A FRAMEWORK FOR GEOREFERENCING BASED AUTOMATED RETRIEVAL OF CONTEXTUAL PROJECT INFORMATION ON CONSTRUCTION SITES

H. M. Khoury, [1] and V. R. Kamat [2]

ABSTRACT

This paper presents research that is evaluating the capability of a georeferencing based automated framework in identifying and retrieving contextual project information on indoor and outdoor construction sites for supporting decision-making tasks of site personnel. For this purpose, a methodology based on a dynamic user-viewpoint tracking scheme using sensors is proposed. Instead of requiring browsing through detailed drawings and other paper based media, contextual information can be automatically retrieved based on the users' location allowing them to directly interact with it in digital format through an Augmented Reality (AR) environment. AR is the superimposition of computer-generated images over a user's view of the real world. The addition of information spatially located relative to the user can assist in the performance of several scientific and engineering tasks. The objectives of this paper are to describe the overall framework being designed as well as to highlight the integration of its various hardware and software components.

KEYWORDS: Context-aware computing, WLAN, GPS, Product models, IFC, Information Retrieval, Visualization, Augmented Reality

INTRODUCTION

Manual search and retrieval of project information in the field is a tedious and time-consuming task. Time is valuable, and decision makers (engineers, managers, inspectors, etc.) typically work with stacks of paperwork and drawings on harsh and dynamic construction sites, and spend most of their time in accessing and retrieving the information necessary for important decision making tasks (Aziz et al. 2005). There is thus a clear need for a new methodology that can allow rapid identification and retrieval of contextual project information for field construction, inspection, and maintenance. The presented research attempts to achieve this by designing and implementing a dynamic user-viewpoint tracking scheme that can allow real-time identification of construction entities visible in a user's field of view using outdoor positioning technologies together with location-based wireless technologies. Contextual project information of interest can then be automatically extracted by cross-referencing identified objects with corresponding design and "as-built" data residing

[1] G.G. Brown Building, Department of Civil and Environmental Engineering, University of Michigan, Ann Arbor, MI 48109; PH (734) 763-6825 ; FAX (734) 764-4292 ; email : hkhoury@umich.edu

[2] G.G. Brown Building, Department of Civil and Environmental Engineering, University of Michigan, Ann Arbor, MI 48109; PH (734) 764-4325 ; FAX (734) 764-4292 ; email : vkamat@umich.edu

in construction databases. Subsets of the retrieved information can be interactively augmented onto the user's view to provide automated real-time information support for decision-making.

The merit of the technical approach lies in taking advantage of the latest developments in location-aware technologies, as well as interoperable product models and visualization tools in order to track users and provide them with real-time automated access to project information.

AUTOMATED GEOREFERENCING BASED INFORMATION RETRIEVAL FRAMEWORK

The primary goal of the proposed research is to minimize the time needed for on-site search and retrieval of contextual project information, and thereby to reduce cost and effort needed for this process. In order to achieve this objective, the authors are researching the requirements of a georeferencing based framework that focuses on automatically retrieving contextual project information and then interacting with that information in an AR environment for on-site decision-making in construction, inspection, and maintenance tasks. Figure 1 summarizes the mechanics of the proposed framework:

