MOBILE COMPUTING PLATFORM FOR CONSTRUCTION SITE MANAGEMENT

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ABSTRACT: Ever improving smart phones and mobile computing technologies provide engineers unprecedented opportunities to innovate the existing processes of construction projects. Researchers in the construction industry tried to use mobile computing technologies for enhancing the management process of construction project on site. This study aims to present a location-based construction site management system using a mobile computing platform. The system was developed using iPhone SDK (Software Development Kit) from Apple Inc. Task information provided in the system was easily associated with the corresponding location information. This unique feature enabled the construction engineers to easily understand where the tasks and problems were. The communication capability of mobile devices through construction drawing presentation also offered effective information exchange among construction participants. The mobile system operated on smart phone is expected to assist construction engineers in achieving real-time access to customized, location-based construction information.

***Keywords**: Construction Management, Mobile Computing, Location Based Service, Site Management*

1. INTRODUCTION

Construction engineers are interested in improving site information exchange for enhancing productivity of the construction project. However, it is not an easy task to conduct timely and effective exchange of construction information among construction participants. Large area of construction site with harsh weather conditions and scattered construction resources makes it difficult for engineers and managers to transfer construction site information.

Ever improving technologies of smart phones and mobile computing provide engineers unprecedented opportunities to innovate the existing processes of construction project management. Various attempts have been made in utilization of mobile computing devices on construction project management. Navarrete [1] utilized a personal digital assistant (PDA) device as information input device to acquire construction inspection data on site. Penã-Mora and Dwivedi [2] suggested application of mobile devices to share project information in a collaborative environment. Wang [3] developed a system for construction quality control processes through integration of radio frequency identification (RFID) technology, mobile devices (PDAs), and web portals. Shin et al. [4] developed a system for managing information of building material on interior construction using a PDA device. Wang et al. [5] suggested a RFID-based mobile supply chain management system for a construction project. Lipman [6] used a PDA device for visualizing three dimensional (3D) computer-aided design (CAD) model of construction components. Kim et al. [7] suggested a mobile computing platform for a construction supervision and quality control. Kimoto et al. [8] presented a mobile computing system for inspection and progress monitoring of a construction project. Zurita et al. [9] developed a collaborative face-to-face design support system on a mobile platform.

Previous research efforts showed that mobile system has a potential to collect and manage construction project information in a more efficient manner. However, the new

generation of smart phones equipped with the localizing capacity opened a new possibility. In other words, the GPS (Global Positioning System) and gyroscope installed in a smart phone, now allows construction engineers and managers to have custom-made information based on the location information. Through the integration of location information and construction site information, construction engineers on site can now easily understand that the construction information is relevant to which part of the site.

The objective of this study is to present a location-based construction site management system using mobile computing platform. The system architecture will first be discussed to show what functional characteristics constitute the whole system. Then, the application of the system is described focusing on how the data are input and used in association of the relevant functions. Lastly, a case study is presented, where the mobile system was deployed in a real construction site, in order to verify the applicability of the system.

2. MOBILE COMPUTING PLATFORM FOR CONSTRUCTION SITE MANAGEMENT

The two major modules of the proposed system are site management module and construction drawing sharing module. The following sections present the two modules in detail.

2.1 Site Management Module

The first module is the site management module. This module has the function of managing work tasks on the construction site. Each task for a construction engineer is assigned by the site management module using location information such as where the task is supposed to take place, where resources are, and where the engineer is. The location information that is available in the mobile device will allow construction engineers to have customized work orders, site report documentation, and collaboration process on the construction site. The defined work tasks are pointed by pins on a map of the mobile device to present the exact locations. With the help of augmented reality technology, the location and direction (from the user of the mobile device) of each work tasks are virtually visualized on screen with real construction site images. This work assignment module, which is associated with the corresponding location information, will reduce the misunderstandings of the work tasks of engineers on site.

