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Smartphone based real-time location tracking system for automatic risk alert in building project

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Abstract. Effective monitoring of worker is one of the crucial elements in accident prevention. With advancement of sensor technologies, real-time tracking research has been conducted for improving effectiveness of monitoring in safety management. However, most of previous studies were limited to outside construction work which normally indicates excavation and heavy equipment operation. This study proposes automatic worker location tracking and risk alert system for effective risk recognition and worker monitoring that integrates smartphone and Building Information Model (BIM). A prototype system has been developed and tested based on small room. The test results show that the system has the potential to reduce labor and time for monitoring and improve the recognition of fall accident risk on the job site in real-time.

Introduction

Fatality record of construction industry is higher than any other industry in most countries[1,9]. Because of dynamic work environment consisting of worker, materials, equipment, work space can be temporarily organized as dangerous location[11]. If not recognized the situation properly through continuous supervision and education, it leads fatality on site [5,12]. Also, loss of awareness, lower focus from the blind spots and repetitive fatigue accumulated from task is still remained as key problem in the construction industry[10].

A recent study by the Phimister et al. [8], the undesired and unwanted situation could be prevented by signals and alerts. Grabowski et al. [3] also consented that identifying alerts and signals before risk inherent work precisely provide the potential of improving safety. To effectively implement the pro-active prevention measure, there are several studies integrating ICTs such as RFID, UWB, Zigbee and GPS. The following is the identified factors to implement ICT integrated system: (1) Causation related data is collected, (2) The data is automatically gathered during construction work[13]. The developed systems mainly focus on outside construction such as soil work, crane operation, and outside scaffolding.

However, the developed system has some limitations to apply it to the building construction site. First, the location tracking system to gather resource location data can't be utilized for indoor work environment. Second, the implemented system creates additional works to safety manager such as attaching Tags.

The aim of this paper is to propose a Smartphone based location tracking and fall risk alert system that does not need additional work and suitable for indoor environment tracking. And the proposed system has been tested with indoor environment.

Fall accident data analysis

The scope of accident risk limited to fall on building construction. To modify the location where has inherent hazard of fall risk, from 2001 to 2011 accident case reports been collected and analyzed. As a result of analysis the fall accident type is modifies as shown in Table 1 according to the location. The total number of building project accidents was 1406 and the total fall accidents record 605. In summary, six groups of fall accidents were analyzed according to the criteria.

From the analysis result we can identify the alert location of workers. If we obtain the real-time location data of worker, we could notify. This process is conducted by comparing the tracked location value and risk location value. For example, if tracked worker working location is too close to opening or edge of the form, it indicates that the worker is exposed to fall from opening or fall accident from form.

Table 1. Fall causation category

Accident caused location		Number	Percentage
1.	Fall from/with ladder	91	15.04%
2.	Fall from/with scaffold	292	48.26%
3.	Fall from/with bucket	15	2.48%
4.	Fall from/with catwalk	15	2.48%
5.	Fall through opening	104	17.19%
6.	Fall from/with form	88	14.54%

Effective tracking system needs and smartphone

The objective of tracking system in construction is gathering location information of resource and providing information which indicates what/when managerial action is required. Up to date, several tracking technologies have been tested, and among the most promising methods Radio Frequency Identification Device(RFID), Global Positioning System(GPS), Wireless Area Network(WLAN), Ultra-Wide Band(UWB) for their wide range of accuracy values and yard areas[4]. These sensors are utilized to triangulation which utilized for a long time to calculate distance among three points. Basically, this method requires minimum two datum points among three points. In that reason, most of the system issues additional work procedure for receiver, tower, and sensor installation on construction site. In addition, because of their wireless communication, their signal is interrupted by diffraction and refraction which related with new object creation, random movement of machine. Also, the developed system does not consider the movement along vertical direction [7,14,15]. From these aspects, to implement accurate location tracking for building construction, the following requirements are considered:

(1) The tracked location is not changed even if the site environment is changed.
(2) Vertical movement should be captured.
(3) For efficient utilization, the additional work is minimized including sensor or receiver installation.

In other words, the errors could be reduced by changing distance calculation method. In the traditional tracking system, the main tracking system is fixed points which are called receiver or cell tower. The sensor just receives and sends signals but doesn't measure distance direction itself. Therefore, in this paper the method is changed by utilizing smartphone. In early days, the smartphone includes various sensors such as GPS receiver, accelerometer, magnetometer, and the gyroscope. The sensor fusion environment provides basic information for direction and distance measurement[2,6]. The following summary shows how the smartphone measure the location of user.

