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A Big-Data-based platform of workers' behavior: Observations from the field

S.Y. Guo*, L.Y. Ding, H.B. Luo, X.Y. Jiang

School of Civil Engineering and Mechanics and Institute of Construction Management, Huazhong University of Science and Technology, Wuhan, China

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ABSTRACT

Behavior-Based Safety (BBS) has been used in construction to observe, analyze and modify workers' behavior. However, studies have identified that BBS has several limitations, which have hindered its effective implementation. To mitigate the negative impact of BBS, this paper uses a case study approach to develop a Big-Data-based platform to classify, collect and store data about workers' unsafe behavior that is derived from a metro construction project. In developing the platform, three processes were undertaken: (1) a behavioral risk knowledge base was established; (2) images reflecting workers' unsafe behavior were collected from intelligent video surveillance and mobile application; and (3) images with semantic information were stored via a Hadoop Distributed File System (HDFS). The platform was implemented during the construction of the metro-system and it is demonstrated that it can effectively analyze semantic information contained in images, automatically extract workers' unsafe behavior and quickly retrieve on HDFS as well. The research presented in this paper can enable construction organizations with the ability to visualize unsafe acts in real-time and further identify patterns of behavior that can jeopardize safety outcomes.

1. Introduction

The frequent occurrence of accidents cannot be ignored in construction; most occur because of workers unsafe behavior (e.g. Heinrich et al., 1950; Lingard and Rowlinson, 2005). To the reduce incidents and improve safety management, it is therefore necessary to focus attention on the unsafe behavior of workers (Choudhry, 2012). Research undertaken by Lingard and Rowlinson (2005), for example, has suggested that unsafe behavior can be controlled by implementing a series of safety measures, and by the workers themselves.

Behavior-Based Safety (BBS) is an approach that can be used to modify the behavior of people so that they undertake work more safely (Geller, 2001). As a result, BBS has been widely adopted by several industries (Chen and Tian, 2012), such as oil and gas (e.g. Ismail et al., 2012), manufacturing (e.g. Yeow and Goomas, 2014; Nielsen et al., 2015), nuclear (e.g. Cox et al., 2004), and construction (e.g. Lingard and Rowlinson, 1998; Li et al., 2015). Yet while it has been effective in some instances (e.g. Krause et al., 1999; Yeow and Goomas, 2014), it still has widely criticized as it has been dependent upon people's observations; it can be a time-consuming and an expensive process (Cameron and Duff, 2007). Moreover, insufficient samples, particular the identification of common unsafe behaviors (Laitinen et al., 1999) and the passive participation of workers have contributed to its demise (DePasquale and Geller, 2000; Han et al., 2011).

With this in mind, this paper proposes and implements a Big-Data-based platform to identify patterns of unsafe behavior so that organizations can implement strategies and techniques to improve the safety of their construction sites. A behavioral risk knowledge base is built to classify and code the observed behavior. Then, intelligent video surveillance and a mobile application are used to collect image data on site. Thus, large and complicated images from behavior observation can be transferred into specific information, which can be recognized by machines, so as to guarantee the data can be finally stored on Hadoop Distributed File System (HDFS).

2. Behavior Based Safety

BBS or Applied Behavior Analysis (ABA) (e.g. Williams and Geller, 2000), is derived from Skinner's behavioral science theory (Skinner, 1953) has been widely applied in construction to improve safety management on-site and better educated subcontractors (e.g. Lingard and Rowlinson, 1998; Chen and Tian, 2012;

* Corresponding author.
E-mail address: gsy.yu@foxmail.com (S.Y. Guo).

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Table 1
Camera function and its application in construction.

Function	Functional explanation	Application in construction
Intrusion detection	Analyzing, positioning and tracking objects entering prohibited area	Workers enter into dangerous lifting area
Stay identification	Tracking over-stayed objects in protected area	Workers stay too long at the edge of the foundation pit
Reverse detection	Monitoring objects moving against the rules	Crane-driving and excavator-driving violators
Traffic analysis	Numbering the amount of people entering into a monitoring area automatically	None
Congestion detection	Identifying the congestion situation in monitoring area	Cross operation in the same area when mounting and dismounting scaffolding and formwork
Line-crossing detection	Detecting objects crossing the warning line	Workers cross dangerous area such as the edge of foundation pit and the sides of the gangway, etc.
Departure identification	Identifying people or objects leaving a given area	No conductor's guardianship in operating radius of working excavator
Appearance identification	Identifying people or objects entering into a given area in the picture (emphasize its sudden appearance but external appearance)	Workers go up and down the foundation pit by establishing channel in private
Disappearance identification	Identifying people or objects disappearing from a given area suddenly	Workers don't replace the firefighting apparatus after using it
Objects-leaving identification	Identifying remnants in given area	Workers place material on steel support
Objects-taking away identification	An object in the picture is taken away	Workers remove their helmets on worksite
Scene-changing identification	The angle of camera is turned, leading to change of scene	None

Note: As auxiliary functions, traffic analysis and identification of scene changes cannot indentify some kind of unsafe behaviors specifically.

