Artificial Intelligence and Blockchain-based Inspection Data Recording System for Portable Firefighting Equipment

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Abstract

Fire poses an enormous threat to human safety; many people get injured or die due to fire accidents each year. As permanent firefighting equipment usually available in a build building, they do not exist in many construction job sites, so they merely depend upon the portable firefighting equipment (PFE) to keep the fire damage limited and minimum. To ensure the proper functionality of the PFE in the case of fire, perfectly located and in-good order are the two vital factors for the PFE. According to standards specified by safety regulations, PFE inspection and maintenance are required to ensure the perfect location and good order of the PFE. Currently, the PFE inspection and maintenance includes the safety auditor from the government and safety manager from the concerned companies. Moreover, the PFE inspection and maintenance process depends on the paper-based manual reporting and recording system, which is time-consuming, cumbersome, and can be easily manipulated. To automate the process of PFE inspection and maintenance, this study will propose optical character recognition (OCR) and Blockchain-based reporting and recording system. A mobile application is developed to validate the proof of concept. One of the artificial intelligence techniques, the optical character recognition (OCR) is adopted in the mobile application, which automatically converts the image tag or report of the PFE inspection and maintenance to the text. The text data is encrypted in a hash using encryption scheme SHA 256 of online service with open API, named as truetimestamp. The generated hash will signify the date inside of the file, which will be immutable and incorruptible. Moreover, the coordinates of the captured image will be extracted from the device to ensure the location of the PFE. It is expected that the proposed system will decrease the paperwork, reduce the burden of the safety manager, with increased efficiency and reliability of the PFE inspection records. The collected inspection record data could also be used to evaluate the safety performance of the concerned contractors.

Keywords –

Artificial Intelligence; Blockchain; Inspection Data Records: Portable Firefighting Equipment

1 Introduction

The construction industry includes many unhealthy activities that are perceived as the causes of workers discouragement, project progress delay, additional cost, low project productivity, damage to reputation, and ultimately human fatalities and injuries [1]. The inherited features of the construction industry itself have potential threats of accidents since its unique nature, open space, working at height, fire risks, exposure to severe weather, confined spaces, unskilled labor involvement, working with toxic and explosive materials, physical and psychologically vulnerable working conditions, and occasionally tight project duration with high productivity demand [2]. Academic researchers and industry professionals have been devoted vital attention to enhance construction safety for many decades. Despite much efforts, construction job sites are still known to be hazardous worksites with high accidents rate, thus, safety in construction remains a vital issue in many countries.

Many people become seriously injured or die due to fire accidents each year [3]. Fire incidents came into existence after its discovery and are intimately proportional to the progress and development of human civilization [4]. World Health Organization (WHO) report for fire-induced burns revealed more than 300,000 deaths annually. Unfortunately, annoying statistics are that 95 percent of these deaths are happening in low-income and middle-income countries [3]. The report from the U.S Bureau of Labor Statistics in 2018 divulge the death of 66 construction workers each year due to fires and explosion [5]. The five years (2010-2014) study by National Fire Protection Association (NFPA) revealed $280 million in direct damage to the property annually in renovation or under construction residential projects (discounting one- and two-units projects) [6].

The quantity of industrial and civil construction projects are swiftly growing due to socio-economic

development policies in many countries [7]. The growing challenges for fire safety with respect to economic progress have significantly supported the evolution of fire science and technology [4]. Initially, fire science and technology's primary intention was to save large factories, properties and evade sweeping fires conflagration [8]. Extensive research has been carried out in the domain of fire safety monitoring and early detection. Many studies have focused on the detection of smoke and heat by using various tools and techniques such as Dual infrared (IR/IR) spectral band flam detection, very early smoke detection apparatus (VESDA), linear infrared flammable gas detection, and fiber optic attached to distributed temperature sensing (DTS) [4,9,10]. Apart from fire safety monitoring and fire detection, several studies have also focused on fire safety and evacuation planning for existing as well as under-construction buildings and tunnels [11–14].