(1) Accelerometer: It measures the acceleration in three axes(x, y, z) in m/s^2. Considering the gravity acceleration (G), if the device does not move, the acceleration is recorded (0, 0, G). Else, if the device moves to any direction, the acceleration value is changed automatically.
(2) Gyroscope: It measures the rotation in around x, y, and z axes in radians/second (angular speed).
(3) Magnetometer: It measures the strength of the ambient magnetic field in micro-Tesla (uT), in the x, y and z axes. The extracted values are passed to a function to find orientation together with accelerometer values.

By combining these values, the smartphone calculate direction (from magnetometer and accelerometer) and distance (integral of accelerometer).

Automatic fall hazard alert system

To develop and test the automatic risk alert system, *Revit 2013* and *Visual studio 2010* were used. Also, the smartphone *Optimus Vu* is selected as test location tracking.

Regarding the inherent fall accident location, the safety manager assigns the risk location on construction site map with computational support, such as picking the opening, wall, catwalk related element in the Revit software. The Fig.1 shows the example indicating the risky area where has the 'fall from/with form' risk. It creates risk location by picking walls (Fig1.a). The risk map is created as 2 dimensional in Fig.1b.

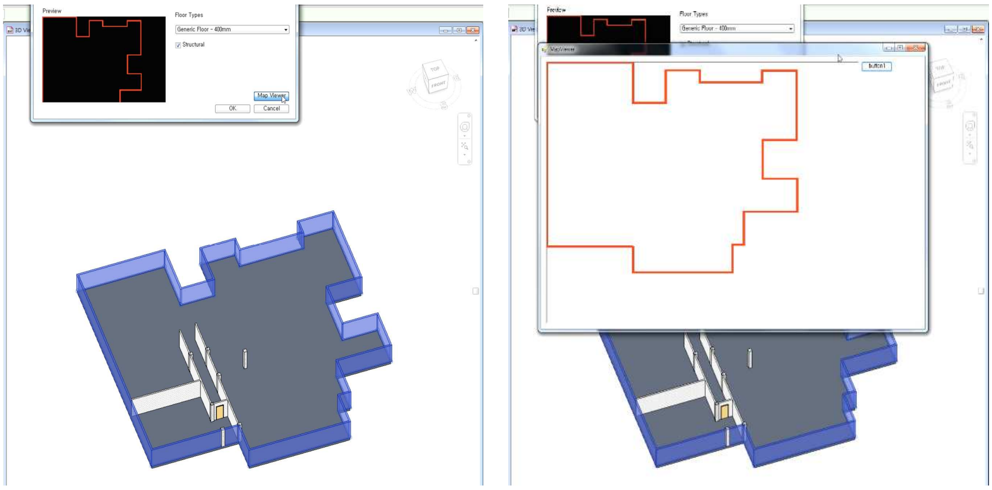

Figure 1. Risk map creation (a) Picking the risk area, (b) Created 2 dimensional map

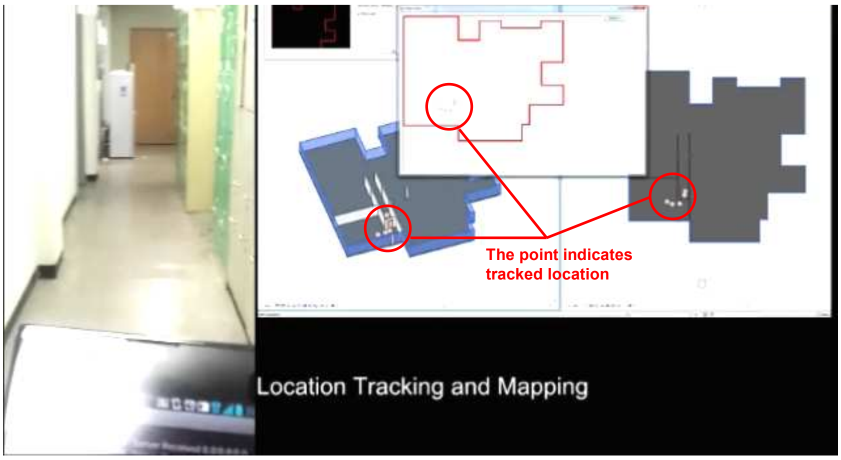

Figure 2 . Loction mapping example

After map is created, the calculated direction and distance data from the smartphone is delivered to created map and presented as a red dot (Fig.2). Depending on the position of red dots, the system sends order that alarming the worker smartphone. Also, the location of the still cut is delivered to safety manager.

