Data Fusion of Real Time Physical Status Monitoring for Building Structure through Mobile Phone

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***Abstract*—This article discusses the requirements for developing a mobile-based real-time physical status monitoring management system. In addition, mobile computing system should support distributed databases and mobile-based monitoring by providing user interfaces that can be used on mobile computers, such as smart phones. In recent years, there has been an increasing interest in the adoption of emerging mobile technologies for instrumentation within a variety of sustainability systems. Researchers have been discovering that mobile computing is an exciting technology that should not be viewed simply as a substitute for traditional tethered monitoring systems. In this study, we investigate how a movement-monitoring measurement system of a complex building is developed as a research environment for mobile computing and related decision-supportive technologies. The results of the field experiment showed an acceptable reading range and rate for the proposed system. Therefore, the monitoring system demonstrated great potential for improving the existing management processes for building health monitoring on large and complex construction site. As a result, this study will suggest possibility of approach that integrates automated data acquisition technologies by pen-based interaction to collect actual data from construction sites to make daily work reports.**

***Index Terms*—building health monitoring, mobile computing, monitoring.**

I. Introduction

The advent of smartphones, coupled with mobile computing technology, provides construction engineers with unprecedented opportunities to improve the existing processes of on-site construction management. [1] After completion of a construction project, the sustainability of the construction site continues to play a crucial role in safety assessment through structural health monitoring (SHM). Due to the harsh and dynamic construction environment, however, it is not easy to acquire construction data in real time. Therefore, use of new technologies, such as tablets and smart phones, has been adopted to expedite the monitoring process. These technologies contain long-term evolution (LTE) technology to connect in real time the main servers with multiple devices. Accordingly, LTE technology can enable effective data transfer from a remote location to the main office. These applications for collecting data are web-based; therefore, monitoring is available from any location with a wireless Internet connection. [2] Through the various calibration tests mentioned above, monitoring instruments can enhance monitoring reliability and durability.

The application of mobile computing in construction is becoming a major research theme in the domain of information technology in construction. Many studies have been carried out to reduce the gap between predictions and real situations. There are many research efforts that focus on the design, development and practices of construction information management system, such as electronic document management system; [3] groupware system; [4] knowledge management systems; [5], [6] web-based project management systems [7], [8] and collaborative systems. [9], [10] However, most research in this area focuses on a detailed aspect or single facet of a mobile computing technology. Motivated by the success of the previous studies, the aim of this research is to develop a framework that explores how mobile computing technology can be used in construction site environments with respect to the retrieval and transfer of on-site information. The following objectives must be achieved to meet the stated aim: site monitoring, task management, and real time information sharing. (1) Obtain more accurate and reliable monitoring data, which

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would enable easier and more effective analysis. To this end, the implementation of automated monitoring systems should be considered for practical construction sites. (2) Enable monitoring for the smooth implementation of the automatic monitoring system and improve economic feasibility assessments to accelerate the implementation.

II. Methodology

In this paper, the applicability of the mobile system was verified on a real building construction site. To validate the framework, an operational scenario was developed to demonstrate how mobile computing can be used to retrieve and transfer information on particular construction sites, and how mobile computing can enhance the effectiveness of the construction process for particular users. Appropriate measuring sensors, such as the EL-beam, cracking test machines, and vibrational measuring devices, are installed in construction sites according to characteristics of the given construction project. The case study involves the practical application of an automatic monitoring system for a complex building in South Korea.

III. Mobile Computing in a Construction Project

Information technology has been widely applied at different information management levels in the construction industry. The emergence of mobile computing has the potential to extend the boundary of information systems from site offices to actual work sites and ensure real-time data flow to and from construction work sites. Mobile computing has the potential to increase the effective use of IT in an integrated and holistic way. The benefits of using mobile computing include reduced lead times, more efficient use of resources in the field and enhanced quality of work. [11] Mobile computing technologies have been implemented in many construction processes. In order to increase the awareness and convince more construction personnel to realize the benefits of using mobile computing in construction, Bowden *et al*. (2006) conducted a number of case studies which involved construction personnel using mobile devices to resolve specific construction problems and summarized the areas that can be improved through the use of mobile IT both in the present and the future. [12] Rebolj *et al*. (2008) developed an automated construction activity monitoring system based on a mobile computing supported communication environment. [13]

IV. Structure of Monitoring System

In Fig. 1, the overall structure of the automated monitoring system is presented. For Project A and Project B of the different construction sites, field-measuring sensors are installed in the construction structure. In addition, a field measuring system is used to wirelessly communicate the measured data from the measuring sensors to the field office. Therefore, these project sites can send organized data from construction sites to the head office and external related organizations, such as inspection teams. Moreover, superintendents and consultants can obtain the organized data over an external network. Security measures are in place to protect the data from viruses.

