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Development of 3-D viewer for indoor location tracking system using wireless sensor network

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Abstract

In this paper we present 3-D Navigation View, a three-dimensional visualization of indoor environment which serves as an intuitive and unified user interface for our developed indoor location tracking system via Virtual Reality Modeling Language (VRML) in web environment. The extracted user's spatial information from indoor location tracking system was further processed to facilitate the location indication in virtual 3-D indoor environment based on his location in physical world. External Authoring Interface (EAI) provided by VRML enables the integration of interactive 3-D graphics into web and direct communication with the encapsulated Java applet to update position and viewpoint of user periodically in 3-D indoor environment. As any web browser with VRML viewer plug-in is able to run the platform independent 3-D Navigation View, specialized and expensive hardware or software can be disregarded.

Key Words : indoor location, wireless sensor network, virtual 3-D environment, VRML, EAI

1. Introduction

The emergence of wireless sensor network has led to the development of ubiquitous computing an attractive research goal to be achieved. The commercial deployment of such applications is gaining popular. One of the most compelling developments would be location tracking which senses and displays user's current location, particularly in indoor and outdoor environments.

For indoor environments, there are several current available indoor context-aware systems such as Active Badge[1]. Cricket[2], and RADAR[3]. However Active Badge and RADAR both implemented 2-D user interface like Cricket did, portray location of user on 2-D topology map sheets. It explores and indicates user in the virtual indoor environment, synchronized it with the physical world through our developed indoor location tracking system[4].

Unlike those ordinary 2-D location-aware applications, an outstanding integration of 3-D graphics technologies with location-aware application would definitely be a selling point since 3-D modeling is progressively getting more and more popular for visualization nowadays. Compare to a rather new field of 3-D system as tourist mobile guide like LAMP3D[4] or 3D GIS application[5], here, 3-D navigation view is presented. It explores and indicates user in the virtual indoor environment, synchronized it with the physical world through our developed indoor location tracking system[6].

On the other hand, due to the rapid growth of economical personal computers which are powerful enough to visualize 3-D models interactively and the widely used of 3-D especially on the Internet, web technologies are playing a great role in the way of presenting data and information to the web users. Under these technological trend and computing environment, a 3-D visualization of physical indoor environments was tried to be developed and implemented in our study.

2. System Design

A new computing platform consists of small battery-powered motes with limited computation and radio communication capability is introduced due to the rapid development in embedded computing systems. Such sensor-based networking structure is used particularly in low-powered, constrained resources networked applications such as ubiquitous healthcare applications[7,8] which permit data gathering and computation to be

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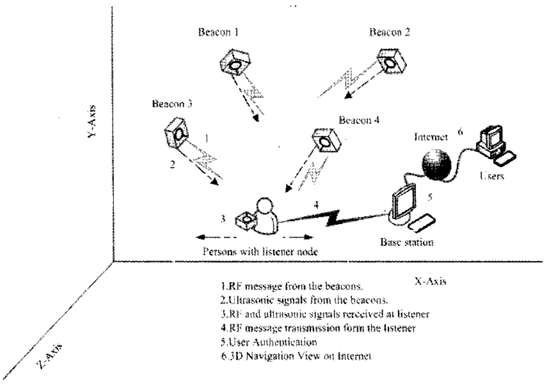

Fig. 1. System architecture of developed indoor location tracking system using wireless sensor network.

deeply embedded in the physical environment.

In this section, the design of our developed indoor location tracking system, generation and interaction of 3-D environment with external surroundings as well as algorithms and approaches used by 3-D navigation view for locating users in 3-D indoor environment are described.

2.1. System architecture overview

As mentioned, our core initiative is to aggregate the developed indoor location tracking system with 3-D navigation view, which utilizes ultrasonic and RF transceivers to estimate and determine users in physical world using Cricket wireless sensor nodes[4], as shown in Fig. 1. The system was developed in a diverse way employing low-powered ultrasonic embedded sensor nodes as active ceiling mounted location-aware sensor computing node to which a variety of sensors can be attached to it and a passive receiver.