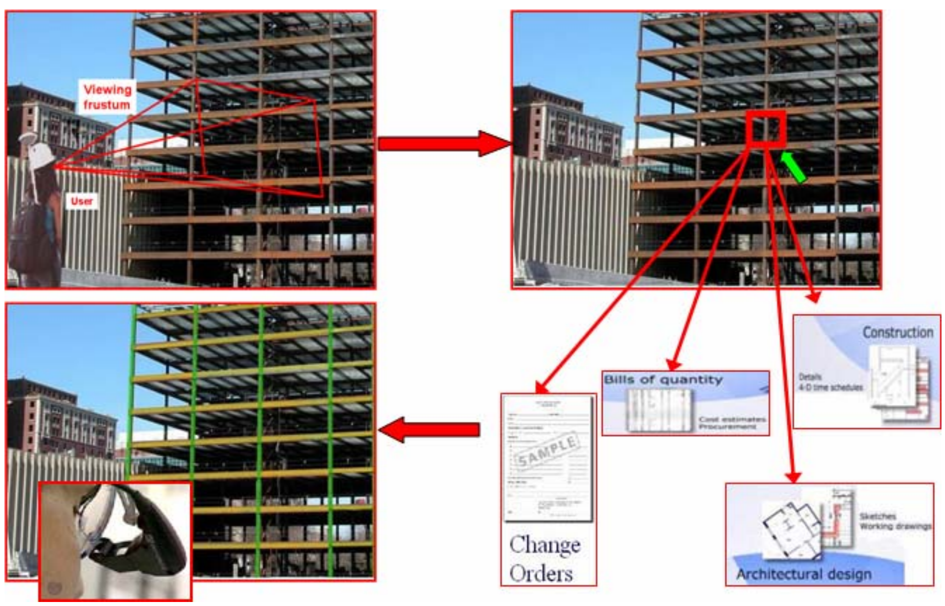

Figure 1. Proposed Georeferenced Methodology.

Location-Aware User Position Tracking

The objective of this section is to show how users can be accurately and continuously tracked on jobsites using location-aware technologies in order to identify relevant entities and retrieve contextual information. Location-aware technologies have evolved over the last several years and have aimed at providing mobile users ubiquitous access to the right information at the right time.

For outdoor applications, positioning techniques have been investigated and validated in recent work by our research group (Behzadan and Kamat 2005, 2006). The outdoor positioning technologies were integrated within an outdoor AR platform

(UM-AR-GPS-ROVER). The hardware configuration consists of a geo-referencing based algorithm developed using Global Positioning System (GPS) receivers and magnetic orientation tracking devices to track user's dynamic viewpoint. A mobile user equipped with UM-AR-GPS-ROVER hardware is shown in figure 2.

Figure 2. Outdoor Hardware Prototype

In the case of indoor applications, GPS technology is not suitable because it becomes less accurate when there is no straight signal path between the satellite and the receiver. Therefore, the need to investigate feasible techniques of user position and orientation tracking in indoor enclosed environments is an important step in providing site engineers, inspectors and other site personnel with project information through an AR indoor environment. In contrast to the outdoor positioning technologies that are capable of identifying the location of an object or person in open areas, indoor positioning technologies set the constraint of a limited coverage range.

In the last few years, WLAN radio-signal-based positioning system (Hightower and Borriello 2001) has seen enormous expansion and it will continue this trend due to the fact that it is an economical solution providing convenient connectivity and high speed links and can be implemented simply in software. These advantages, together with the fact that WLAN covers a large area and is not restricted to line of sight, have led the authors to consider the integration of WLAN within the proposed methodology as a possible indoor location-based technique.

Recent work by Aziz et al (2005) developed a prototype application for context-aware information delivery that relies on the Ekahau position tracking system (Ekahau, 2004). A technology similar to that adopted in the Ekahau system offers the best promise for this research study. Ekahau is a software-based real-time location system that can easily integrate with WLAN networks and identify the location of tracked objects within a few meters (Figure 3). The positioning engine tracks the real time position of a WLAN-enabled mobile device. It discovers all the WLAN-enabled devices using their IP addresses, and makes use of the signal strength measurements as detected by the access points to determine the actual position (Aziz et al. 2005).

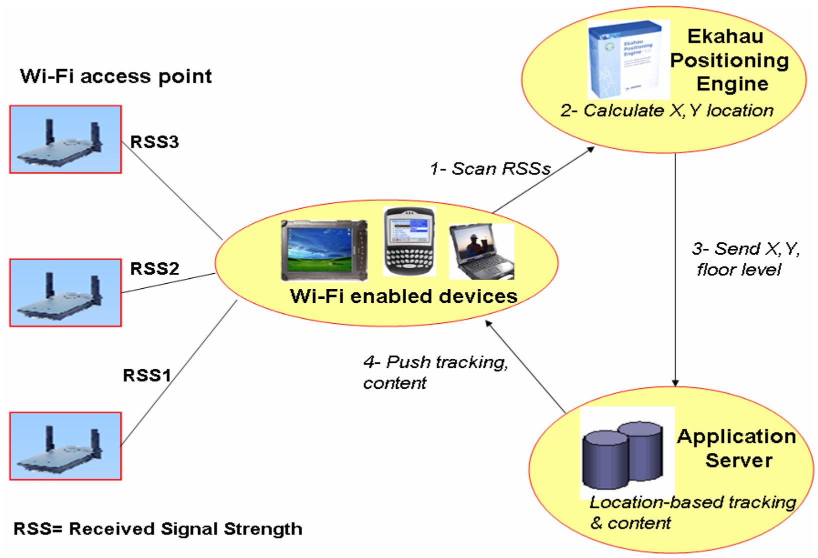

Figure 3. Ekahau Positioning Engine Mechanism

In this research, one of the basic approaches of wireless techniques, triangulation, is being studied. This approach is based on the estimation of the location of the Mobile User (MU) by combining measurement signals (Signal Strength SS) from a number of Access Points (AP's) situated at known locations in a building as shown in figure 4.