Fire safety management is a significant issue for every business; however, it is notably vital in construction due to several reasons that engender grim fire risks frequently. Firstly, workers are exposed to combustible substances in many construction job sites, and the presence of wind around the unfinished buildings can immediately cause a fire. Secondly, as under-construction sites do not possess permanent and adequate fire protection system, so, PFE or sometimes water tanks are the only preventive measures which they can adopt. With this regard, the Occupational Safety and Health Administration (OSHA) stipulates that a site-specific safety plan should include a fire protection plan for every construction project. Since many construction job sites depend on the PPE as a preventive measure, the vital factors which need to be considered are two: (1) perfect location of PFE, and (2) good working order of PFE [15]. The former is addressed in the previous study using a visual programming approach [16], while the latter is considered in this study. To ensure the maintenance of the fire extinguisher and overcome fraud or modifications in inspection records, this research work proposed an android app that uses optical character recognition (OCR) and blockchain technology for inspection data recording system PFE for maintaining the right order of the equipment.

2 Current Issues in Recording Safety Inspection of PFE

In the past, people typically have to depend on themselves or rely on their nearby vicinity for rescue operations in case of fire [17]. However, based on the necessities, new tools and techniques are developed over time. Many buildings, tunnels, or any other workplaces are currently using fire extinguishers (portable firefighting equipment). To maintain the PFE, frequent interval inspection and maintenance are required. In the past, the essential inspection information about these types of equipment was often dispersed between the stakeholders, which sometimes could lead to data loss [18]. Another significant issue is filling the documents or tags of PFE falsely with the same pen and the same pattern of dates [19]. To sort out the issue, a BIM-based approach has been introduced, which could store the necessary information about these devices such as device name, manufacturer name, maintenance staff, type, equipment warranty, last repair/inspection time, exterior features, and other specifications, as well as the location of fire-fighting equipment, equipment status [15]. However, to take the inspection data recording system to the next level, a much reliable and transparent system is inevitable to make the PFE in order and ultimately use it as a performance evaluation metric in the bidding process.

3 Blockchain and optical character recognition technologies applications

The rapid evolution in the internet of things (IoT), artificial intelligence (AI), and blockchain technologies have witnessed unprecedented contributions to the current world. This has resulted in many automated devices, time-saving, cost reduction, and a paradigm shift from the real world to the digitized world. Blockchain technology offers encrypted, distributed, and secure logging of digital transactions that could revolutionize many areas, mainly where transparency and privacy are essential [20]. As the name indicates, the blockchain can be regarded as a series of blocks (virtual cubes) in a vertical structure, aligned linearly, where each block contains a specific amount of data in the form of ciphers and codes [21]. Once the block's data is completed and validated, the said block is then permanently locked, which cannot be modified. This technology has the potential to address some problems that discourage the construction industry from using new technologies such as BIM, for instance, confidentiality, disintermediation, provenance tracking, non-repudiation, inter-organizational recordkeeping, change tracing, and data ownership [20]. Considering optical character recognition (OCR) with blockchain, previous efforts depict extensive research on recognizing characters through optic vision. OCR intends to convert handwritten or typed texts in the image to encoded texts [22]. Compared to typed or printed texts, recognition of handwritten text is challenging. Generally, an individual's handwriting style varies from others; thus, handling these variations is vital in OCR [23]. The OCR techniques include image acquisition, pre-processing, segmentation, feature extraction, classification, and recognition [22–24]. Previous efforts witnessed of OCR and blockchain technologies in construction safety

inspection and record keeping. Therefore, the innovative and useful approach for the construction safety inspection data recording system pertaining to PFE is presented in this research work.

