Hazard Avoidance System using Augmented Reality in Wearable Device

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Abstract:

Efforts have been made to improve safety conditions of construction sites. Safety training, personal protective equipment, and safety regulations have been utilized to reduce construction accidents. However, poor working environment and imperfect safety management practices still persist due to innate nature of construction industry. This paper proposes a hazard avoidance system that informs workers of dangers so that they could take proper defense/avoidance action. The proposed system displays hazard information on the site using a wearable device. The system is composed of three modules: vision-based site monitoring module, safety assessment module, and hazard information processing and visualization module. In the first module, image capturing devices such as closed circuit television (CCTV) are used to recognize construction site hazard factors. The safety assessment module use the captured image data to evaluate a safety level of each worker; fuzzy-based reasoning can be used for the safety assessment. Finally, the visualization module present actionable safety guidance regarding hazard category, location, and orientation; safe route can be provided to the worker in danger by augmented reality in a wearable device. The proposed system is expected to provide safer site conditions for workers by allowing them to avoid hazard.

Keywords: Safety management, Wearable device, Visualization, Augmented reality.

1. INTRODUCTION

Safety management practices, such as safety education and PPE (personal protective equipment), are conducted for safer working environment. However, such practices are not able to fully protect workers from accidents in construction sites mainly due to the dynamic nature of construction environment. Workers' awareness of dangerous situations is difficult to achieve in complex and noisy jobsite conditions. Struck-by accidents can easily happen, which can lead to serious injuries.

This paper suggests a system that allows workers and managers to take a proper defense/avoid action by using safety information of the particular construction site. The safety information is derived from an image-based safety assessment system. The information is displayed using augmented reality in a wearable device so that the worker can instinctively recognize and react to the dangerous situation. The proposed system is composed of three modules: vision-based site monitoring module, safety assessment module, hazard information visualization module. In the vision-based site monitoring module, image data and the sensor data from the wearable device are collected to extract hazard information. In the safety assessment module, safety condition of each entity is assessed using a fuzzy inference logic. Finally, the hazard information is visualized using the safety condition and spatial information of the worker. The user interface of the wearable device is constructed to present the hazard information in the form of augmented reality so that real-time safety information can be effectively delivered to the worker. The proposed system is expected to improve hazard awareness of workers and managers.

2. LITERATURE REVIEW

2.1 Safety Management

Previous studies where technologies were used for improved safety were investigated. Safety condition of construction site of earthmoving and surface mining can be assessed by image-based safety rule violation algorithm (Chi and Caldas 2012). Heavy equipment workspace can be identified and utilized, considering pose, state, speed, geometry of equipment so that collision from equipment can be monitored (Vahdatikhaki and Hammad 2015). Park and Kim (2013) used Building Information Modeling (BIM) and mobile augmented reality to display jobsite hazard factors. Workers' recognition of hazard could be enhanced using a virtual 3D construction site simulation (Albert et al. 2014).

2.2 Augmented Reality

Augmented reality is mixed reality of real world with virtual components so that user's awareness can be enhanced (Behzadan et al. 2015). Augmented reality can be used for site context monitoring such as progress, equipment operation, safety, guidance for proper action, and facility inspection. Progress could be monitored using 4-dimensional augmented reality (Golparvar-Fard et al. 2009). Real-time location system was used for augmented reality application; based on users' location, accurate operation information and emergency information could be delivered to users as augmented reality (Behzadan et al. 2008). Interactive equipment operation analysis was conducted using a table-top augmented reality; using BIM models, equipment operation can be analyzed with spatial constraint like collision and workspace (Kim et al. 2012). Invisible facilities like underground pipeline could be protected from excavator operation using hybrid reality (Talmaki and Kamat 2012). As shown in the previous research, augmented reality can be effectively used to enhance user's recognition of construction information.

3. METHODOLOGY

A framework of proposed system is as shown in Figure 1. Hazard avoidance system is comprised of three modules: vision-based site monitoring module, safety assessment module, and hazard information processing and visualization module. In the system, google glass is used as wearable device. Google glass is a wearable computing device similar to glasses we wear. GPS data, gyroscope sensor data, and accelerometer data can be obtained from the google glass using embedded sensors.