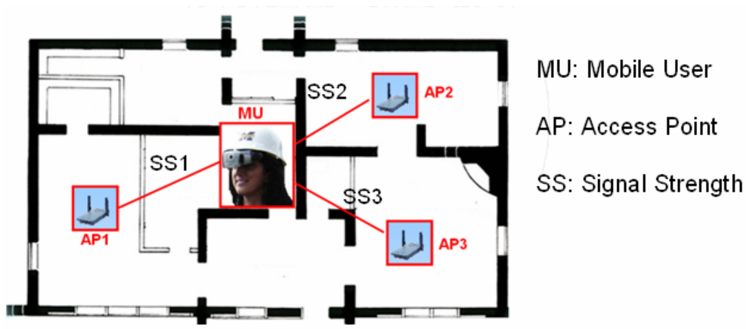

Figure 4. WLAN Triangulation Approach

In some potential applications of the developed methodology, such as fire response and emergency guidance, there is a need to find techniques of positioning and orienting a user indoors without the use of any "infrastructure" or installed sensors inside the building. Such an objective can be achieved by implementing a mobile ad-hoc network (MANET), within which routers mounted on GPS sensors, are installed outdoors at known locations (Plagemann et.al 2004).

Identification of Construction Objects

In any three-dimensional space, the subset of existing objects visible in a user's field of view at any given time depends on the user's position and orientation. Thus, in order to interpret the construction entities that might be visible to an on-site user at a given instant, two things are required: 1) the position where the user is located on the jobsite; and 2) the direction in which the user is looking. The techniques that will allow accurate computation of a user's position and orientation in three-dimensional space were described in the previous section. The objective of this section is to use this information to interpret precisely the design objects (in CAD) that correspond to the user's field of view at a given time.

Once the position and orientation of a user is accurately determined, the volume of space visible in the user's field of view (i.e. the view frustum) can be computed using documented algorithms from computer graphics (Woo et al. 1997). Reconciliation of the user's coordinate system with the coordinate system used in creating the design of the constructed facility in context can then allow the determination of the design objects that could be expected to be in the user's view frustum at that time. In order to infer which designed entities are located in the user computed viewing frustum, one important aspect of this task will be to detect any intersection between the designed model and the viewing frustum. The goal of intersection or interference detection is to automatically report a contact between geometric objects when it occurs (Lin and Gottschalk 1998).

In this case, any intersection between the model and the user's viewing frustum will be reported. The ability to detect this geometric interference is essential to know if the designed entity is in the user's view in the first place. To enable interference analysis in the framework implementation, an implementation of the raycasting technique (Foley et al.1990) is presented. Raycasting involves casting imaginary lines originating at the user's viewpoint and traveling in the general direction of the line of sight. The objective is to test for intersection between the rays cast from the viewpoint and geometric representations of the objects identified to be in the user's view (i.e. contained in the view frustum). This process is presented in Figure 5. Each time the user moves on the construction site, the intersection between the rays and construction objects is computed and interference detection is reported.

Figure 5. Identifying Contextual Objects with Raycasting

In order to identify the object of specific user interest, the deviation of the cast ray from the line of sight will be measured. In particular, an object intersected by a ray that is closer to the line of sight (i.e. center of the frustum) can be considered to be of more interest or context than an object intersected by a ray at a periphery of the frustum. For instance, in Figure 5, even though several columns are in the user's view, column C12 can be identified to be the most relevant.

Standard Product Models for Retrieval of Contextual Information

The objectives of this section are to 1) Explore the means for directly comparing relevant designed data in product models with the construction entities positively identified to be in a user's field of view at a given time instant and 2) Retrieve the contextual information for interactive presentation to the user.

A building product model is a digital information structure of the objects that make up a building, captured in the form, behavior and relations of the parts and assemblies within this building.