2.2 Construction Drawing Sharing Module

The second module is the construction drawing sharing module. This module has the function of sharing construction drawing on the mobile platform. When multiple engineers want to share the construction drawings, it is not easy to communicate the same information of the construction drawing with one another. To solve this problem, the developed module supports the interactive sharing of the construction drawing among construction participants. In this module, construction engineer can move and zoom in/out of the construction drawing on the mobile device through a simple finger movement. At the same time, this movement and zoom in/out commands are also conducted on the other mobile devices which are connected with the main server; thus the users of the mobile devices can share the drawing with the same perspective and magnification.

3. SYSTEM DEVELOPMENT

In this study, the iPhone 3GS was chosen as the mobile device for the interactive construction site management system. The system was developed on the iPhone SDK (Software Development Kit) from Apple Inc. Wireless technology, along with a database server, was used to implement the mobile system.

3.1 Hardware System Components

For the system development, internal functions of the iPhone 3GS, such as GPS module, digital compass, and data transfer system (802.11b/g Wi-Fi and wideband code division multiple access (WCDMA) network) were utilized. The database for construction site information was structured on the main server of the system. To visualize the augmented reality (AR) on the mobile device, the imbedded camera (three megapixel still camera) and the GPS module of the iPhone were utilized for the system.

3.2 Software System Components

When the construction manager on site manually input the information of work task items, the corresponding location information is automatically derived from the imbedded GPS module. The registered work tasks are then displayed in the AR environment to realistically visualize the location of each work task on site. Fig. 1 shows the algorithm for the AR visualization. The current location of the user is derived from the GPS module of the mobile device, and then the distance (d_i) between the current location and the location of the work tasks (w_i) is calculated. When the calculated distance (d_i) is less than a predefined distance threshold (T), a graphic symbol indicating the work task (w_i) is superimposed on the real construction site images to produce the AR effect. This process is repeated until the AR visualization is completed for the particular user location.

The process for work tasks visualization on the map is the same as the process for the AR visualization. When the user wants to see the location of the work tasks, the distance between the current user location and each work task is calculated. All the work tasks, of which distances are less than a predefined distance threshold (T), are then displaced on the map.

For the development of the construction drawing sharing module, a transmission control protocol/internet protocol (TCP/IP) socket programming was used. The TCP/IP socket programming enabled multiple clients to exchange data through the main server. Fig. 2 shows how the drawing sharing module works. If the users want to share the construction drawing on the mobile devices, the users should first log on to the system. In this module, when a client (eg. client 1) conducts a finger movement on the touch screen on the mobile device, the event (finger movement) is transferred to the main server and again transferred to other clients. Through this process, all clients can share the same perspective and magnification so long as the users are connected with main server. For example, when the commands from the first client are automatically transferred to other clients who are connected with the server, the transferred commands are executed on the mobile devices of the other clients to show the movement and zoom in/out of the construction drawings.