To track a particular user, active ceiling-mounted beacons are placed throughout the building which periodically broadcast ultrasonic and RF signal to user-carried passive listener to facilitate the application at base station to study and examine user's physical location via RS-232 serial interface. RF message contains beacon specific information such as unique space ID, beacon's coordinate, physical space associated with the beacon and etc. Simultaneously, ultrasonic signal is as well transmitted. Time difference of arrival (TDOA) between the receipt of RF information and ultrasonic signals is determined as soon as listener receives these signals by measuring the one way propagation time of ultrasonic signal emitted by beacons, taking advantage of the fact that the speed of light is greater than the ultrasonic signal in the air. The product of ultrasonic signal's speed and computed TDOA determines the distance from listener to each beacon. Listener thereafter forwards the distance information to base station where further computation of user's current x-, y-, and z-coordinate is performed.

The developed indoor location tracking system works on triangulation algorithm[9]. Such algorithm requires listener to receive at least three beacon messages before determining user's physical coordinate. Once physical coordinate is computed, the activated 3-D navigation view thereafter updates position and viewpoint of user in 3-D indoor environment and thus displays it over internet.

2.2. 3-D virtual environment

Construction of the 3-D indoor environment was the first step of work. Indoor environment was proposed to be modeled using a platform independent format, VRML[10] defined by Web3D consortium for representing 3-D interactive vector graphics particularly with the www in mind. It is supported by most common 3-D packages.

Building of our laboratory, Ubiquitous-IT building, Dongseo University, was the modeled building. Fig. 2 shows the construction of 3-D indoor environment. Dimension of the objects in the room was measured manually and scaled to exact values before modeling.

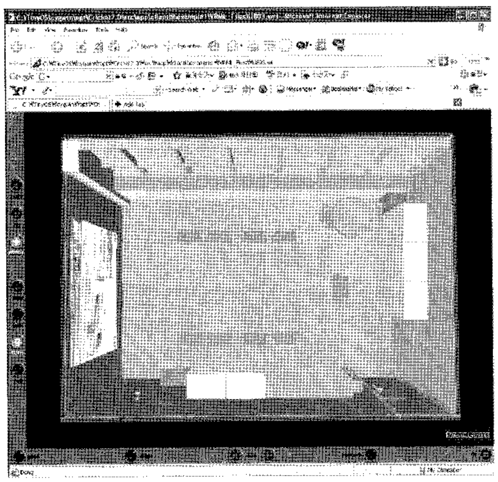

Fig. 2. 3-D environment models in VRML format.

All the furniture and walls are pre-mapped into the room and positioned correctly to each other. Manual modeling is definitely the drawback of the application. It would be troublesome, yet in near future process of constructing 3-D floor maps for every floor of a particular building will be done automatically.

VRML viewer[11] is required to view such environment. Different VRML viewers give slightly different appearance in terms of color, size, orientation and initial viewpoint. Cortona VRML Client[12] from parallel graphics is preferred as it provides extensions to the standard and a programming interface to access external complex applications.

2.3. 3-D navigation view elements

HTML, the markup language for creation of web pages provides a mean to describe the structure of text-based information in a document and supplement it with interactive forms, embedded images and other objects. In spite of describing the appearance and semantics of the document, it supplies additional cues, such as embedded scripting language code, that can influence the performance of web browsers. Thanks to this ability, the integrated Java applet and VRML 3-D files can be embedded into the web browser, as highlighted in Fig. 3.

VRML enables dynamic linking of other web resources for interaction. With its EAI[10], a direct communication between VRML and external scripting language is possible. Hence, 3-D navigation view is capable to update user's position in 3-D environment from Java applet that extracts valuable spatial information from indoor location tracking system periodically via EAI which defines a set of functionality of VRML browser that external application can access.

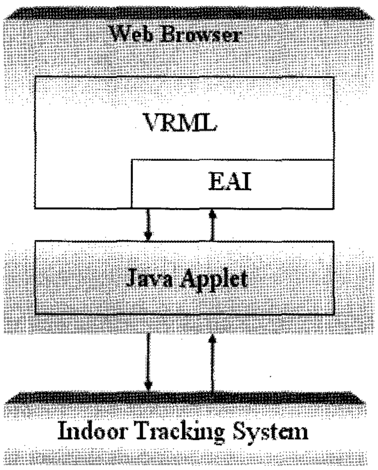

Fig. 3. System components for 3-D interface and 3-D Navigation view.

