USING THE MOBILE AUGMENTED REALITY TECHNIQUES FOR CONSTRUCTION MANAGEMENT

JUMPHON LERTLAKKHANAKUL, ILJU LEE, MIYUN KIM
Department of Housing and Interior Design
Yonsei University, Seoul, Korea.
{jumphon, ijlee, michelle1014, jchoi}@yonsei.ac.kr

AND

JIN WON CHOI

Abstract. In this paper we attempt to develop a new system called "C-Navi" for construction site simulation and management system. By integrating AR technology with mobile computing, the new system will extend the abilities of AR systems to be implemented in large outdoor space. The concept of 4D CAD system is utilized by integrating related information and displaying them in the time-based visualization approach. Our system could help with decision making and also act as a tool for improved communications between project partners.

1. Introduction

Design visualization plays a key role in collaboration among project members. Understanding of design enhances the accuracy of design works. For many years, several methods of visualization have been invented and implemented for better communication in the architectural field including Augmented Reality (AR). It helps the user interact with the design model in a more intuitive way.

By implementing AR techniques, we had developed our previous system called 'Building Scanner' (Park and Choi, 2004) that recognizes interior spaces and information of building equipment frequently on a floor plan and enables a user to browse or retrieve more naturally and easily. In this paper we attempt to expand the boundary of 'AR' by developing a new system called "C-Navi" which is a construction site simulation and management system using mobile augmented reality techniques for outdoor space.

The new system is used during the building construction process in which many construction issues could be explored with AR techniques. The process can be simulated in real-time manner. This leads to the concept of 4D CAD by integrating all information and displaying it in the time-based visualization approach. A 4D simulation of the construction process could help with decision making within the project and act as a tool for improved communication between the project partners. This could result in an increase in the quality of the project management and a reduction in defects and construction times and costs (Murray et al., 2000).

2. Related Works

In this section, some related researches in mobile augmented reality systems and 4D CAD systems are investigated and explained.

2.1. MOBILE AUGMENTED REALITY SYSTEMS

The mobile augmented reality system (MARS) was first introduced by the development of a Touring Machine (Fiener et al., 1997). By combining AR technology with mobile computing in which increasingly small and inexpensive computing devices, the campus information system could overlay the building information upon the building image while a user is exploring and looking at the building using a head-worn device. To date, there are some research groups investigating how to apply mobile augmented reality technology in outdoor space for other architectural purposes. Kuo et al., (2004) have developed a mobile spatially-aware computational device as a visualization aid to students learning small outdoors. The system used the comparison of captured images to track the user's position and orientation whereas other research groups used Geographic Positioning System (GPS) and some orientation sensing devices for tracking the user location. This could enable the user to explore outdoors in a larger area. Güven and Fiener (2003) have modified and developed an authoring tool for creating and editing 3D hypermedia narrative. Piekarski and Thomas (2003) have developed a 3D modelling tool called Tinmith for large structures in outdoor augmented reality environments. The system can perform 3D modelling in real-time and create an interface that allows the user to interact with the augmented environment directly. Benford et al. (2003) have developed a portable mixed reality device for outdoors called Augurscope II. The system is used for exploring the history of outdoor museum sites or for viewing planned developments of public spaces. Our system is different from those researches in that we focus on applying mobile augmented reality technology to building construction processes as a management tool integrated with the concept of 4D CAD system in which time plays the main role for user interaction.

2.2. 4D CAD SYSTEMS

4D (CAD) models are models in which schedule activities are linked to 3D CAD objects. Doing so, a time-based CAD model can be created. A simulation of the construction process is the result of linking all significant building parts to schedule activities. This simulation enables visual schedule analysis and communication (Broekmaat, 2002). 4D models helped build synergies between the design and construction teams. 4D promoted an awareness of constructability and field issues among the design team, while encouraging the construction managers to appreciate the design concepts and rationale (Fischer and Kam, 2002). Nowadays, a number of 4D tools are available. Some commercial 4D tools such as Autodesk Revit are bundled with various functions including modelling and scheduling functions, while other tools such as Bentley Schedule Simulator, Visual Project Scheduler, Project 4D and VIRCON (Dawood et al., 2003) are more lightweight. Users have to import 3D model data and construction schedule data to perform those 4D CAD systems. However, our system is different from those tools in that none of them is applied and utilized in augmented reality environment which enables a user to investigate the construction process on the site in real-time manner. Our research aims to explore the state-of-the-art in 4D CAD system, find its appropriate characteristics and apply them to our mobile augmented reality for building construction processes.

