# WLAN BASED USER POSITION TRACKING FOR CONTEXTUAL INFORMATION ACCESS IN INDOOR CONSTRUCTION ENVIRONMENTS

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## Abstract

This paper presents research that is investigating the requirements of an automated location-based methodology to rapidly identify and retrieve contextual project information on indoor and outdoor construction sites for supporting decision-making tasks of site personnel.

The proposed approach to this retrieval task is the design and implementation of a dynamic user-viewpoint tracking scheme that can allow identification of construction entities visible in a user's field of view at any given time and location. For outdoor applications, a geo-referencing based algorithm has been developed using Global Positioning System (GPS) receivers and magnetic orientation tracking devices to successfully track user's dynamic viewpoint (Behzadan and Kamat 2005). For indoor applications, this research is studying the applicability of Wireless Local Area Networks (WLAN) for dynamic user position tracking.

The objectives of this paper are to describe the overall methodology being designed as well as to describe the proof of concept experiments performed outdoors and indoors. The obtained results highlighted the potential of using location-aware technologies for rapidly detecting contextual objects in construction environments.

## Introduction

Field construction tasks such as inspection, progress monitoring, and others require access to a wide range of project information (visual and textual). Currently, site engineers, inspectors and other site personnel working on construction sites have to spend a lot of time in manually searching through detailed drawings and other paper based media to access the information needed for important decision making tasks. Such lost time amounts to lost productivity, and thus lost money.

As a possible alternative to this tedious manual retrieval task, research being conducted at the University of Michigan is investigating a new methodology that can allow rapid on-site identification and retrieval of contextual information from project databases.

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 at any given time and location. Within this scheme, outdoor positioning technologies together with location-based wireless technologies are being integrated. For outdoor environments, positioning techniques have been investigated and validated through the use of GPS receivers and magnetic orientation tracking devices (Behzadan and Kamat 2005, 2006). However, GPS is not reliable for indoor applications because it depends on a clear line of sight between the satellites and the receiver. Thus, for indoor environments an alternate positioning scheme that does not rely on GPS is needed. Wireless-based positioning technologies, in particular WLAN offers the best promise for achieving this objective.

## Importance of the Research

Manual search and retrieval of project information is a tedious and time-consuming task. Time is valuable, and decision makers (engineers, managers, inspectors, etc.) have to currently work with stacks of paperwork and drawings in harsh and dynamic construction sites, spending most of their time in accessing and retrieving the information necessary for important decision making tasks. This repetitive, mundane, and seemingly innocuous activity consumes a significant amount of time, and thus money (Aziz et al. 2005).

The motivation of this research is to remedy this situation and design a new methodology that can allow rapid identification and retrieval of contextual project information for important decision making tasks of site personnel (engineers, managers, inspectors, etc). The merit of the technical approach lies mainly in taking advantage of the latest developments in outdoor and indoor positioning technologies in order to track users and provide them with real-time automated access to project information.

The overarching goal of the presented research is to minimize the time and effort needed for search and retrieval of contextual project information, and thus to reduce the time, cost and effort currently needed for this process.

## Overview of Proposed Location-aware Methodology

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. The challenge in the proposed research project is to accurately and continuously track users on jobsites using location-aware technologies in order to identify relevant entities and retrieve contextual information. Figure 1 summarizes the proposed methodology.

