ICCEPM 2022
The 9th International Conference on Construction Engineering and Project Management
Jun. 20-23, 2022, Las Vegas, NV, USA

Building a Big Data Platform Using Real-time Wearable Devices and Cases of Safety Accidents in KOREA

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1. Abstract

Safety accidents are of concern during construction projects, even given the recent innovations in digital technologies. These projects remain focused on overcoming specific and limited applications on construction sites. For this reason, the development of an inclusive safety management system has become crucial. This study aims to build a Big Data platform to inform decisions on how to proactively eliminate worker hazards on construction sites. The platform consists of about 100,000 real records and a real-time monitored database featuring various safety indices, such as workers' altitudes, heart rates, and fatigability during construction, which are determined through various wearable devices. The data types are customized and integrated by a research team in accordance with the characteristics of a specific project using hypertext transfer protocol (HTTP). The results can be helpful as efficient tools to ensure successful safety management in complex construction situations. This study is expected to provide three significant contributions to the field, including real-time fatigability analysis and tracking of workers on-site; providing early GPS-based warnings to workers who might be accessing dangerous spaces or places; and monitoring the workers' health indices, based on details from 100,000 cases.

Keywords: Big data platform; Hypertext transfer protocol; Knowledgeable cases; Wearable device-based safety indices

1. INTRODUCTION

With the recent acceleration of the aging of the population, construction workers in Korea are increasing in age[1]. For this reason, ensuring systemic safety management for aged workers at construction sites has become a key factor that needs to be considered for successful safety management. In relation to this, the Act on the Punishment of Serious Accidents will come into effect on January 27, 2022. The Act states that in the event of an accident in a workplace with 50 or more employees that is fatal or requires two or more people to receive treatment for 6 months or longer, the business owner, business managers, and safety and health managers will be penalized. For this reason, the importance of safety management is expected to grow [2].

Examining the state of industrial accidents in 2020, it was reported that 28,840 people were injured in the manufacturing industry, while 26,799 people were injured in the construction industry. In the manufacturing industry, 469 workers died from serious accidents; in the construction industry, the number was 567[3]. To prevent fatal accidents, the Korean government launched a campaign to promote a “safe society without industrial disasters” in 2017 to intensify the management and supervision of safety measures across three major risk factors in the construction industry: falls, jams, and failure to wear personal protective equipment (PPE). It also imposed a fine for negligence on workers who failed to wear PPE or follow safety rules, while implementing strong measures to expel the person in question from the construction site if a safety incident occurs more than two times.

Furthermore, construction workers in Korea have gotten older. According to the current industry results published by Statistics Korea, workers over the age of 55 years accounted for 14% of all workers in 2007, 20% in 2012, and 30% in 2017 [3]. When examining the statistics on industrial accidents, as of 2020, 77.2% of workers (354 of 458 people) who died in construction accidents were elderly workers over the age of 50 years. It is almost impossible for a management supervisor to fully understand the conditions of the entire construction site and all workers in real time.

For this reason, this study aims to build a real-time safety management monitoring system that monitors the physical information (such as heart rate and location change) of vulnerable elderly workers over the age of 50 years at construction sites. The system promptly notifies the supervisor of any critical changes, so that they can provide proper safety management, if necessary. In 2020, of the 567 people who died from serious incidents at construction sites, 77%, or 354 people, were elderly workers over the age of 55 years. It is thought that elderly workers’ declining vision, hearing, muscle strength, endurance, and agility may contribute to the occurrence of industrial accidents. Therefore, if the physical characteristics of elderly workers are understood based on actual physical information, it is expected that possible accidents and injuries can be prevented, or at least injury can be minimized through a notification alarm.

2. LITERATURE REVIEW

To develop a real-time monitoring system that reduces fatal disasters at construction sites, we analyzed the current statistics on disasters and intelligent safety management for disaster prevention, and also sought to understand the limitations of the existing system.