Han and Lee, 2013; Choudhry, 2014; Li et al., 2015). Noteworthy, a detailed review of BBS in construction and its limitations can be found in studies such as Zhang and Fang (2013) and Li et al. (2015). Essentially, however, BBS focuses on what workers do, analyzes why they do it, and then applies a research-supported intervention technique to improve behavioral processes (Geller, 2005). BBS intervention adds goal setting and/or feedback to alter response probability (e.g. DePasquale and Geller, 2000; Cameron and Duff, 2007). As workers move toward a goal of safety compliance level, the positive feedback they receive can contribute to improving safety performance. The BBS process contains the following steps (Geller, 2001): (1) unsafe behavior is listed, which requires close attention on site; (2) workers' unsafe behavior is observed and its frequency is recorded; (3) feedback is given and their unsafe behavior is modified. Despite studies highlighting the limitations of BBS, it has also has been proven demonstrated as being an effective approach for improving safety management in construction (e.g. Geller, 2001; McSween, 2003; Turnbeaugh, 2010). For example, Krause et al. (1999) study that compared workers' casualty figures from 73 companies over a five year period, found that workgroups that had been subjected to an intervention through BBS recorded fewer accidents. Yeow and Goomas (2014) proposed an outcome-and-Behavior-Based Safety incentive program (OBBSIP) to reduce accidents in a fluid manufacturing plant, the results demonstrated the number of accident were significantly reduced by 75% using BBS.

A pertinent issue observed by Lingard and Rowlinson (1998), however, is that BBS is over reliant on workers observations and validation of unsafe behaviors. However, in many instances they are unwilling to report their co-workers (Saba and Mohamed, 2008). Thus, a reliable and objective technique that can readily determine unsafe behaviors is required to support BBS.

3. Big Data and behavior observation

Big Data is capable of transforming the way in which organizations can visualize, function, and perform its routines and practices (Mayer-Schönberger and Cukier, 2013). According to International Data Corporation (IDC), Big-Data describes a new generation of technologies and architectures that are designed to economically extract value from very large volumes and a wide variety of data, by enabling high velocity capture, discovery, and/or analysis (Gantz and Reinsel, 2011).

In construction, a large number of workers' behavioral data is generated on site every day, which is rarely, or not all used to examine unsafe acts. According to Heinrich's (1950) for every 300 unsafe acts there are 29 minor injuries and 1 major injury: since this observation there has been limited empirical evidence that has been able to observe and quantify repeated patterns of unsface behavior. If unsafe acts through the observation process can be controlled, then the potential for accidents can be significantly reduced; behavior observation in this instance therefore becomes a valuable tool. With this in mind, Big Data-based technologies can be used to observe, to collect and store image data reflecting workers' unsafe behavior.

The development of image recognition provides support for collecting unstructured data. Camera-based behavior analysis technology, for example, a branch of image recognition research, can assist with the discovery of abnormal behavior and extract their feature images from video sequences. Several studies have examined how video cameras can be used in construction (e.g. Chi and Caldas, 2011). For example, the use of video monitoring system was been found to contribute to the improvement of productivity and safety on construction site (e.g. Aguilar and Hewage, 2013; Teizer et al., 2013). A functional of explanation and the application of cameras in the construction can be seen in Table 1.

Camera technology has been utilized in transportation (e.g. Hu et al., 2014), commerce (e.g. Lablack and Djeraba, 2008) and security (e.g. Ko, 2008). However the application of direct image recognition has its limitations, such as sematic gap between low level image features and high level semantics tends to exist (Zhang et al., 2012). To address limitation, the derived semantic information extracted by people can be labelled so as to quickly understand the expression of images. This is widely used in image retrieval (e.g. Harmandas et al., 1997; Hu et al., 2003), as it can avoid analyzing visual elements of images. Using a Java version of Google File System (GFS) (Ghemawat et al., 2003), Hadoop Distributed File System (HDFS) provides a distributed file system satisfying the demand of huge amounts of data storage. It can potentially provide high resolution images of unsafe behaviors on-site, which can be produced efficiently.