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AUTOMATED GEOREFERENCED USER POSITION TRACKING FOR CONTEXTUAL INFORMATION RETRIEVAL ON CONSTRUCTION SITES

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ABSTRACT

This paper presents research that is evaluating the capability of an automated location-based methodology in identifying and retrieving contextual project information on indoor and outdoor construction sites for supporting decision-making tasks of site personnel. Under this methodology, construction entities visible in a user's field of view at any given time and location can be identified and cross-referenced with corresponding design and "as-built" data residing in construction databases and management information systems. The presented research attempts to achieve this by integrating outdoor positioning technologies together with location-based wireless technologies. Outdoor positioning techniques have been investigated and validated in other research efforts [1] [2] through the use of Global Positioning System (GPS) receivers and magnetic orientation tracking devices. For indoor environments, this paper aims at identifying Wireless Local Area Networks (WLAN) indoor positioning technique, a cheap, easily deployable and universally compatible location system for indoor use.

KEYWORDS

Context-aware Computing, WLAN, GPS, Tracking, Information Retrieval

1. INTRODUCTION

Field construction tasks such as inspection, maintenance, progress monitoring, and others require access to a wide range of project information. While working on construction sites, site engineers, inspectors and other site personnel currently have to spend a lot of time in manually searching into piles of papers, documents and drawings to access the information needed for important decision making tasks [3]. Such lost time amounts to lost productivity, and thus lost money. There is therefore a clear need for a new methodology that can allow rapid identification and retrieval of contextual project information for productivity improvement on construction sites.

The objective of this paper is to describe the automated GPS and WLAN based methodology that is being proposed in order to improve productivity on construction sites while minimizing the time, cost and effort currently needed for contextual project information retrieval process. Proof-of concept experiments were performed outdoors on a building structure at the University of Michigan as well as indoors in one of the laboratories. The objective was to evaluate, given users' location and head orientation, the extent to which objects visible in a user's field of view can be dynamically identified and continually tracked. The obtained results highlighted the potential of using location-aware technologies for rapidly detecting contextual objects.

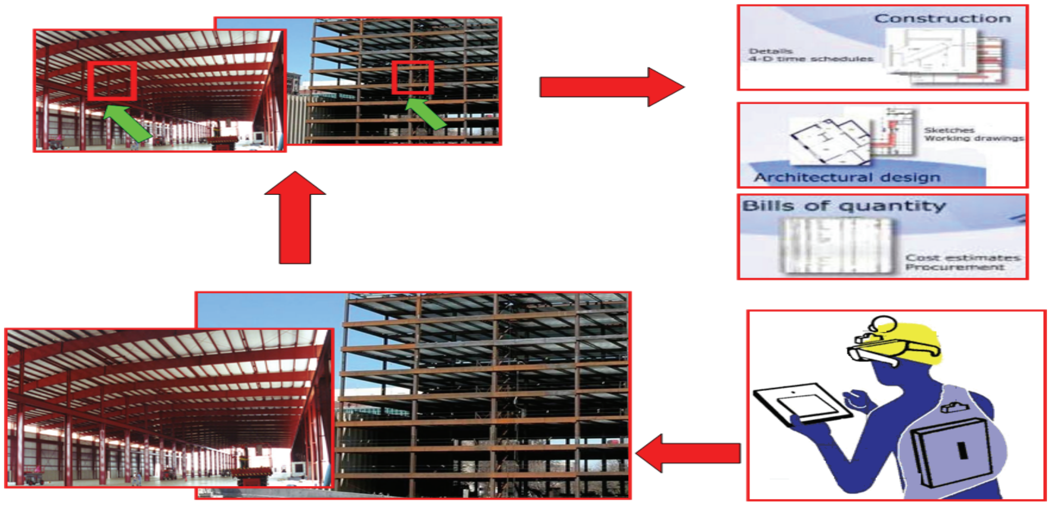

Figure 1 Proposed Location-Aware Information Retrieval Methodology

2. PROPOSED LOCATION-AWARE METHODOLOGY

In this paper, the authors are researching the requirements of a location-aware based methodology that focuses on automatically retrieving contextual project information for on-site decision-making on construction sites. Figure 1 summarizes the mechanics of the proposed framework.

2.1. User Position Tracking in Outdoor Environments

For outdoor applications, positioning techniques have been investigated and validated in recent work by our research group [1] [2]. 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.