2.1 Current state of fatal disasters

Table 1 provides fatal disaster statistics from the construction industry over the past 10 years. The number of accidental deaths decreased to 458 people in 2020, down from 499 people in 2011. However, the death rate has increased by 2.00% in 2020 from 1.62% in 2011, indicating a slight increase in or maintenance of the death rate.

Table 2. Fatal disaster statistics in the construction industry from 2011 to 2020[5]

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Accident Deaths	499	461	516	434	437	499	506	485	428	458

Death Rate	1.62	1.65	2.01	1.34	1.30	1.58	1.66	1.65	1.72	2.00

Table 2 provides the fatal disaster statistics from the construction industry based on age over the past 9 years. The number of fatalities among elderly workers over the age of 50 years has remained consistent or slightly increased. However, the number of fatalities among elderly workers over the age of 50 years was 2.3 times higher than that of workers under the age of 50 years [4]. These results highlight the importance of safety management for elderly workers over the age of 50.

Table 2. Fatal disaster statistics by age in the construction industry from 2011 to 2020[5]

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019
Over the age of 50	396	310	395	342	330	407	432	431	383
Under the age of 50	225	186	172	144	163	147	147	139	134

2.2 Elderly workers' physical characteristics and main tasks

According to a study that studied the body of elderly workers, since the physical functional characteristics of workers change with age, conduction, fall, and occupational diseases are important factors in industrial accidents instead of common types of disasters such as stenosis and hyperactivity[6]. In addition, elderly workers over 55 years of age say that a sharp decline in equilibrium function and a decrease in attention inevitably appear[7].

Looking at the main tasks of elderly workers, there are simple tasks such as shoveling, moving construction materials, assistance in assembly of construction sites and machinery, and simple cutting, and few differences can be found from those in their 20s and 40s. Since a simple accident of an elderly worker with reduced physical ability can lead to a death accident, it is necessary to monitor physical information and take action with a minimum time [8].

2.3 Smart safety management

Among the OECD member countries, the death rates resulting from industrial disasters remain very high in Korea. Therefore, the Korean government mandated the introduction of Smart safety equipment to a public construction project in April 2019. It also prepared a legal framework that ordered the organization to pay for the costs of the Smart safety equipment, even for private construction projects. Reasearch on the development of a wearable technology platform for personal safety management at construction sites[10], construction site safety and health management using wearable technology[11], and construction worker safety management system through wearing wearable devices are being actively conducted[12]. Therefore, this study aims to establish a safety management system that can efficiently monitor risk factors for vulnerable elderly workers.

3. SYSTEM PROCESS

In this chapter, we will study an optimized, real-time, Big Data monitoring system of heart rate and position data using a wearable device that can retrieve a worker's biometric information.

3.1. Heart rate variability

Two heart rate parameters can be examined in workers. First, by inputting the height, age, and weight of a worker, the maximal heart rate (MHR), resting heart rate (RHR), and heart rate reserve (HRR) can be analyzed. Based on the analyzed heart rate information, one can anticipate whether the work intensity can lead to an accident. Second, if instantaneous changes in heart rate (1–2 seconds) are found to be vertical and irregular, a possible accident can also be predicted.

3.2. Changes in position

Three parameters can be determined with changes in position using horizontal (X, Y) and height (Z) information. First, dangerous areas can be registered, including openings, scaffolding, and the presence of a hazardous material reserve, so that if someone who does not have access to the area goes into that area, it can be interpreted as a risk. Second, the maximum, minimum, and average moving speed of a worker are calculated. If the worker moves faster than the hoist, the results can be interpreted as a fall. Third, if a worker does not move at all, it may be interpreted as an emergency.

3.3. Big data platform

The process of implementing the Big Data platform for real-time monitoring is shown in Figure 1. First, we collected information on the age, height, weight, and occupation of workers. Second, based on the collected data, we collected changes in the workers' heart rates and positions. Third, based on the Big Data platform, we combined workers' physical and biometric information with the associated risk information from a construction site.