3.1 Vision-based Site Monitoring Module

In the vision-based site monitoring module, large-scale images of construction site are acquired using image capturing device like CCTV (Closed-Circuit TeleVision) and UAV (unmanned aerial vehicle). Those images are used as raw data for the safety assessment module. Google glass on the worker is also used to capture user-view images and acquire GPS and gyroscope sensing data. GPS and gyroscope data are used to calculate location and orientation of the worker.

Basic information for safety assessment are derived from jobsite images. Distance between each entity and crowdedness of each entity are calculated using an object tracking algorithm. Location and orientation of the worker are calculated using the google glass sensor data. Those data are used to assessment the safety condition in the next module.

3.2 Safety Assessment Module

Safety condition of the worker is assessed using the vision-based fuzzy reasoning method (Kim et al. 2015). The vision-based fuzzy reasoning method assesses safety condition of each entity in images as numerical index using a fuzzy inference logic (Figure 2). Safety condition of workers can be derived without observation of a manager. The assessment method decides safety condition using predefined if-then rules and input parameters (proximity and crowdedness) extracted from images automatically.

3.3 Hazard Information Processing and Visualization module

In order to prevent workers from struck-by accident in construction site, spatial relationship has to be delivered to workers. Spatial relationship means the orientation and distance of approaching equipment or vehicles based on location and orientation of the worker with the wearable device. The worker in danger can be aware of hazard with the assessed safety condition and the spatial relationship. Once the worker recognizes dangerous approach of equipment, an immediate reaction of the worker can be performed so that fatal accidents can be avoided.

Safety information including safety condition and spatial relationship is visualized in wearable device, i.e. google glass as shown in Figure 3. It is presented as three dimensional arrow form. Orientation of the arrow means the approaching orientation of equipment. Color of arrow means the assessed safety condition of the most dangerous equipment. Safety condition is matched with red-green color map as shown in figure 4. The most dangerous condition is presented as red color, whereas the safest condition is presented as greed color. The worker can instinctively recognize and immediately react to the hazardous situation by glancing the wearable device display showing the safety information.