Using the aforementioned outdoor positioning tools, a preliminary proof of concept experiment was performed to validate the proposed georeferenced information retrieval methodology (Figure 3). It was conducted at the G.G. Brown (GGB) building at the University of Michigan and the objective was to identify the different zones of the building (i.e. the Civil and Environmental, Mechanical and Dow sections) as the user navigates around the building and observes the different segments. At all times during the experiment, the user's position and orientation were tracked by the GPS and magnetic tracker and the designed algorithm was executed to automatically interpret which portion of the building the user was inspecting at a particular time. The identified components were retrieved from a 3D CAD model of the building and were presented to the user interactively. In fact, given the near and far distances as well as the field of view angles, the eight coordinates of the truncated pyramid (i.e. viewing frustum) are computed [4].

Then the viewing frustum is aligned with computer representations of objects (i.e. building structure) that exist in the space the user is navigating in. In this case, a 3D VRML model of GGB's external shell is registered at the known outdoor location. In order to interpret which entities in the environment are visible to an on-site user at a given instant, an interference analysis technique known as raycasting [5] is used. Raycasting (Figure 4) was implemented, using a simple method to determine the intersection between a ray (virtual line segment originating from the user) and a polygon in 3D (the building model in this case).

Figure 2 Outdoor Hardware Prototype

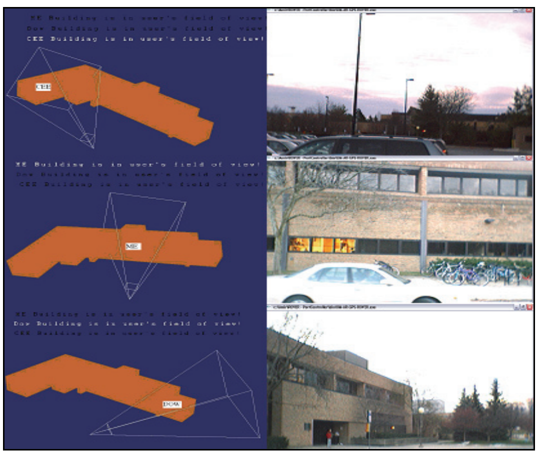

Figure 3 Virtual (i.e. Computer Interpreted) and Corresponding Real Views of G. G. Brown Laboratory Building

Figure 4 Identifying Contextual Objects with Raycasting

Each time the user moves on the site, the intersection between the rays and the object of interest (designed entity) is computed and interference detection is reported [6].The obtained results indicated a near perfect match between the real building components in the user's view at a particular time and the corresponding CAD components that were retrieved based on the proposed methodology.

2.2. User Position Tracking in Indoor Environments

In the case of indoor applications, GPS technology is not suitable because it becomes less accurate when there is no continuous straight signal path between the satellite and the receiver. Therefore, there is a need to investigate feasible techniques of user position and orientation tracking in indoor enclosed environments. WLAN technologies are being studied as a possible indoor location-based technique to be integrated in the proposed methodology (Figure 5).

This technique 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 5.

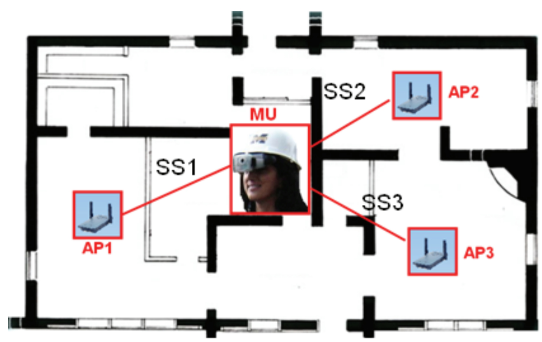

Figure 5 WLAN-Based Approach

Recent work by [3] developed a prototype application for context-aware information delivery that relies on the Ekahau position tracking system [7]. 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 6).

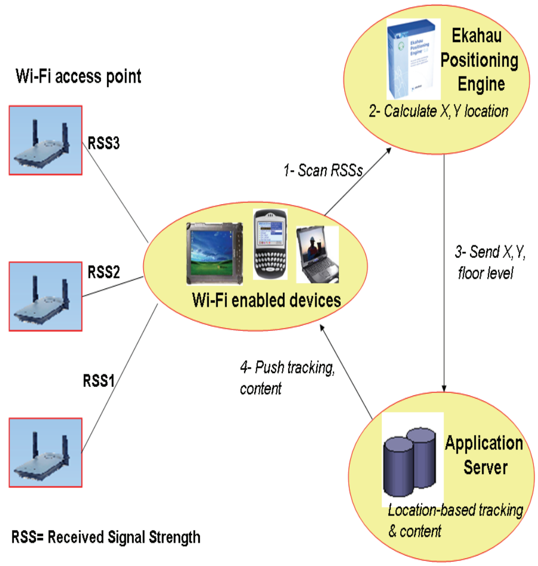

Figure 6 Ekahau Positioning Engine Mechanism

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 [3]. Based on this system, another preliminary experiment was also conducted indoors at GGB in the Construction Laboratory. The objective was to identify the position (X, Y and floor level) as well as the head orientation (pitch, roll and yaw) of a mobile user as he is walking inside the lab (Figure 7, 8).