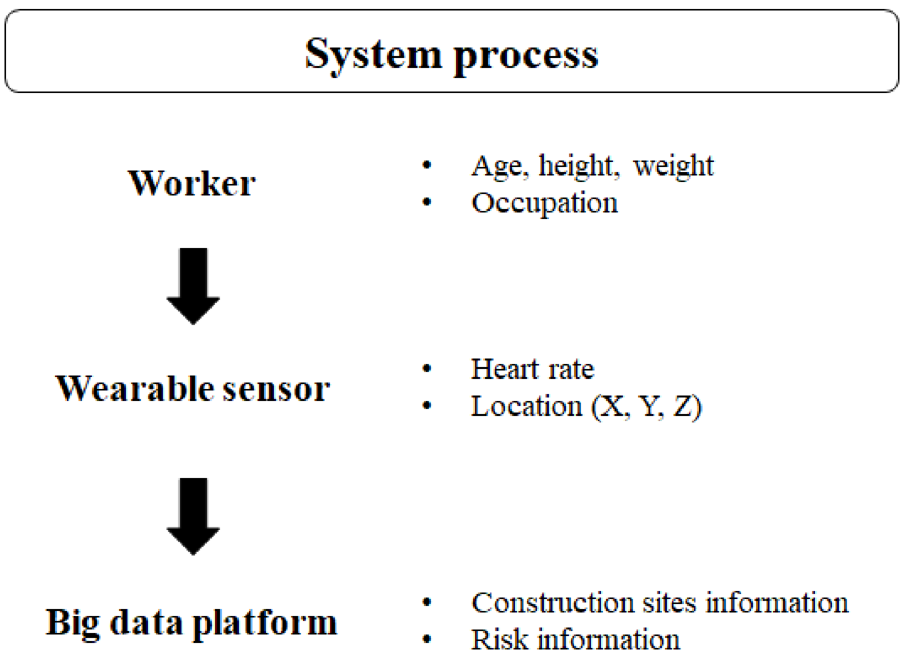

Figure 1. Big Data Platform Process

4. SYSTEM DEVELOPMENT

In this chapter, we intend to design a wearable app and web-based big data platform capable of monitoring system in real time.

4.1. Setting of personal information

Figure 2 shows the workers' personal information settings. In the wearable device, workers can select their age, height, weight, and occupation. The wearable device App is designed to transmit the information selected by the operator to the relay server.

Figure 2. Wearable App

In addition, the designed App tracks the worker's GPs, Altitude, and heart rate and delivers tracked status data to the relay server using the HTTP protocol.

4.2. Big data platform

In this step, we designed a web-based real-time monitoring system that allows managers to monitor data generated from wearable devices for the development of big data platforms.

The web-based real-time monitoring system was designed as shown in Figure 3. The top end of Figure 3 provides the location of the construction site, and the next middle is the worker's name, sex, age, weight, job group, heart rate, number of steps, distance traveled, location, status, and real-time worker monitoring. It also includes the ability to store the worker's data. The next lowest The month statistics provides information for a month by graphing the number of workers who are found to be at risk on a daily basis.