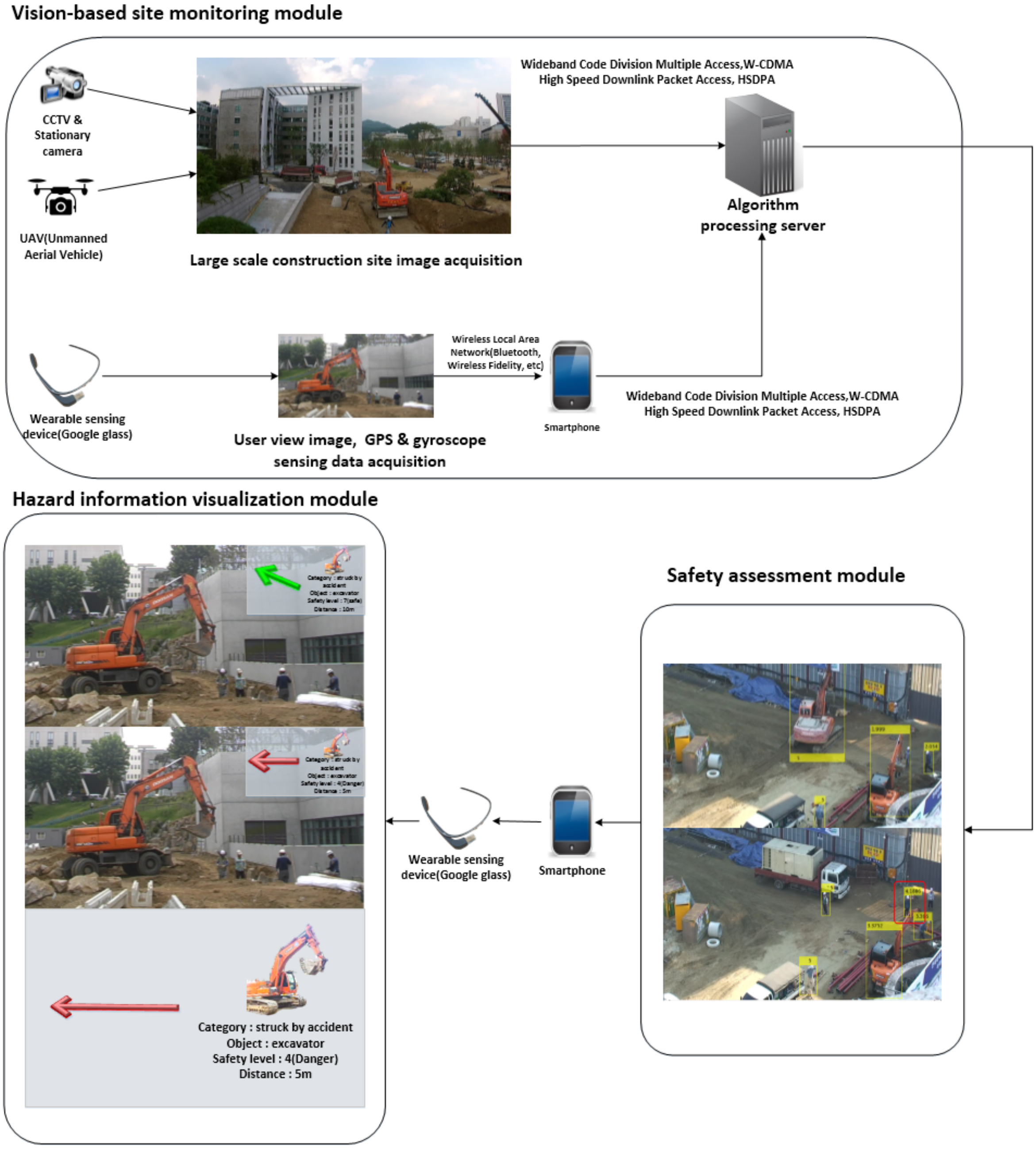

Figure 1. Hazard avoidance system framework.

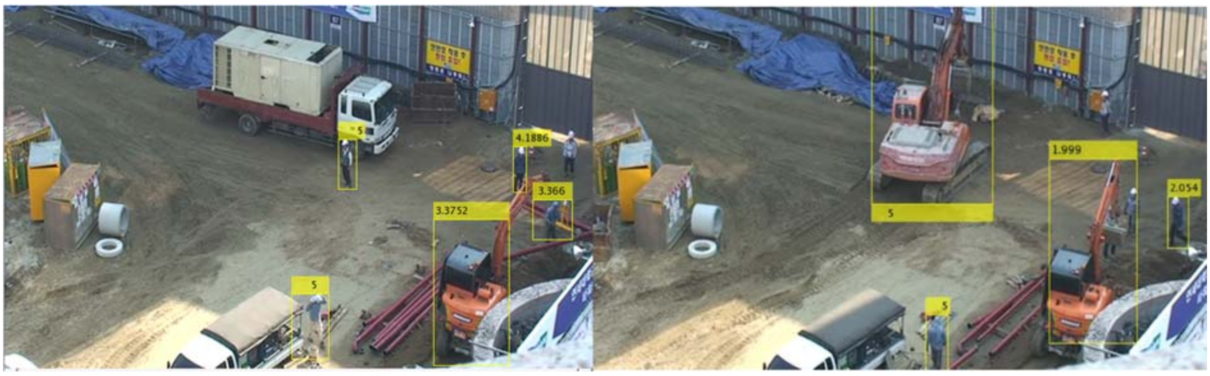

Figure 2. Safety assessment using fuzzy inference.

Figure 3. Conceptual display of hazardous information on a wearable device

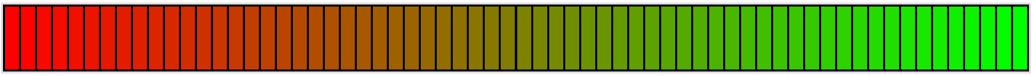

Figure 4. Red-green color map

4. DISCUSSION & CONCLUSION

This paper suggests a hazard avoidance system using a wearable device. Safety condition of a worker is assessed and provided to the worker by augmented reality. The system focuses on preventing worker from struck-by accidents. In the proposed system, jobsite images, GPS data, gyroscope sensor data of the wearable device are used for safety monitoring. Safety condition is then assessed by the fuzzy inference logic, and the safety information is visualized using a spatial relationship between worker and dangerous equipment. The spatial relationship is geometrically calculated and expressed as augmented reality in the form of a three dimensional arrow. Orientation and color of the arrow enhance hazard awareness of the worker.

The current version of the hazard avoidance system is not fully automated; the modules of the system are not yet fully integrated. The seamless integration of the modules would show the true effect and benefit of the proposed system. In addition, the system, as for now, considers only the numerical safety information and the approaching state of equipment as input variables. Other information such as characteristics of activities and proficiency levels of workers can be included to provide more accurate safety information.

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