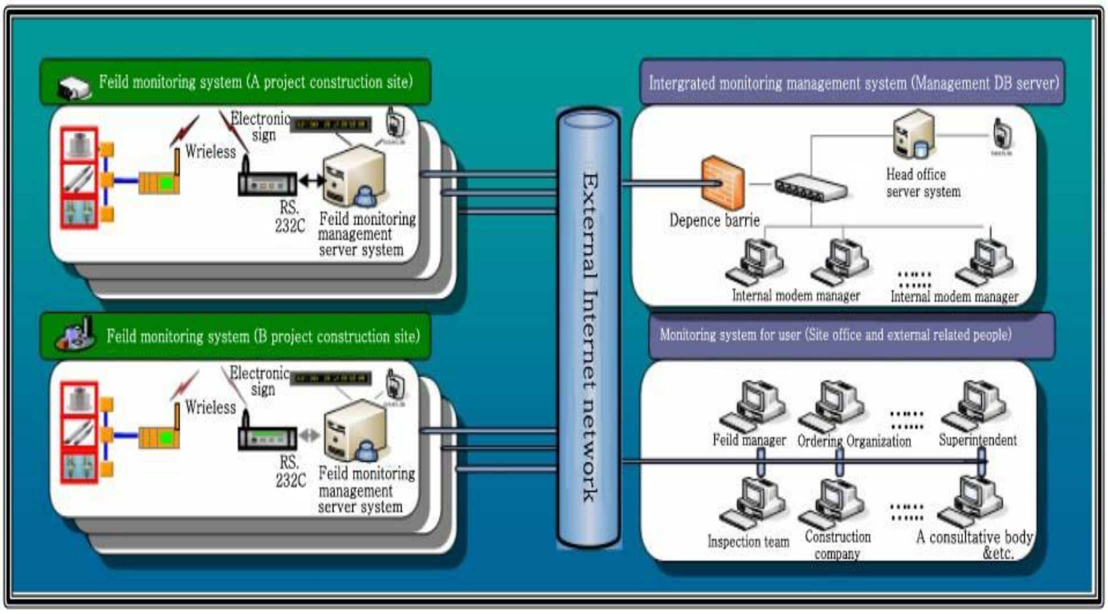

Figure 1. The architecture of monitoring system

V. Case Study

We now consider a case study and demonstrate how the USN environment can help personnel from different functional groups conduct collaborations. For the case study, the Gongneung-dong complex building project from the apartment industry sector of Hyundai-Amco Construction Ltd. was selected. The project was a complex building located at 670-20 Gongeung-dong, Nowoan-gu, Seoul, South Korea. It was composed of two buildings with 36 stories and exclusive use of the apartments. The total lot area was 84 m^2 out of 6,026.50 m^2, as shown in Table I.

TABLE I. THE PROJECT SUMMARY

Location	670-20 Gongneung-dong, Nowon-gu, Seoul, South Korea
Total lot areas	6,026.5m^2
Type of building	Complex building
Number of basements	5
Number of stories	36
Gross areas	53,489.1066m^2
Building coverage ratio	59.51%
Floor area ratio	587.72%
Exclusive use of apartment	84m^2/2 buildings
Total house holds	234 (A-118/B-116)

Efficient communication systems are important for the improvement of information transmission speed between the site office, headquarters and the supply chain. The field measuring instruments used in the case study included the EL-beam, cracking test machine, and vibration measurement apparatus. The EL-beam sensors monitored differential movement and rotation in the structures. The horizontal beam sensors monitored settlement and heave. The vertical beam sensors monitored lateral displacement and deformation. These two methods of installation enabled monitoring of structural behavior under loads as well as the stability of structures. Stabilization measures were then provided. The EL-beam operates by means of a beam sensor consisting of an electrolytic tilt sensor— a precision bubble-level electrically sensitized as a resistance bridge—that is attached to a rigid metal beam. The beam, typically one to two meters long, was mounted on anchor bolts set into the structure. Structural movement changes the tilt of the beam and the sensor output. The cracking test machine then evaluates progressive cracking in the walls. Lastly, vibration can be simply defined as the cyclic or oscillating motion of a machine or machine components from a position of rest. Construction vibration can be generated from various forces, such as the movement of large-scale equipment and progressive work packages. With the results of direction change over time, the analysis enables breakdown maintenance and scheduled or preventative maintenance.