3. CONCLUSION

This paper presented the overall architecture of a georeferencing based automated methodology for identifying and retrieving contextual project information on indoor and outdoor construction sites for supporting decision-making tasks of site personnel.

In order to demonstrate the feasibility of the proposed research, a proof of concept experiment was first conducted in an outdoor environment. A user equipped with a GPS receiver and magnetic

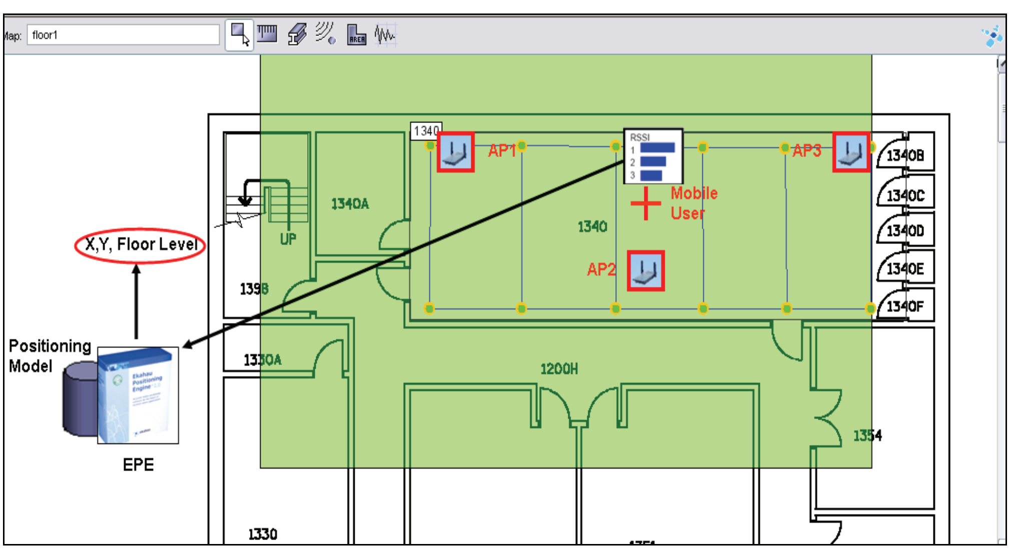

Figure 7 Ekahau Calibration in GGB (Construction Lab, Room 1340)

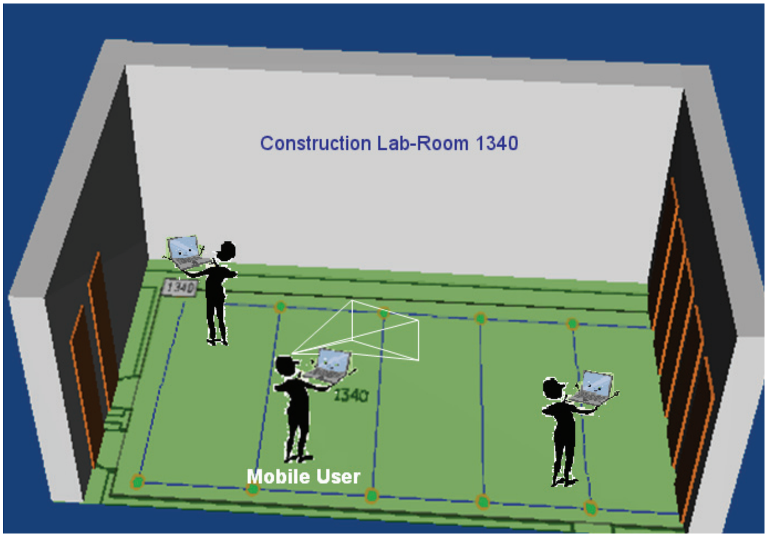

Figure 8 Virtual Representation for Different User's Positions and Orientations Inside the Lab

orientation tracker inspected the segments of the GG Brown laboratory building at the University of Michigan. The obtained results highlighted the potential of using location-aware technologies for rapidly identifying and retrieving contextual information for on-site decision making tasks in construction and other fields. Another proof of concept experiment was carried out in the Construction Laboratory of the Civil Engineering Department at the University of Michigan. The results highlighted the potential of using indoor technologies to identify the position (X, Y and floor level) and head orientation of a mobile user as he is walking inside an enclosed space.

4. REFERENCES

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