3. Research Methodology

Our mobile augmented reality system called C-Navi is developed by the following processes, as shown in Figure 1. First of all, we established the 3D construction models, the construction schedule and the site database such as 2D models of surrounding buildings and roads. Second, we developed the position and orientation tracking modules based on our GPS navigation system called "CityScape". Third, we developed the AR-based visualization module by means of a modified ARToolKit (Billinghurst et al., 2001). Fourth, the core engine of C-Navi is created by integrating all earlier components together. During this integration process, some calibration methods are needed to adjust the accuracy of matching two worlds. Fifth, the graphic user interface are designed and applied. Finally, three simulation modules composed of 4D CAD module, solar analysis module and view analysis module are generated and applied.

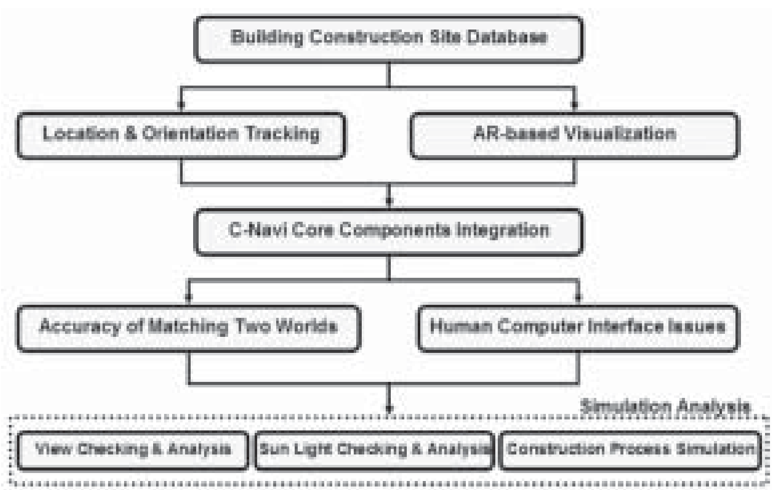

Figure 1. The processes of C-Navi development.

4. System Architecture

4.1. HARDWARE

Currently, our hardware based on reasonable priced equipments is composed of HP Compaq Presario-X1409AP (Pentium M 1.4 GHz, 256 MB with 64 MB graphic card) equipped with Logitech Quickcam Pro-4000 using CCD 1.3 mega pixel sensor. As we had done a preliminary hardware test, a CMOS-sensored web camera is not suitable since it cannot display images from a distant perfectly. In fact, Compaq TabletPC-TC1000 (TM5800, 1.0 GHz, 256 MB with shared-16 MB) was used as a main part in our previous prototype and was changed because of its 3D rendering performance. We use RoyalTek Oynx (RFG-2000) as our GPS Receiver, which is 15 metres position accuracy. ROBOT Electronics SE-CMPS-03 is used as our electronics compass.

4.2. SOFTWARE

Fundamentally, C-Navi is developed by using C++ and OpenGL as a graphic modelling library. The system consists of sub-modules performing specific tasks. The overall system architecture is shown in Figure 2.

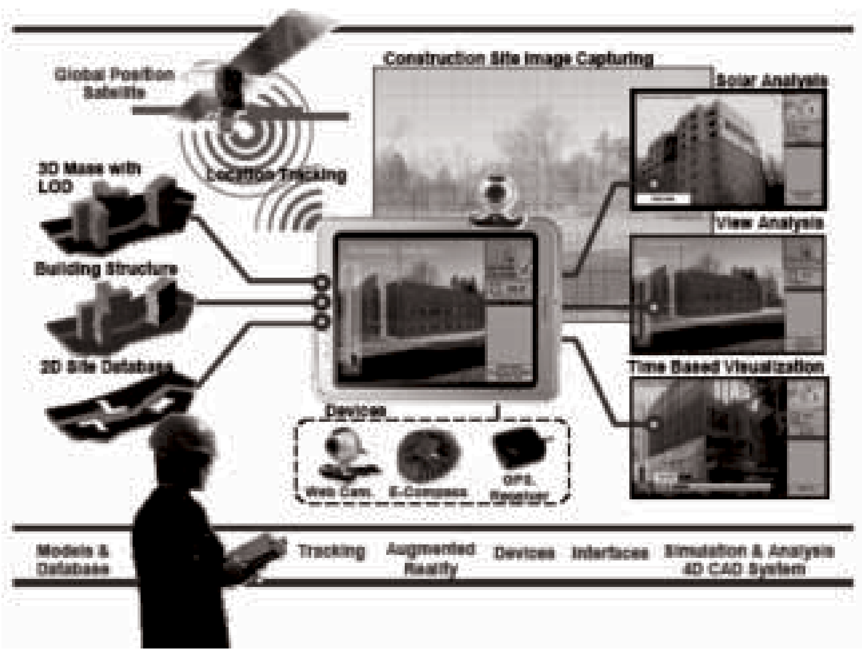

Figure 2. The System Architecture of C-Navi.