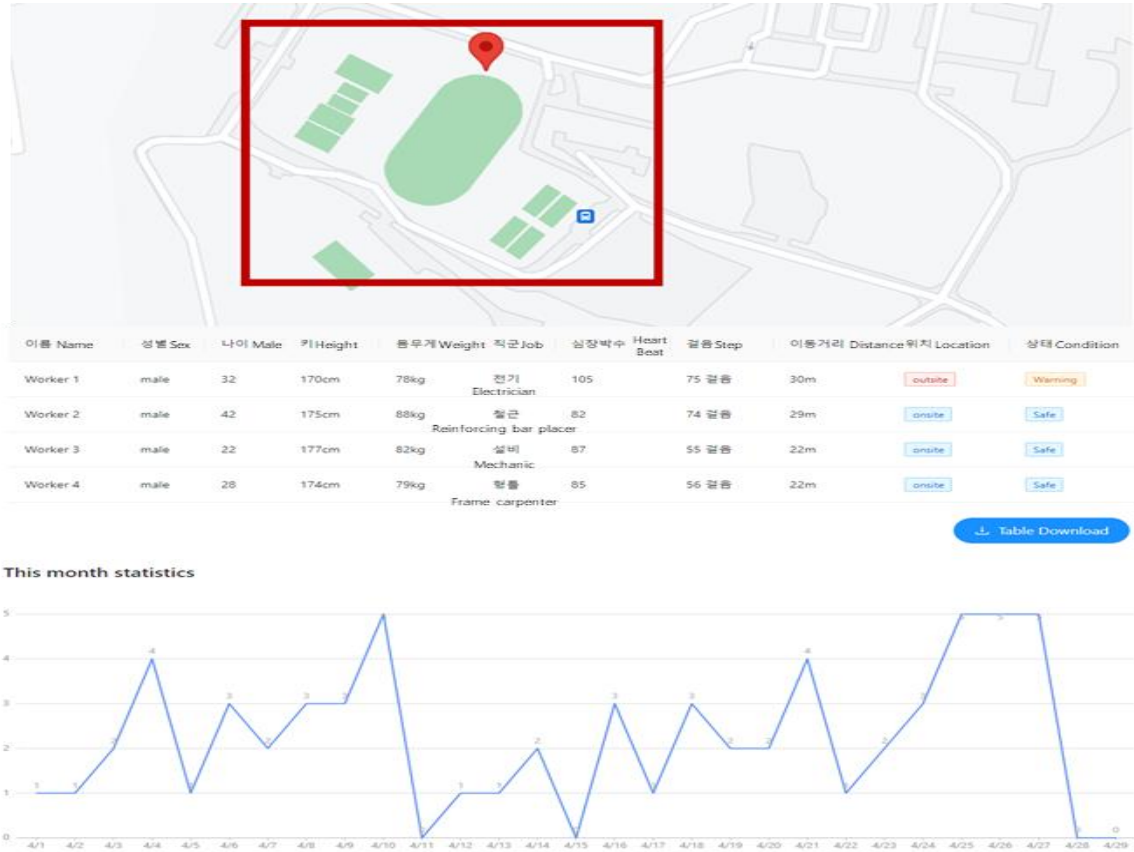

Figure 3. Monitoring System

5. CONCLUSION AND FUTURE RESEARCH

To prevent safety accidents at construction sites, we developed a Big Data platform that can be linked to wearable devices. The main results are as follows.

First, when a worker is approaching a dangerous area, the monitoring system sends an alarm to the safety manager and the worker. Risk factors related to safety accidents at construction sites, such as dangerous areas based on work or construction site were identified through questionnaires and expert interviews. Dangerous areas based on work were characterized by the removal of mold, the pouring of concrete, and the installation and removal of scaffolding. Dangerous areas based on the construction site included openings, scaffolding, and so on, from which a person or a thing can fall. Second, an alarm will sound if there are drastic changes in heart rate or position. This was developed, so that an alarm would be sent if the system determines that someone is in danger, as based on the real-time monitoring of the workers' positions.

The system developed in this study is expected to prevent accidents and respond quickly if an accident occurs. Furthermore, data collected by the system will provide basic data to predict future disasters at construction sites.

There are limitations to the capacity to prevent all construction disasters using a Big Data platform-based, real-time monitoring system. Thus, more detailed studies should be conducted in the future to enhance the accuracy of the monitoring system, such as those that use building information modeling (BIM), a detailed analysis technique, to determine the accuracy of workers' heart rates and positions, as determined through the use of wearable devices.

ACKNOWLEGEMENTS

This study is basic research conducted in 2021 with the support of the National Research Foundation with the funding of the government (Ministry of Education) (2021R1A2C2013841).

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