Development of a Dynamic Information System for Safety Management of Construction Workers Based on IoT and BIM Tools

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Abstract: In this paper, according to the current situation of safety management of construction workers, BIM and the Internet of Things are jointly applied to the safety management of construction workers, and a safety management system for construction workers is constructed. Solutions are put forward for accident-prone areas, construction personnel’s physical condition, construction personnel's operation and safety training, hoping to fundamentally and effectively reduce construction personnel safety accidents.

1. Introduction

With the continuous development of the construction industry, the safety management of construction workers on the construction site occupies an increasingly important position. Good safety management can not only promote the realization of project management objectives, but also benefit the longer-term development of enterprises. However, due to the characteristics of the construction industry, such as more open-air and high-altitude operations, large population base of construction workers and uneven educational level of workers, the construction industry has become hazardous industry, and security incident occurred frequently. Therefore, the research of management methods based on new technologies is extremely urgent.

This article effectively combines the 3D simulation technology and model information of BIM technology with the data information collected on-site of the Internet of Things technology, and integrated analysis is carried out in the platform. The combination of Internet of Things technology and BIM technology can carry out real-time and all-round monitoring and feedback management for every construction worker on the construction site, which can not only more effectively guarantee the life safety of on-site construction personnel, but also ensure the safety of their property.

2. Construction of safety management system for construction personnel

The safety management system for construction personnel based on BIM and Internet of Things technology aims at to solve the current deficiencies in the safety management of construction personnel. Four subsystems of the safety management system are proposed to reduce the safety accidents of construction personnel, which are positioning supervision subsystem, vital signs monitoring subsystem, behavior recognition subsystem and safety training subsystem, as shown in Figure 1.

The positioning supervision subsystem can locate the location of the construction personnel in real-time, give early warning when the construction personnel enter the dangerous area, and quickly locate...
when the construction personnel are in danger, so as to facilitate the rescue work[1]; The vital signs monitoring subsystem can monitor the physical condition of the construction personnel in real-time and reduce the potential safety hazard caused by the personal physical condition of the construction personnel; The behavior recognition subsystem can monitor the operation behavior of construction personnel in real time to reduce the potential safety hazards caused by personal operation errors of construction personnel; The safety training subsystem makes up for the deficiency of the current safety training and improves the effect of safety training.

3. Operation process of safety management system for construction personnel

As shown in Figure 2, the system started by establishing a BIM model in the design stage and performing construction simulations based on the construction plan. At the same time, the BIM construction simulation animation was used to conduct safety training for the construction staff before the construction began. During the construction process, the BIM model will be synchronized with the actual construction situation. Construction personnel who have received safety training will wear safety bracelets and safety protection equipment before entering the construction site[2], if any of them are not worn, they will be prohibited from entering the construction site. The positioning supervision subsystem, vital signs monitoring subsystem and human behavior recognition subsystem will be started simultaneously after the construction personnel with complete clothing enter the construction site, and the frid tags and sensors in the safety bracelet will start to operate.

In the positioning supervision subsystem, when the construction personnel enter the dangerous area, the dangerous area where the construction personnel are located will match with their safety authority, if the construction personnel have no authority, the early warning device will be started.

In the vital signs monitoring subsystem and human behavior recognition subsystem, the safety bracelet will carry out real-time monitoring, and the alarm device will be started when the vital signs of the construction personnel are abnormal or the operation is wrong. When the alarm rings, the construction personnel should stop the dangerous action, and the safety management personnel will deal with it according to the actual situation. If the construction personnel do not leave in time or do not obey the command of the management personnel, when the cumulative number of times exceeds the specified number, they will lose the authority to enter the construction site, and must receive the safety training again. All the project data will be stored, which can be used as the database of similar projects to gradually realize data-driven.
4. Introduction of the subsystem of safety management system for construction personnel

4.1 Positioning supervision subsystem

4.1.1 BIM module.
In the design stage, through BIM construction process simulation and collision detection, the rationality of the design plan and the construction plan is checked, and the possible safety accidents are estimated, repeated simulations are carried out for the parts where the accident may occur, and the plan is changed in time to make it reasonable. The dangerous accidents are defined and classified in the parts with potential safety hazards, and the FRID label is defined and set for different categories of potential safety hazards. According to the main types of safety accidents on the construction site, the dangerous area is defined in the BIM model, and the special color marking of the dangerous area...
attracts the attention of safety managers and construction personnel. In the construction process, BIM model is updated timely according to the actual progress of the site, so that the BIM model can be synchronized with the actual construction results, to accurately carry out risk warning. At the same time, the data from the positioning module is processed and displayed in the BIM model[3], so that the safety management personnel can supervise and manage and make decisions quickly according to the actual situation.