The interoperable CIMsteel Integration Standards (CIS/2) product model is being investigated in this research. CIS/2 (http://www.cis2.org/) is a logical product model for structural steel building information (Lipman and Reed 2003). CIS/2 has been implemented by many steel design, analysis, engineering, fabrication, and construction software packages to create a seamless and integrated flow and archival of information among all entities involved in the design and construction of steel framed structures. The CIS/2 standard provides data structures for multiple levels of detail ranging from frames and assemblies to nuts and bolts. CIS/2 structures can be represented as analysis, design, or manufacturing models. In addition, any software application can seamlessly have CIS/2 import and/or export capabilities. As a matter of fact, the CIS/2 standard has been demonstrated to be a very effective communication tool and was successfully deployed on a mobile computing at NIST (Lipman 2002). For these reasons, the CIS/2 standard model presents a suitable data structure to represent cross-referenced building data for the evaluation of automated information retrieval technique.

Among other existing interoperable product models, the Industry Foundation Classes (IFC),using basic data units of the EXPRESS language, *entities, attributes and relations* (Owolabi et.al. 2003), offers another possible option for this research. IFC models all types of Architecture, engineering, construction, and facilities management (AEC/FM) project information such as parts of a building, the geometry and material properties of building products, project costs and schedules etc. The information from almost any type of computer application that works with structured data about AEC building projects can be mapped into IFC data files (Froese 2003).

As the user is moving on the jobsite, relevant information about the entities of specific interest at a particular instant in time can be retrieved from the underlying product model. Specific information of a user's interest at a given time can be retrieved by interpreting spatial context as well as time, identity and current task with a level of precision sufficiently high to accurately prioritize identified contextual data (Burrel et al 2001). The concept behind PageRank, a trademark of Google, can be useful in this case. PageRank is a quality ranking for each webpage. It is an excellent way to prioritize the results of web keyword searches. In the case of well-known subjects, a simple text matching search restricted to web page titles works ideally when PageRank prioritizes the results (Brin and Page 1998). PageRank algorithm is defined as follows:

$$PR(A) = [PR(B)/L(B)] + [PR(C)/L(C)] + [PR(D)/L(D)]$$

where PR conferred by an outbound link L (link to page A) is equal to the document's own PageRank score divided by the normalized number of outbound links. Thus, any page's PageRank (A) is derived in large part from the PageRanks of other pages (B, C and D). By analogy, each type of document residing in the construction project database can be assigned a certain rank depending on its relevance to the user at a specific time. Therefore, when querying project databases following a keyword search, results can be prioritized according to rankings given to documents of construction and design entities.

AR visualization of retrieved information

Identification of the design and construction entities can make it possible to interactively present the retrieved information to the user in an AR view to support the decision being contemplated at that time and location. AR proves promising for effective on-site communication (Dunston et al. 2002). It offers a wide range of options with digital contextual information. The most important aspect of AR is that the virtual elements provide to the person relevant and useful information not contained in the real world. In all conventional AR systems, registration should be achieved and maintained by monitoring and tracking the movements (body motion and head rotation) of the user and using that information to continuously align augmented images with real world counterparts (Barfield and Caudell 2001). Users visualizing contextual information in AR can potentially increase their efficiency a lot by readily interacting with the mobile computers generating the augmented graphics in order to display the relevant subset of information in their views. Using mobile computers in the field requires different types of human-computer interaction techniques to increase the efficiency and safety of users .They must be able to observe the real facility in the background and rapidly interact with and select subsets from project information identified as contextual for that location.

In this research, a see-through overlay is needed to visualize retrieved information. A HUD (Heads-Up Display) is a widely used piece of hardware for achieving this objective and is often used in military applications (Lievin and Keeve 2001). It is a display which projects information directly into the user's field of view. When projected onto transparent surfaces such as glass, the information can appear to be superimposed onto the outside real environment (figure 6).

Figure 6. A Heads-Up Display

CONCLUSION

This paper presented the overall architecture of a georeferencing based automated framework for identifying and retrieving contextual project information on indoor and outdoor construction sites for supporting decision-making tasks of site personnel. For this purpose, a methodology based on a dynamic user-viewpoint tracking scheme using sensors is proposed. The innovative aspects of this research lie in the ability to automatically identify, retrieve and visualize project information that is of importance for decision-making in particular spatial contexts. It is anticipated that the proposed dynamic user-viewpoint tracking scheme will significantly enhance the work efficiency of site personnel who manage, build, inspect, and maintain constructed facilities. In order to demonstrate the extent to which the proposed methodology can be applicable in diverse decision-making contexts, ongoing research at the University of Michigan is investigating the use of GPS for outdoor positioning, and WLAN based user positioning for indoor or enclosed environments.

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