The current state is indicated on the mobile phone screen through the main monitoring sensors. The information can be obtained from saved data in the computer or by directly accessing the field-measuring machine. The current monitoring state is automatically updated every ten minutes. The function of the main monitoring sensor is to issue a notification on the mobile phone when the standard is exceeded as shown in Fig. 2. The collected information from field monitoring sensors and machines are sent to the monitoring system in a construction site. This information can be shared between the construction site and remote locations. The monitoring system can regularly record collected data through a backup process. In addition, it can perform statistical analysis through the information analysis system in the data flow processing system. This system can then issue notifications to the administrator, depending on the standard of value and the set limitation.

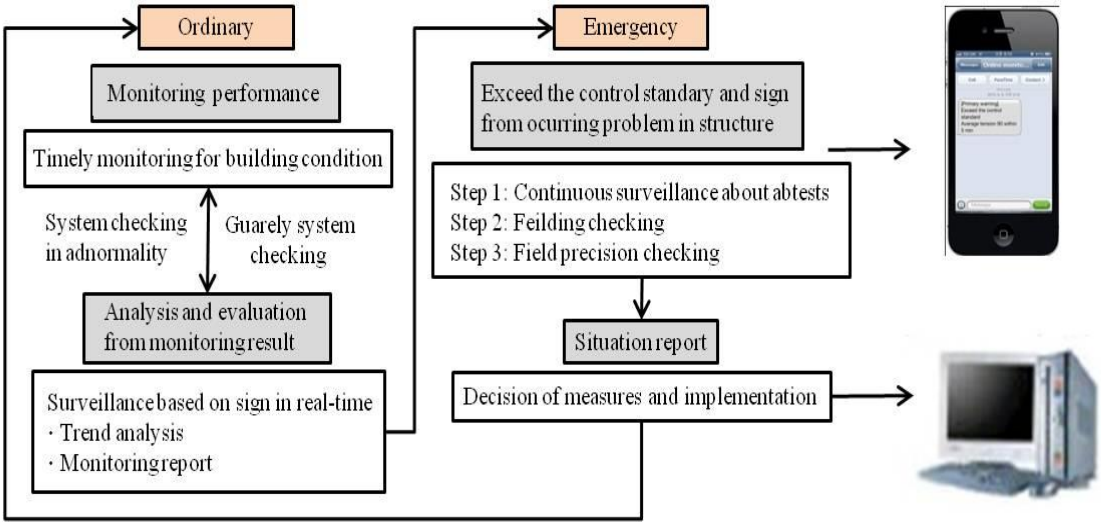

Figure 2. Monitoring system

VI. RESULT AND DISCUSSION

The applicability of the mobile system was verified on a real building construction site. Timely field monitoring can resolve the gap between predictions and real situations by enabling the analyzing of construction validity. The automated monitoring system can provide an improvement of HS based on its timely acquisition of data. In addition, it enables the establishment of countermeasures for the HS and ensures integration with building maintenance in contribution to construction management. Maintenance monitoring contributes effective, economic maintenance for construction facilities by generating objective, effective data. These benefits can improve management of the entire process of increasingly complex construction projects currently constrained under the inadequacy of traditional monitoring systems. However, the above applications consider economic aspects in utilizing portable devices and analysis software. This is because the initial cost of installation, such as for the server construction and field experimental setting, would be expensive.

VII. Conclusion

This study contributed to the body of knowledge by illustrating how mobile computing technology embodied in smart phones can be used to streamline on-site construction management. With the advance of IT applications, all project participants, such as clients, construction companies, and inspection teams, expect smooth communication because standardized measurement data can be rapidly accessed using the Internet and portable devices. Capitalizing on smartphone technology, coupled with mobile computing technology, provides construction engineers with unprecedented opportunities to improve the existing processes of on-site construction management. This enables transformation of the work environment, which was previously a vertical business relationship in which it was difficult to share information.

In this paper, we introduced monitoring equipment, such as a continuous analyzer, and measuring instruments, such as the EL-beam, cracking test machines, and vibration measuring devices for operating automated monitoring systems. Furthermore, we explained the methods of data connection and the technology of information processing. The advantages of construction industry efficiencies, reduced construction time, and a cost-effective integrated monitoring program using the Internet yield potential for the growth of construction technology. Therefore, continuous maintenance monitoring becomes ever more important for improving the whole construction performance in terms of safety elements, such as checking structural differential movement and rotation, cracking, and building vibration. The proposed system is also expected to assist construction engineers in achieving a high level of productivity and efficiency.

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