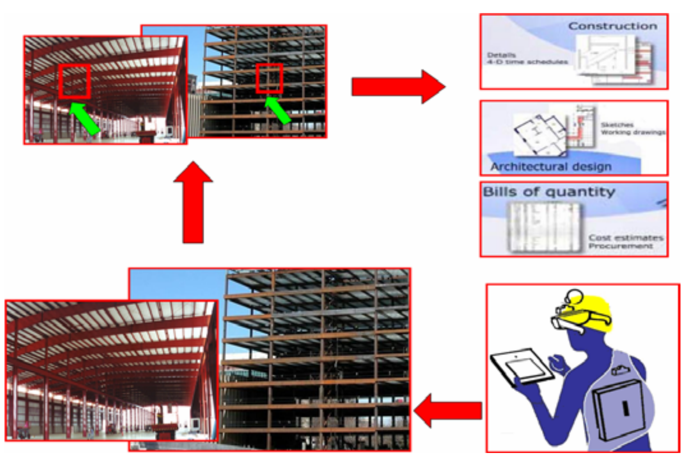


**Figure 1. Proposed Georeferenced Information Retrieval Methodology**

The position where the user is located on the jobsite (whether indoor or outdoor), and the direction in which the user is looking are continuously monitored to interpret the construction entities that might be visible to the user (i.e. in the user's field of view) at a given instant. Once the entities in context at the particular location are identified, the backend project databases and information resources can be queried for information pertaining to those entities that can then be interactively presented to the user.

***GPS-based User Position Tracking for Outdoor Applications***

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**

Using the aforementioned outdoor positioning tools, a preliminary proof of concept experiment was performed to validate the proposed georeferenced information retrieval methodology.  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. The position where the user is located on the jobsite and the direction in which he or she is looking are obtained from the GPS and orientation tracker. Additionally, 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 (Shreiner et al. 2005). 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 (Foley 1990) is used. Raycasting 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). 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. As a matter of fact, the user in this experiment was moving around the building and based on his position obtained from the GPS and the orientation provided by the tracker, the computer was interpreting which building segment is in the view at each time instant. Figure 3 shows both virtual and real camera views of snapshots taken during the conducted experiment.