4.1.2 Positioning module.
Considering the anti-interference ability, location range, data transmission speed accuracy and other factors, RFID technology is selected as information acquisition technology, ZigBee as data transmission technology. RFID includes RFID tags and readers. RFID tags are placed on construction personnel's safety bracelets, safety protection equipment, construction machinery, components and other objects, and relevant information is entered on each tag. Place smart access control equipment at the entrance of each construction area, place readers continuously in dangerous areas, and place readers scattered throughout the construction area. Positioning module includes the positioning of construction personnel and the positioning of construction machinery respectively. When the construction personnel enter the construction area, the scattered readers start to use the continuous information collected by the radio frequency tags for positioning and tracking, and the location of the construction personnel will also be dynamically displayed through the BIM model[4]; The location of mobile machinery can be obtained by mechanical positioning, and the corresponding dangerous range of the construction machinery can be calculated. A reader will be placed on the portable equipment, and the alarm will sound when the construction personnel enter the dangerous area.

4.1.3 Early warning module.
When the constructors appear at the edge of the dangerous area or the unauthorized area, the reader will identify and transmit the constructors' information to the early warning module. At the same time, the early warning module will start to send an alarm signal to the safety bracelet worn by the construction personnel[5], and the safety bracelet will start to flash and vibrate. At the same time, the BIM model will display the corresponding alarm. When the construction personnel leave the dangerous area automatically, the alarm will stop. If they do not leave the early warning module, the early warning will send out a stronger alarm and inform the safety management personnel, who will quickly go to the scene to check the situation. Violation statistics means that when the construction personnel still do not leave the dangerous area after being reminded by the alarm, the statistics will be made once. After reaching upper limit, the work of the personnel will be stopped, and they can return to their posts after receiving safety training again.

4.2 Safety training subsystem.
The safety training subsystem uses the 3D model established in the design phase of the BIM module in the positioning supervision subsystem. Its animation roaming, simulating construction process and other functions can provide safety training and safety technical clarifications to the construction personnel. The three-dimensional model and animation can allow construction personnel to quickly learn safe construction operations, so that some construction personnel with low academic qualifications and poor learning ability can also better master it. BIM and VR technology can also be used to simulate the occurrence of safety accidents, so that the construction workers can feel falling, being hit and shaking more intuitively, and make them more aware of the serious consequences of the accident, thus achieving more standardized operation and stricter prevention.

4.3 Vital Sign Monitoring Subsystem.
The construction personnel vital signs monitoring subsystem is based on the characteristics of the construction site, using sensor equipment (safety bracelet) to monitor the construction personnel's body temperature, heart rate and respiratory rate in real-time to ensure that each construction worker
always performs operations under normal physical conditions. It can improve work efficiency while ensuring the safety of construction personnel.

4.4 Behavior Recognition Subsystem.

The behavior recognition subsystem uses video surveillance and wearable sensor (safety bracelet) equipment to monitor the behavior of construction workers in real-time and predict the activities of construction workers. The data collected by video and sensor are sent back to the background, and compared with the behavior model, to identify different behavior[6]. When the constructors enter the construction site, the video monitoring and sensors in the safety bracelet start to work, automatically collect data, and the human body behavior identity is connected with the positioning and early warning subsystem. When the operator's operation error is detected or predicted, the positioning early warning subsystem can be triggered, which can effectively reduce or avoid the potential safety hazard caused by the operator's operation problems. At the same time, the operation errors of the construction personnel will be recorded. After a certain number of times, they need to receive safety training again before returning to the construction site to operate.

5. Conclusion

The safety management system proposed in this article integrates the advanced technical advantages of BIM and the Internet of Things. This system broke the present situation of the traditional safety management of manual monitoring, manual recording, slow information transmission, management based on experience, and poor communication. With the advantages of automatic data collection, automatic information update and throughout the whole life cycle, safety management has realized informationization, automation, paperless and visualization. Therefore, the system has certain practical application value.

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