4 System Development

This study proposed an android app for the inspection data recording system pertaining to PFE. The research was initiated with the analysis of fire-related accidents in the construction industry. Since PFE was determined as a significant measure for the first quick response to the fire emergency in the construction job site, therefore, pivotal attention is inevitable to make sure the good location and good order of PFE. Traditional inspection of PFE and its manual recording process were studied. The roles responsible for the safety inspection data recording and conformance were identified. Optical Character Recognition (OCR) and Blockchain technology were adopted to develop the proposed approach. This android app was developed in android studio using Java and Extensible Markup Language (XML). Streaming API for XML (StaX), which is considered dominant to Simple API for XML (SAX) and Document Object Model (DOM), was used in Java 6.0 for parsing XML documents. Java was used for backend business logic, while XML was used for the front end design. An objected-oriented language, Java, is user-friendly, which is platform-independent to operate; however, it is compiled in bytecode with the support of Dalvik Virtual Machine. To extract the ID of PFE and other relevant information from the tag, this system integrated the open-source google OCR library, named as, Vision API that extracts and detects text from images. The Vision API executes feature detection on an image file through sending the contents as abase64 encoded text. The database was designed in MySQL for storing the user's information and record saving. To make the server and Android App layers separate from each other, REpresentation State Transfer (REST) API was utilized to interact with the reside database and share information between them in JavaScript Object Notation (JSON). REST API was developed in PHP to make communication between the app and the server. An open-source blockchain service TrueTimeStamp (truetimestamp.org), is used as a proof of existence for each transaction. When an image of PFE's tag is submitted, the complex mathematical formula converts the file into a string of numbers and characters. Two different submissions, even with a slight variance, would generate a different hash. The system then uploads that hash, not the image, to the TrueTimeStamp Service, where it is then stored in the database. The transaction can then be verified by going to the TrueTimestamp website and putting the same hash in the verify box. The confirmation of time and date when it was initially being updated can then be seen. Moreover, the network-based location service API from google was also integrated into the app, which determines the location based on Wi-Fi access point or cell tower available in the area.

5 Process description of inspection data recording system for PFE

In this study, an application for reliable and transparent recording of PFE's inspection is developed that runs on the Android device. The entire system can be delineated in Figure 1. The developed application process includes two major stages, such as OCR and blockchain time stamping, as portrayed in Figure 1.

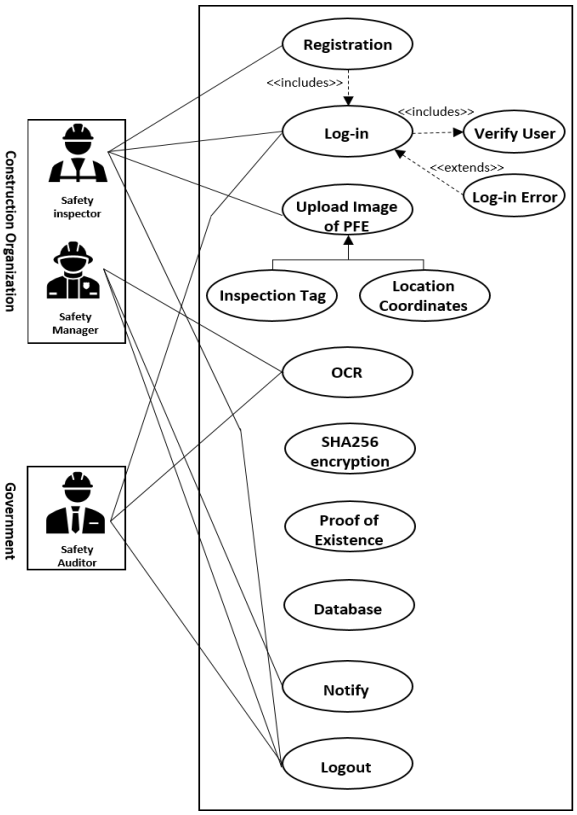

Figure 1. A use case diagram for the developed application

Figure 2 explains the process for users to register and access the functions and database of the application. The associated stakeholders must be registered in the system before they need to use this application. In the OCR process, image taken by built-in camera of the smartphone will go across three phases, including localization (region of test is located), segmentation (extraction of each symbol), and recognition

(reconstruction of words and numbers using contextual information). Next, the system will extract the ID of the focused PFE and will match it with the corresponding input ID for submission to the database. Matching extracted ID and input ID will ensure the exact tag image of the given PFE, which will reduce false reporting. The submission process would be smoothly done if both the IDs are identical, and a hash value would be allocated to the uploaded image using the Secure Hashing Algorithm (SHA-256). This hash value is a digital signature that provides cryptographic proof to avoid any modification or reproduction. As Figure 1 depicts, the uploaded image will be store in the database, and the generated hash value will be recorded on a server using truetimestamp service. All the associated stakeholders, particularly the safety auditor from the government agency can see the stored records and verify any transaction from the server.