4.2.1. Location Tracking Module

Tracking the user's location is done by means of a GPS receiver and an electronic compass. Based on our existing GPS navigation system called "CityScape", shown in Figure 3, the location tracking module is created. As a user moves in the physical environment, this module can locate the current user's position and orientation in 2D map and 2D-extrusion virtual environment, which are stored as ESRI shape file format.

4.2.2. AR Visualization Module

The physical images captured by a web camera are overlaid with 3D objects in real-time manner. Those 3D VRML (Virtual Reality Markup Language) objects can be created and exported from 3D modelling tools such as FormZ and 3D StudioMax. The augmented reality environment is accomplished by the modified ARToolKit shown in Figure 3, which was originally developed by the University of Washington HIT Lab using OpenGL graphic modelling library. Markers are not applied in our system since they are not suitable for using with large buildings in outdoors. As a result, a calibration method for mapping objects and cameras in two worlds is needed. Another function of this module is to provide the various methods of visualization to users. The virtual objects can be displayed in wire-frame, pointed or surfaced rendering mode.

Figure 3. CityScape User interface (left), modified ARToolKit User Interface (right).

4.2.3. 4D CAD Module

The main function of 4D CAD module is to establish linkages between 3D VRML objects and the processes in the construction schedule created by an external project management information system (PMIS) such as Microsoft Project. In this way, the construction process simulation can be performed. A user can use C-Navi to investigate the construction process on the construction site in real-time manner. The output from linking the models and the schedule are stored in our 4D file format (“.4D”) as shown in Figure 4. The graphic user interface design of 4D module and the construction process simulation mode of C-Navi are shown in Figure 5.

4.2.4. Other Simulation Modules

The functions of C-Navi can be expanded by the development of other add-on simulation modules. The Solar Analysis module is developed to be used for investigating the amounts of direct sunlight, shade and shadows that will cast on the new building as well as on the surrounding buildings. The View Analysis module functions as a tool for checking the visual effects that the new building will cause on the surrounding context.

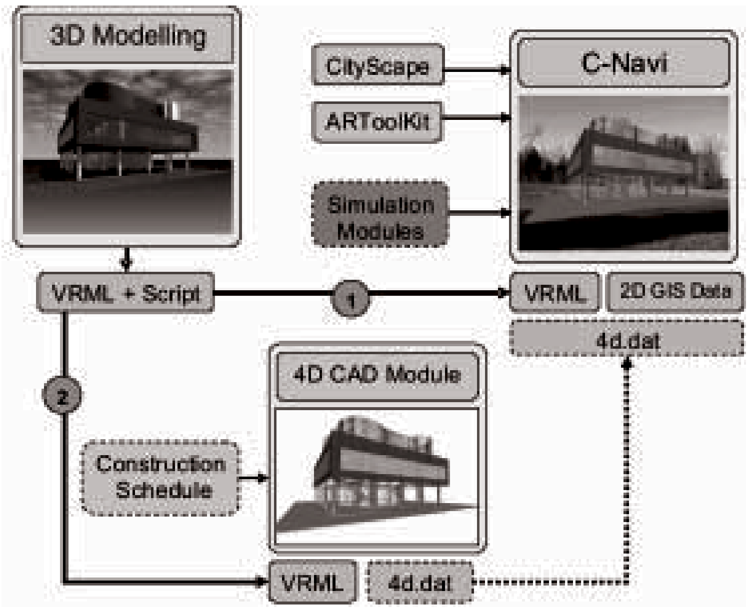

Figure 4. The information flow of C-Navi.

Figure 5. 4D CAD Module (left), C-Navi in Construction Process Simulation mode (right).

5. Conclusion and Discussion

At the time this paper was being written, we had tested the latest prototype of C-Navi in our campus for the preliminary system evaluation. The user's position and orientation tracking modules perform well in large open space such as the soccer field. However, the system integration has not been completed yet. The 4D CAD module and the calibration method for mapping two worlds are still under developing.

Some problems are detected and discussed here. First, there are some errors in displaying the building height when we implemented our system in none-plane area since we use the ESRI Shape file format as the data of the surrounding buildings which basically are 2D extruded model data. Second, a user had to adjust the alignment of virtual environment manually because the parameter of virtual camera and the real camera were not the same. Third, the distance between the user and the construction models should be taken into account because the building size is very large compared with the user's scale. Finally, the 3D VRML models must be well-organized while they are modelled since the classification of layers will be used as a key part in 4D CAD module for linking with the construction schedule.

The next steps of C-Navi are the accuracy in mapping 2 worlds and the completion in system integration with all simulation modules. Some further functions will be added to make our system more effective in terms of a construction management tool. After all, the prototype will be tested in the real construction project to investigate all missing factors and perform a system evaluation.

Acknowledgements

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