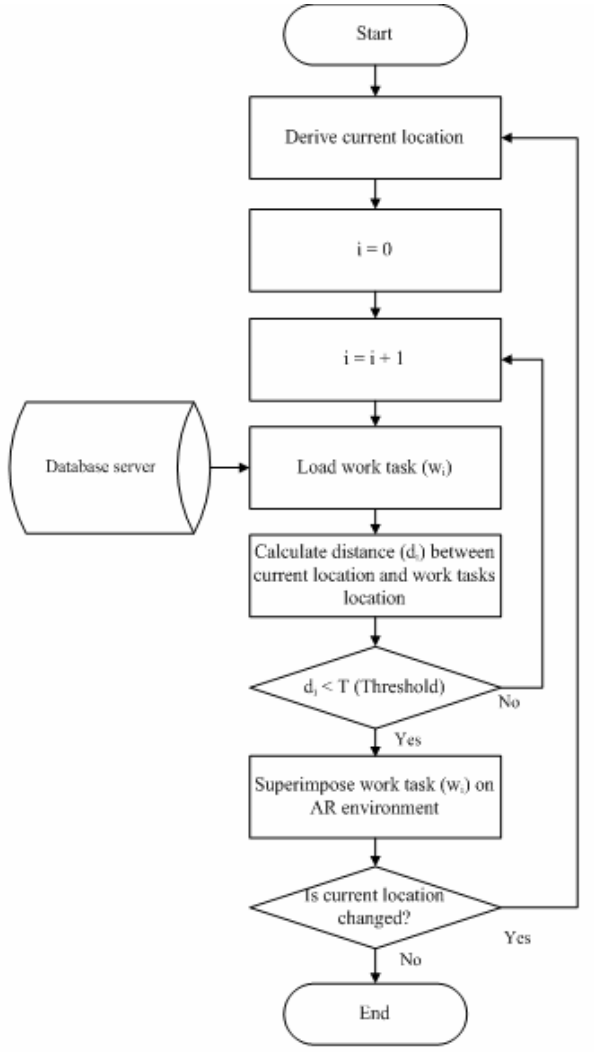

Fig. 1 Algorithm for AR Visualization

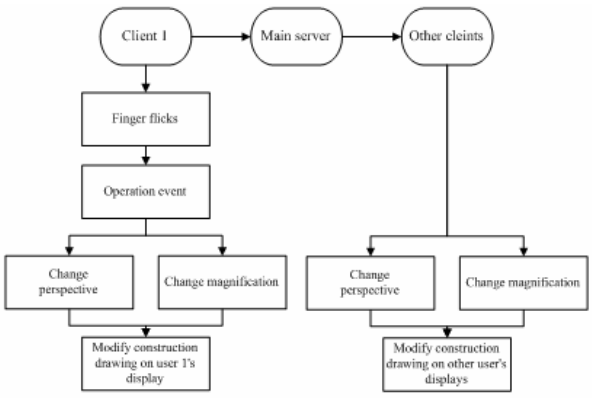

Fig. 2 Construction Drawing Sharing Module

4. SYSTEM IMPLEMENTATION

To use the interactive construction site management system, the user has to log on to the mobile platform using his or her own account ID and password. After the

successful log-on, the user can access the site management module and the construction drawing sharing module.

4.1 Register Work Task

The first step of using the site management module is registration of work tasks. As shown in Fig. 3, users can input various work task information, such as work task title, description, start and end date of the task, the crew in charge, the supervisor, and the location of the work tasks on the construction site. Once the registration is finished, the information is transferred to the main server via a wireless local area network (WLAN) (802.11b/g Wi-Fi) or a WCDMA network for mobile devices. Fig. 4 shows the process where the construction manager specifies the engineer who should handle the registered work task.

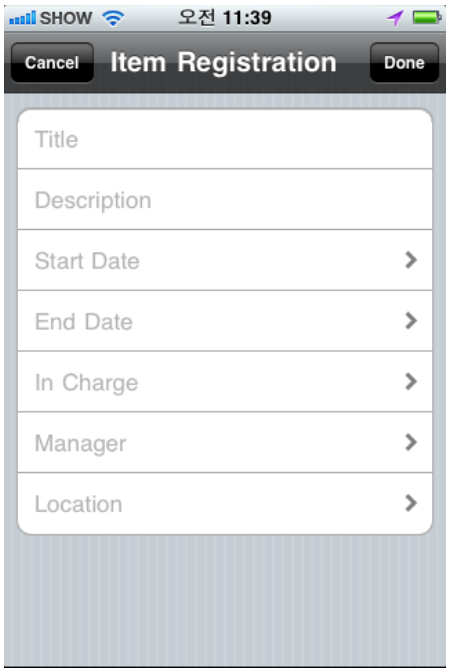

Fig. 3 Work Task Registration

Fig. 4 Select a Person in Charge on the Engineer List

4.2 Work Task Scheduling

According to the registered start/end date of the work task, the work task is scheduled on the calendar of the mobile device (Fig. 5). Through this function of the system, the construction engineers on site can easily identify the priority of the work tasks based on the list of the calendar.