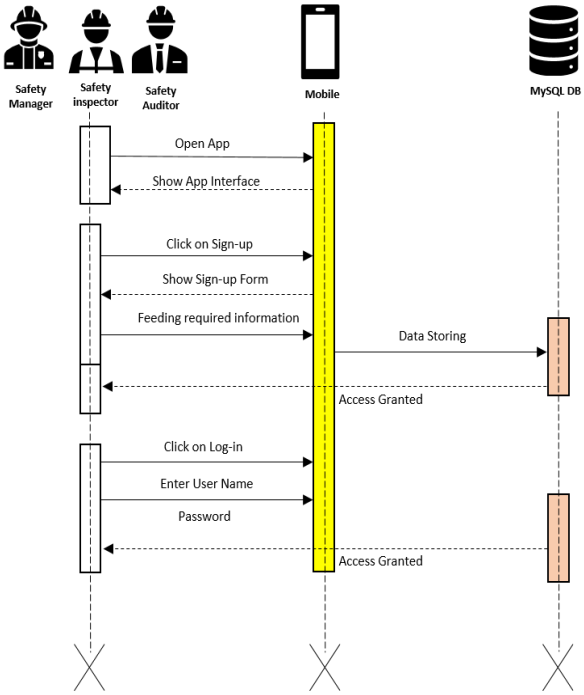

Figure 2. The sequence of users registration

6 Case testing of developed application

This section presents a case study for the Optical Character Recognition and Blockchain-based inspection data recording system pertaining to PFEs. This case study intended to validate the concept; therefore, the second-floor corridor in the Department of architecture engineering building (208) was selected for the experiment (see Figure 3).

Figure 3. Location of a case study for the developed application testing

The app users consist of three major participants, such as a safety auditor from the government agency, a safety manager, and a safety inspector from the given company. Figure 4. explains the registered roles using the sign-up process for the developed app and database. Following the exhibited procedure in Figure 2., three emails have been registered against the corresponding roles (see Figure 4). A new project named "Construction Technology Innovation Lab (ConTIL)" is registered in the project list (see Figure 4-(b).) using the safety inspector account (see Figure 4-(a).). Tags after inspections were assigned to each PFEs, and images of those tags were captured and uploaded to the database with the ID of each PFE, as shown in Figure 4-(b). The embedded OCR technology in the app extracts the ID from the image and matches it with the manually entered ID. Next, the blockchain-based proof of existence service allocates a unique hash value (a digital signature) to each record and will store that on the server using the procedure discussed in the previous section. In our case, several images have been uploaded to the server, however, one of the tag's image is exemplified in Figure 4-(b) and the hash value generated for this specific inspection can be seen in Figure-(c-2)., which is "b5f4687aff73ba6418d15ecb2f2eb3bc3a3ea90d358a0b 036d67f9e9105764b6". As depicted in Figure 5-c, the safety auditor from the government agency or safety officer from the company can remotely check and verify

the inspection done by a safety inspector through logging-in to their concerned accounts. The respective transaction of each PFE's inspection associated with the enlisted projects can be verified by clicking on the "VERIFY TIMESTAMP" button in their corresponding interval is inevitable to ensure the good order and location of PFE. Currently, the PFE inspection process depends on the paper-based manual reporting and recording system. So, during the government agency's scheduled visits of safety auditors, the manual and paper-

