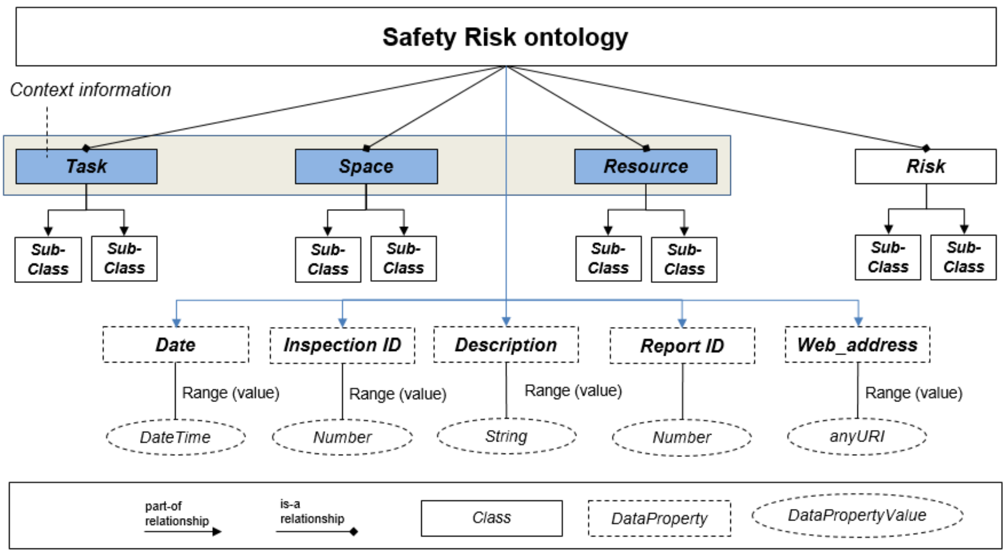

Figure 3. Safety risk ontology for assessing task incompatibility

4. IMPLEMENTATION

To demonstrate the feasibility of the framework, the author conducts to analyze accident reports with inspection number 1324218.015 from the IMIS database [15]. The collection template, as Fig. 4, is generated to categorize information for supporting ontology imported.

Report Title: **Employee Is Killed When Struck In The Head By Steel Beam**		
1	General information	
	- Description	*At 11:30 a.m. on June 20, 2018, Employee #1 was observing the crane's movement and placement of a steel beam. The steel beam disengaged from the crane's haul line and fell, striking the employee on the head. Employee #1 sustained a fractured skull and was killed.*
	- Event Date	*06/20/2018*

- Inspection ID	*1324218.015*
- Report ID	*0213900*
- Source	*https://www.osha.gov/pls/imis/accidentsearch.accident_detail?id=106661.015*
- Keywords	*Struck by, crane, head, falling object, steel beam*
2 Analyzing	
- The pair of tasks incompatibility	
+ Task A	*Deliver material*
+ Task B	*Inspection of the crane's movement*
+ Task C	
- Resource	
+ Equipment	*Crane*
+ Human resource	*Supervisor*
+ Material	*Steel*
- Risk	
+ Degree	*Fatality*
+ Prevention method	
+ Cause	*Struck by falling object/projectile*
- Space	
+ Exposure	×
+ Inside	☐

Figure 4. Accident report collection template

By analyzing the accident report, adequate information is collected. *Delivery material* and *inspection of the crane's movement* are two tasks that occurred in the same time-space. Besides, context information also is filled in the template. Fig. 5 illustrated the accident case imported in protégé.

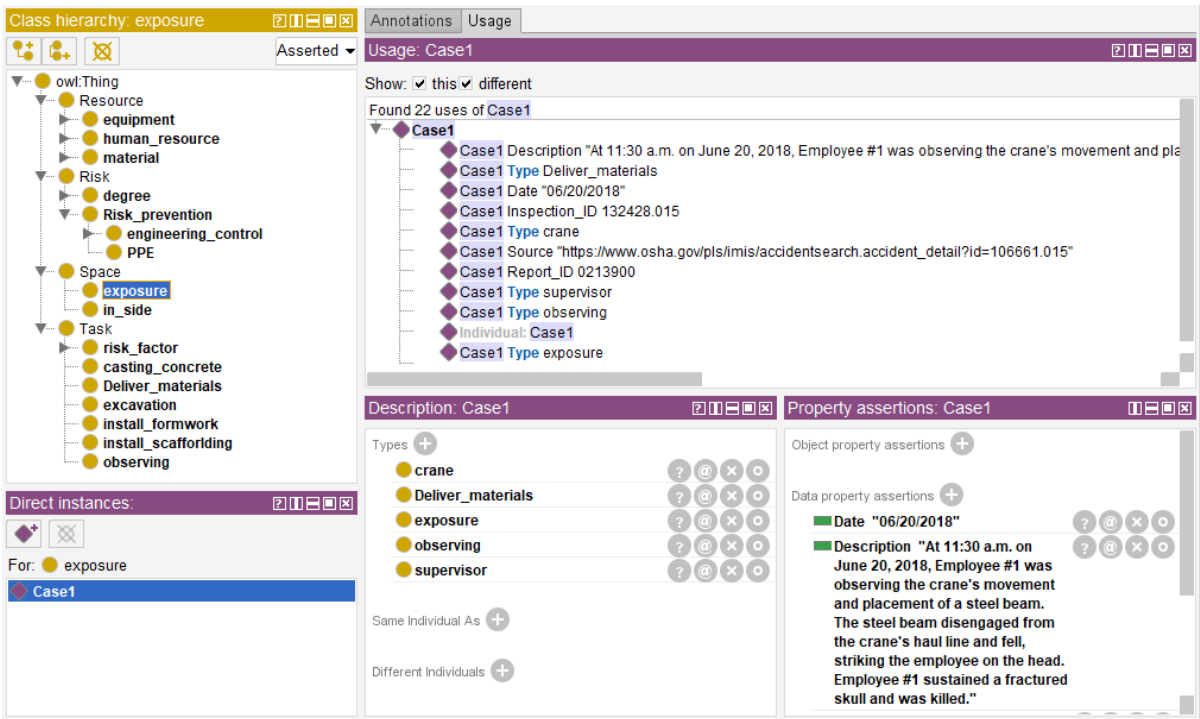

Figure 5. The screenshot of the example in protégé

5. DISCUSSION AND CONCLUSION

Simultaneous tasks are characteristic of construction work that aims to guarantee the project's cost, time, and quality. However, they lead to construction sites as the most complicated and dangerous workplaces resulting in fatal accidents and facing unexpected challenges to satisfy industry requirements. Hazard identification before work can play an essential role in decreasing accident rates. This study commenced by collecting accident reports from the OSHA database. Based on the analyses, the pair of task compatibility can support project employees' understanding and prepare prevention methods when conducting simultaneous tasks.

This paper conducts a preliminary analysis of a scenario that the task is delivering the material. Even though the preliminary studies revealed an accident occurred in the case of simultaneous tasks and a novel approach for building Safety risk ontology was proposed, it is still necessary to comprehensively analyze the full range of construction safety risks. As such, future developments will consider this. Furthermore, spatial and temporal interactions in the pair of task compatibility can be analyzed through innovative technology. Studies have been conducted on this ontology into BIM 4D. One of the ideas is to help the scheduler prevent risk when adjusting the schedule.

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