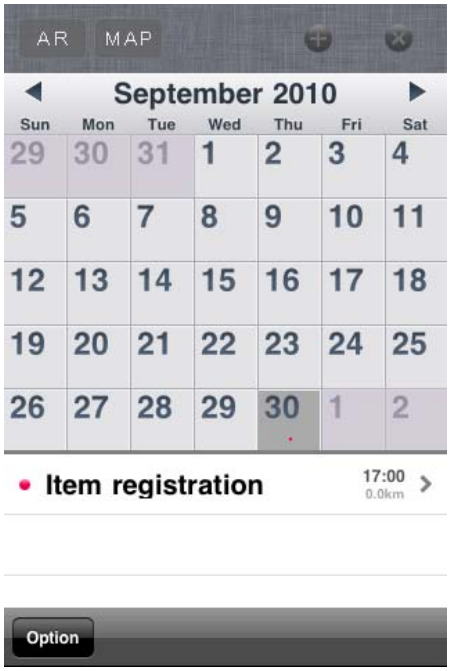

Fig. 5 Work Task Scheduling

4.3 Locate Work Tasks on the Map

Fig. 6 shows the system presenting the location of the work task on the map of the mobile device. This function of the system offers an effective way to find the location of the work tasks on the construction site. From the current location information of the construction engineers (blue ball on the Fig. 6), the engineers on the construction site can deduce the direction and distance to the work tasks on the site.

4.3 AR Visualization of Work Task

The system also has a function of AR visualization of the work tasks. The technology of AR has more visualization capability than the display on the map, therefore, the construction engineers can save time and efforts to search work tasks on the construction site. As shown in Fig 7, when construction engineers look around the construction site through the camera on the mobile device, the V shape graphic symbols with text information are superimposed on the real construction site image. This ability of AR visualization enables construction engineers to easily search the direction and location of the work tasks on the construction site.

Fig. 6 Location of the Registered Work Task

Fig. 7 Augmented Reality of the Work Task on the Construction Site

4.3 Construction Drawing Visualization

The last function of the site management module is to visualize the construction drawing on the mobile device (Fig. 8). The construction engineers on the site can download drawings from the main server and analyze them on the mobile device.

When two construction engineers on site wanted to see the same construction drawings on the mobile devices, this module allowed the construction participants to share the same screen of the mobile devices via the wireless communication system. The movement and zoom in/out of one's construction drawing on the device influenced the others screen visualization. In other words, multiple users could share the screen of the mobile devices in the real time manner. Using TCP/IP socket programming, the construction engineers with the mobile devices could interactively control the construction drawings on the mobile devices. Through this interactive capability, the construction engineers on the site could effectively discuss the certain design problems on the construction drawing.

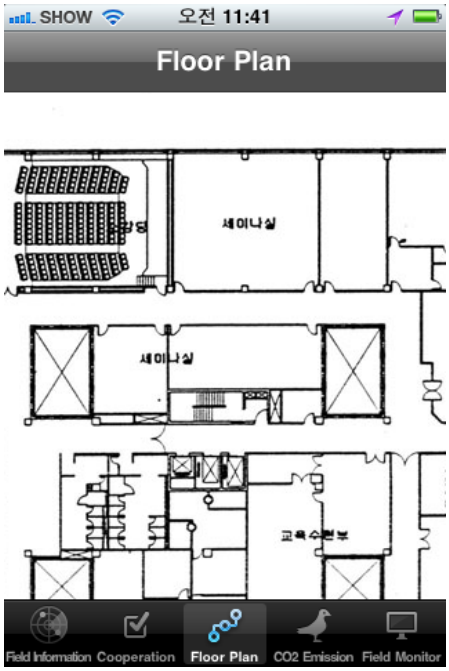

Fig. 8 Construction Drawing Visualization

5. CONCLUSIONS

The objective of this study was to develop a mobile system for construction site management. The system was composed of two main modules: site management module and construction drawing sharing module. Using the site management module, the work task information provided in the system was able to be easily associated with the corresponding location information. The drawing module presented the capability of interactive communication among construction engineers by sharing the construction drawing on their own mobile devices. Future studies are required to further advance the capability of the mobile system, including a more comprehensive testing of the system on a real construction site. However, the mobile system shows a strong potential to implement a truly ubiquitous and intelligent construction site, by improving the current level of data sharing and communication practice in the construction industry.

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