2.4. User positioning

A space descriptor and user's current position is required for location positioning. Space descriptor includes building, floor and spaceID field to identify the location of a particular space. For the case where user is contained within the current floor of current building, the building and floor field can be disregarded.

Coordinate system is defined by Cartesian representation and local reference point. A set of local reference point is defined throughout the building (e.g., corner of a room). Similarly to 3-D environment modeling, Cartesian coordinate obtained from indoor location tracking is scaled according to defined scaling ratio 1 : 10.

With scaled Cartesian x-, y- and z-coordinate and spaceID, location mapping of user can be accomplished by placing him in the exact 3-D indoor environment matches the spaceID.

3. Experiments

Experiments have been carried out to examine the integration between indoor location tracking system and 3-D navigation view as well as the accuracy of real-time user location positioning in 3-D indoor environment based on user's spatial information in physical world.

To conduct this, four formerly configured beacons is mounted on the ceiling of a room at our laboratory with dimension of 5 m by 7 m, as shown in Fig. 4. User is

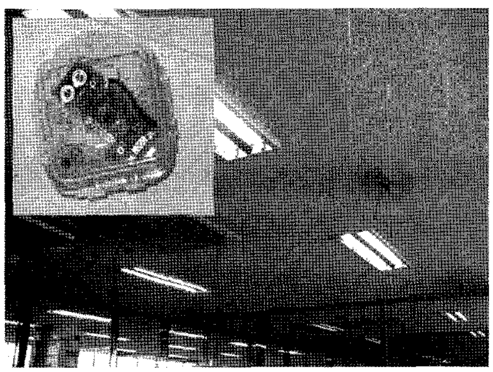

Fig. 4. Deployment of the beacons on the ceiling for experimental purpose.

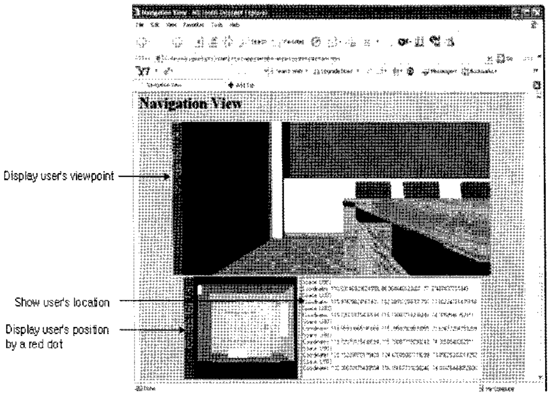

Fig. 5. 3-D Navigation view for the indoor location tracking system.

required to carry the passive listener in order to receive and transmit spatial information messages from beacons to base station where user's current position is computed and determined.

As shown in Fig. 5, 3-D navigation view, the GUI for indoor location tracking system in web environment, comprises of three main elements. Two VRML browsers, one shows user's viewpoint and another indicates user's position in the 3-D indoor environment represented by a red dot. Java applet is loaded together with initial VRML scene to read and extract spatial information from indoor location tracking system and thus place user at his new position in VRML scene and update viewpoint using EAI provided by VRML. Although the 3-D environment was not automatically generated but instead hand-drawn, they looked very similar to user.

4. Performances

At this stage of development, performance of this application was described in terms of its accuracy and precision. As per our experimental the user's location is estimated by placing beacons 200 cm apart. As user moves, 3-D navigation view displays user's current position and viewpoint in 3-D indoor environment based on extracted space and coordinate information from indoor location tracking system. The location positioning is proved to be sufficiently accurate after a comparison between locations in 3-D environment with the one in the physical world. The indoor location tracking system is known to affect positioning accuracy in 3-D environment. This is one of the factors that we should take into consideration. As a result, the desired positioning can be obtained only if the provided location information from indoor location tracking system is sufficiently accurate and fine-grained.

5. Conclusions

Nowadays, users demand not only the functionalities of location-aware application, but also a better visualization of interface. Our concept of aggregating indoor location tracking system with 3-D innovative technologies can be a solution for the promise of providing users an interactive and appealing navigation view. 3-D Navigation View was designed to provide user a tremendous visualization of physical world showing his current location and viewpoint based on spatial information.

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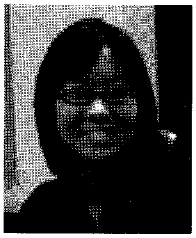

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