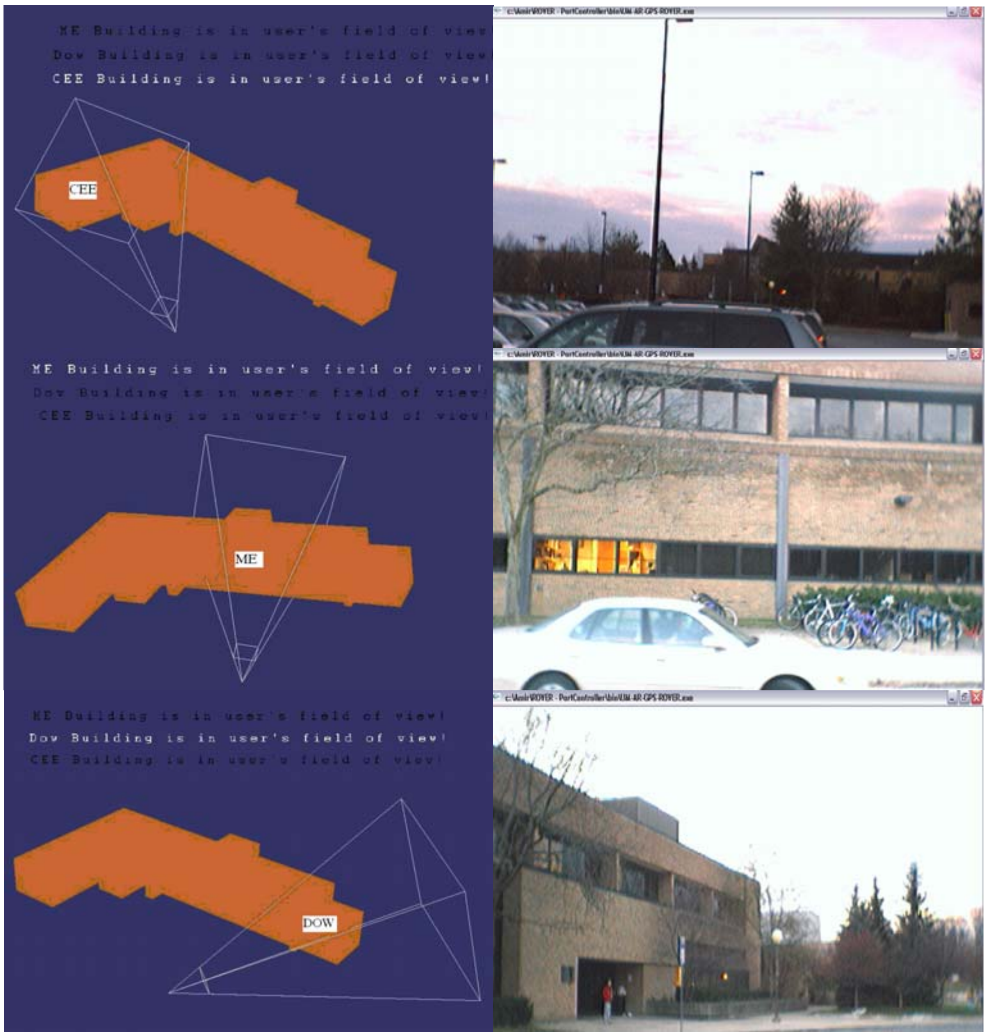


**Figure 3. Virtual (i.e. Computer Interpreted) and Corresponding Real Views of G. G. Brown Laboratory Building**

***WLAN-based User Position Tracking for Indoor Applications***

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. Indoor positioning technologies are mainly dependent on a set of technologies used for transmitting wireless data in closed environments. Wireless Local Area Networks

(WLANs) in particular, have been studied in recent research for their applicability in indoor positioning and identification of objects and persons in indoor areas.

Drawing great attention in recent years (Hightower and Borriello 2001), WLAN has distinct advantages over all other wireless systems such as Bluetooth, dedicated spectrum, or RFID-based indoor positioning. First, it is an economical solution because the WLAN system usually exists already as part of the communications infrastructure. For WLAN mobile devices, the positioning system can be implemented simply in software. Second, the WLAN-based positioning system covers a large area and may work across many buildings. Third, it is a stable system owing to its robust Radio Frequency signal propagation (Xiang, et al. 2004).

For the above reasons, WLAN technologies are being studied as a possible indoor location-based technique to be integrated in the proposed methodology (Figure 4).

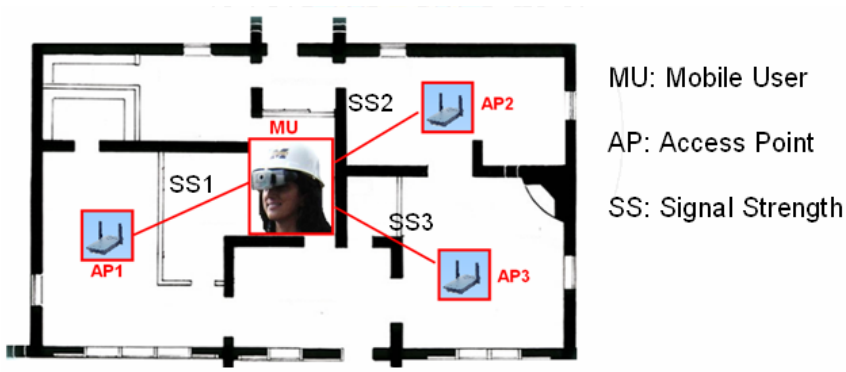


**Figure 4. WLAN-based Approach**

Recent work by Wang, Jia and Lee (2003) led to the design of a wireless positioning and tracking system based on a WLAN infrastructure. A three–tier design was implemented to demonstrate this system, consisting of: (1) wireless positioning and tracking client side, (2) tracking and monitoring server side and, and (3) remote monitoring client side. A test bed experiment, including six access points installed at different locations, was established on the fourth floor of the Electrical Engineering Building at The University of New South Wales (UNSW). Experiments results showed that a wireless access point-based indoor positioning system is feasible and a positioning accuracy of 1-3 meters can be achieved while an accuracy of 0.1 meter-level can be obtained under an idealized situation.

Gümüskaya and Hakkoymaz (2005) presented a Wireless Position Detector (WiPoD), a supportable wireless positioning system, based on 802.11 WLAN infrastructure, for locating and tracking users inside a building. K-Nearest Neighbor (KNN) and Triangulation (TN) algorithms were implemented in the system to estimate the position of a mobile user. Triangulation has been widely used by various known location systems including GPS. KNN has been first used in RADAR (Bahl and Padmanabhan 2000). The algorithms are based on the received signal strength information from access points. The goal is to establish a one-to-one correspondence between a given position and the received signal strength from at least 3 transmitters with known locations. The experimental results highlighted, using KNN algorithm, that WiPoD is able to estimate a user's location to within a few meters of his actual location and that a large class of location-aware services can be built over this system.