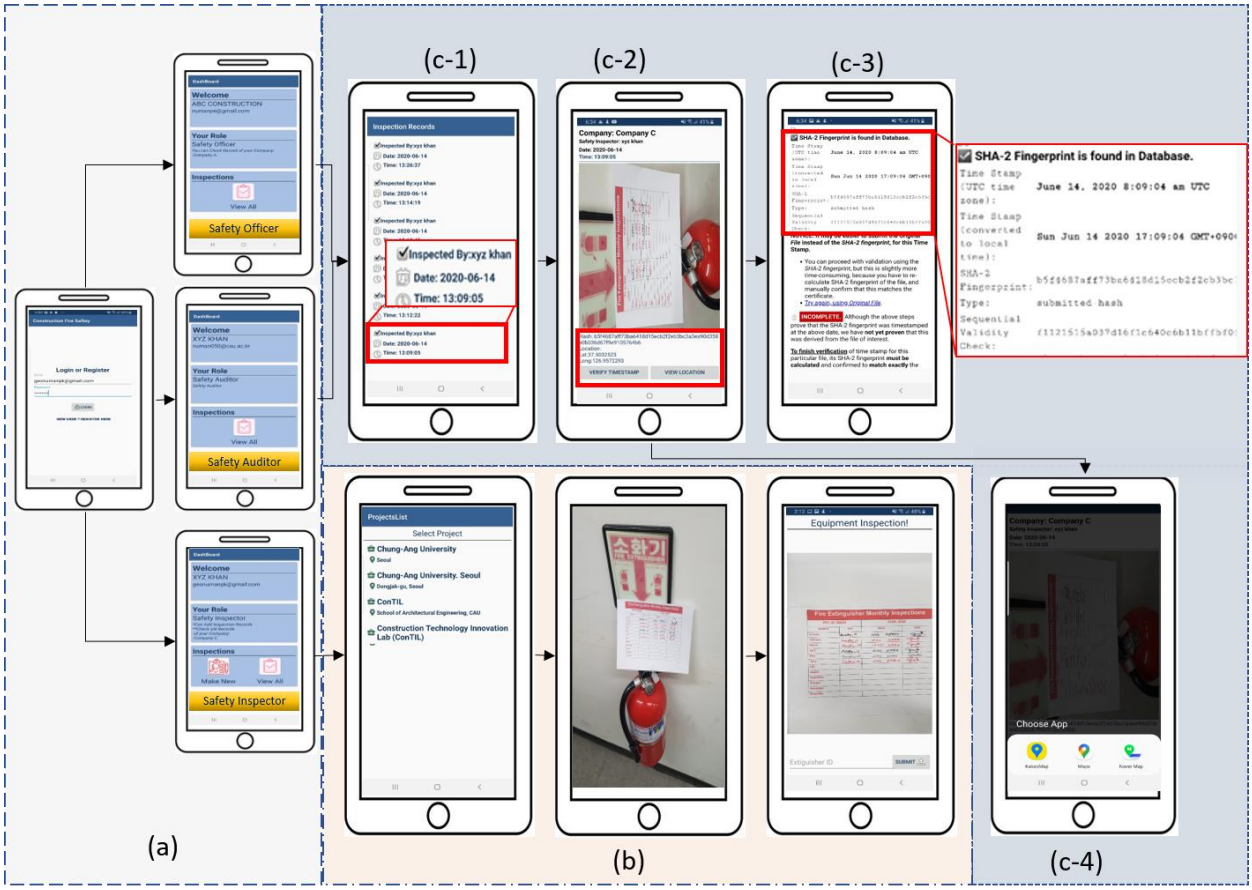

Figure 4. Screen shots of the andriod application depicting data flow and functions

dashboards. For instance, in our case, the inspection done by xyz khan on dated 2020-06-14 at 13:09:05 is verified, and the results regarding the record are visualized in Figure 4-(c-3)., which shows that SHA-2 Fingerprint is found in the database", with the same hash, date and time. In addition to verifying the transaction, the location can also be traced using different maps such as kakao, Naver, or google.

7 Conclusion

In construction, numerous workers get injured or died due to fire accidents each year. To keep the fire damage limited and minimum, many construction sites solely depend on PFE due to the absence of permanent firefighting equipment during the construction stage. Therefore, appropriate inspection with an identified based records can be easily manipulated. To address this issue, this study has developed an android mobile app that utilizes OCR and Blockchain technology for reporting and recording data. The OCR intends to automatically detect the ID from the captured tag image and the blockchain assigns a digital signature to the image.

A simple case study within the campus has been carried out to validate the concept that confirms the functionality of the developed app. It is anticipated that this app will enhance transparency, minimize the usage of paper, decrease the burden of the concerned stakeholders, and reduce the physical visits of safety auditor and safety manger, which is significantly required in the current situation of COVID-19 pandemic.

In the future, a comprehensive system will be designed to collect PFE inspection records and other

inspections or reported unsafe behavior data for the safety performance evaluation of the concerned contractors in the bidding process.

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