Summary

This study begins with an inquiry on how to implement worker location tracking to building construction project that is unsuitable for traditional triangulation method. Based on accident case reports analysis, the six categories of fall related location is defined. Also, to compare the location and worker location the smartphone based location tracking system was proposed. Then a prototype system for an automatic alert was set up considering real-time data gathering and alert system integration. The system was developed using the *Visual Studio 2010*, *Revit 2013* and *Optimus Vu* and its practical applicability was tested with small area of building. The main findings and limitations of the study are summarized as follows:

(1) In the previous tracking technology applications, it has been well proven that real-time location data collection has many potential to improve recognition of risk on construction site. By adopting smartphone based location tracking system, the effect caused by site environment change could be reduced. Also, the alarming method could give improved recognition to workers before unsafe action or work is begun. The representation of worker location in real-time and automatic alarming of risk location give a chance to safety monitor in a remote environment. That means the labor and time which was spent for a safety monitoring task could be reduced.

(2) However, normally building construction project is performed vertically and many trades are attended in a same time. Therefore, the working level and group classification method will be integrated. Also, the errors caused by cumulative calculation of acceleration integral must be considered for improving tracking accuracy.

In conclusion, even though the potentials and practical applicability of the proposed automatic alert system has been ascertained with the simple evaluation of a simple prototype system. For future works, the system applicability should be validated to be more technical in terms of the performance of field monitoring task such as required number of safety manager, risk recognition effective, and work interruption.

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References

[1] C.-F. Chi, T.-C. Chang, H.-I. Ting, Accident patterns and prevention measures for fatal occupational falls in the construction industry, Applied Ergonomics 36 (4) (2005) 391-400.

[2] H. Falaki, R. Mahajan, D. Estrin, SystemSens: a tool for monitoring usage in smartphone research deployments, ACM, 2011, pp. 25-30.

[3] M. Grabowski, P. Ayyalasomayajula, J. Merrick, J.R. Harrald, K. Roberts, Leading indicators of safety in virtual organizations, Safety Science 45 (10) (2007) 1013-1043.

[4] H.M. Khoury, V.R. Kamat, Evaluation of position tracking technologies for user localization in indoor construction environments, Automation in Construction 18 (4) (2009) 444-457.

[5] KOSHA, Annual Accident Report, Korea Safety and Health Agency (2011).

[6] C. Lukianto, C. Honniger, H. Sternberg, Pedestrian smartphone-based indoor navigation using ultra portable sensory equipment, IEEE, 2010, pp. 1-5.

[7] R. Navon, O. Kolton, Model for Automated Monitoring of Fall Hazards in Building Construction, Journal of Construction Engineering and Management 132 (7) (2006) 733-740.

[8] J.R. Phimister, V.M. Bier, H. Kunreuther, Accident precursor analysis and management: reducing technological risk through diligence, Washington, DC: National Academy Press, 2003.

[9] S. Poon, S. Tang, F.K.W. Wong, Management and economics of construction safety in Hong Kong, Hong Kong Univ Pr, 2009.

[10] S.G. Pratt, D.E. Fosbroke, S.M. Marsh, Building safer highway work zones: Measures to prevent worker injuries from vehicles and equipment, 2001.

[11] R. Sacks, O. Rozenfeld, Y. Rosenfeld, Spatial and Temporal Exposure to Safety Hazards in Construction, Journal of Construction Engineering and Management 135 (2009) 726.

[12] P. T Michael Toole, Increasing Engineers' Role in Construction Safety: Opportunities and Barriers, Journal of Professional Issues in Engineering Education and Practice 131 (2005) 199.

[13] J. Teizer, B.S. Allread, C.E. Fullerton, J. Hinze, Autonomous pro-active real-time construction worker and equipment operator proximity safety alert system, Automation in Construction 19 (5) (2010) 630-640.

[14] J. Teizer, B.S. Allread, U. Mantripragada, Automating the blind spot measurement of construction equipment, Automation in Construction 19 (4) (2010) 491-501.

[15] H. Yang, F. Yao, S.H. Yang, Zigbee enabled radio frequency identification system, ACTA Press, 2007, pp. 163-168.

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DOI References

[11] R. Sacks, O. Rozenfeld, Y. Rosenfeld, Spatial and Temporal Exposure to Safety Hazards in Construction, Journal of Construction Engineering and Management 135 (2009) 726.
http://dx.doi.org/10.1061/(ASCE)0733-9364(2009)135:8(726)
[12] P. T Michael Toole, Increasing Engineers' Role in Construction Safety: Opportunities and Barriers, Journal of Professional Issues in Engineering Education and Practice 131 (2005) 199.
http://dx.doi.org/10.1061/(ASCE)1052-3928(2005)131:3(199)