Aziz et al (2005) developed a prototype application for context-aware information delivery that takes advantage of Appear Networks. Appear employs a layer of context-aware intelligence to provide mobile workers with the relevant tools and information they need in order to work faster and more efficiently. It makes use of WLAN to capture context parameters. The WLAN-based positioning engine from Ekahau (Ekahau, 2004) was used. Ekahau is a software-based real-time location system that can easily integrate with WLAN networks and identify the location of tracked objects/people within a few meters. The Ekahau positioning engine (EPE) 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. A technology similar to that adopted in Ekahau system offers the best promise for this research study. 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) of a mobile user as he is walking inside the lab (Figure 5).

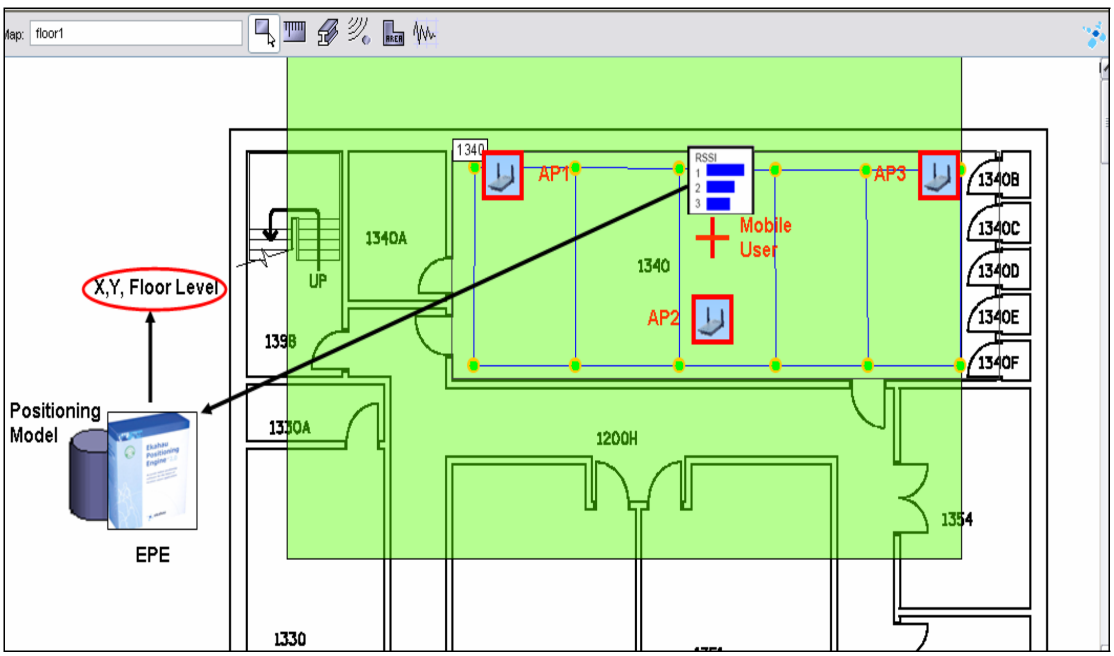


**Figure 5. Ekahau Calibration in GGB (Construction Lab, Room 1340)**

In many situations, such as fire response and emergency guidance situations, 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).

## Conclusion

Designing and implementing a dynamic user-viewpoint tracking scheme that will allow the identification of construction entities visible in a user's field of view at a given time is one of the primary objectives of this ongoing research work. It is anticipated that the designed scheme will allow construction personnel to increase their productivity in field tasks such as inspection and maintenance, thereby achieving cost and time savings and lesser life cycle costs in constructed facilities. The innovative aspects of this research lie in the ability to automatically identify and retrieve project information that is of importance for decision-making in particular contexts.

In order to demonstrate the feasibility of the proposed research, a proof of concept experiment was conducted in an outdoor environment. A user equipped with a GPS receiver and magnetic orientation tracker inspected the segments of the GG Brown laboratory building at the University of Michigan. 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. 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. 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.

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