Indoor 3D Virtual World Representation for Multi-user Tracking System on Mobile Device

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Abstract. The encroachment of wireless mobile technology had led to the advancement of tracking system through the mobile device. This paper concentrate on delivering the indoor tracking system that utilized the 3D virtual world as the representation of indoor sensing information. (Virtual Reality Modeling Language) VRML is powerful 3D modeling software that suitable to build the virtual map for visualization on the PDA. Moreover, culling algorithm is integrated to decrease the rendering time of VRML files on the PDA. In case of the tracking approach, Received Signal Strength Indication (RSSI) provides the low-cost implementation to locate multi-target user in indoor environment. A feasible accuracy refinement algorithm is proposed to cater the low accuracy position estimation by the unstable RSSI signals caused by the indoor environmental factors. Lastly, the enrollment of digital magnetic compass indicates the user current viewpoint; dynamically update the 3D map on the PDA, synchronized to the physical world.

Keywords: VRML, RSSI, digital magnetic compass, culling algorithm, accuracy refinement algorithm.

1. Introduction

As the increasing popularity of utilizing the mobile technologies as one of the tracking system in this new decade, people tends to rely on the mobile device to indicate his/her location during the business trip or travel. However, the stress point of the disadvantage found on the current existing system is representation of indoor sensing spatial data on the mobile device. Traditional old fashion 2D flat scenes along with textual format tracking system are still being utilized nowadays. Not much involvement of 3D computer graphics into the tracking system for presenting the target mobile user current position. Our paper stresses on the design and implementation of indoor location-awareness system with 3D virtual world as the representation of the tracking data. 3D scenes provide the additional feature such as the visualization of objects in certain viewpoint based on the user position.

Several localization methods had been introduced such as Active Badge [2] that performs the position calculation based on line-of-sight infrared technology while Active Bat and Cricket utilized the microwave signals for localization. The well-known GPS [1] system possesses the ability to track user by transmitting the microwave signals between the satellite and receiver. LAMP3D [3] system supports the GPS services by synchronize the user position with virtual world displaying on the mobile device. Unfortunately, GPS is insufficient to track user specifically in indoor environment as the microwave signals can't penetrate through the building wall. Therefore, RSSI model is ideal range estimation as it doesn't required additional hardware or cost to support the signal transmission between transmitter and receiver. Lots of researchers utilized the WLAN system [4] on the RSSI to estimate user's location.

Most of the tracking system determines the user orientation based on the built-in camera on the mobile device itself. Thus, the exactly same system can't perform the angle calculation on the non-camera mobile device for instance PDA. In the light of this, our work designs a simple digital magnetic compass (DMC) to

cater such issue. DMC manages to calculate the orientation within 0.1 degree based on the earth magnetic. Nevertheless, the proposed compass integrated with wireless sensor node to transmit the data packets to the receiver attached to the PDA to update the viewpoint in 3D scenes dynamically. Our proposed system is beneficial in various fields such as the military, navigation, indoor route guidance as well as the monitoring of indoor construction.

2. System Design

Our work demonstrates the system design inside the hospital where the doctor (navigator) tracks a patient (target) by using the PDA (see Fig. 1). Reference nodes attached to the room ceiling transmit the coordinates and RSSI signals respectively to the blind node attached or hold by the patient. Eight highest RSSI signals are filtered as they provide the highest accuracy on distance computation. After gathered the nearby signals, blind node transmit the organized data packets including reference nodes ID as well as their respective RSSI signals to the base station attached to the PDA. Radio frequency may lose its path in the long distance. Thus, routing protocol programmed to transmit the signals in two or more loops through reference nodes nearby to reach to the base station. The PDA analyzes the packets received, render the VRML files into graphic pipeline and visualize the 3D scene on the PDA screen based on the estimation position and target current viewpoint.
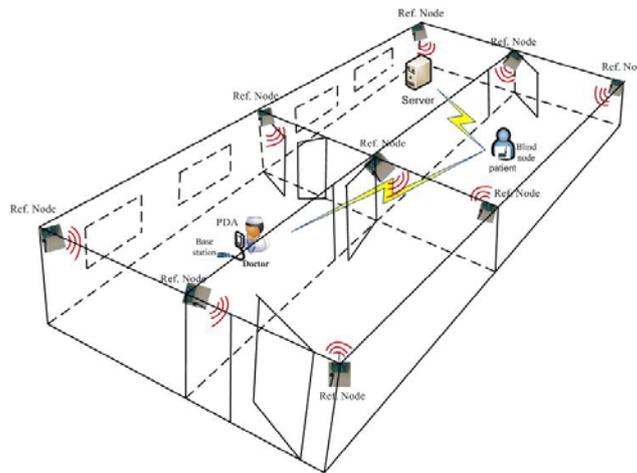

Fig. 1: System design.

3. Virtual Reality Modelling Language (VRML) for 3D Virtual Reality

VRML firstly designed for displaying the 3D objects on the World Wide Web (WWW). Even so, VRML had been utilized in various applications for education purposes or as the system user interface. The reasons behind this option are mainly because of its simplicity and fast rendering speed of 3D graphics on the low-power processing PDA. VRML is able to present the 3D objects through animated dynamic processing together with multimedia objects consists of video, sound and animation, suitable to model for an interactive 3D virtual reality. Moreover, its high-level abstraction and user interface with simple syntax prior to its platform independent definition.

VRML browser is required for the system to visualize the VRML files on the PDA screen. Pocket Cortona VRML browser [5] provides the features to customize the display scene, offered the user to view the scene in different viewpoint. Extra software CFCOM [6] is necessary to interact and manipulate VRML objects in VRML browser to allow mobile computing programming to handle VRML automation interfaces for accessing the multiple functionalities in VRML. Sadly, the limitation of VRML browser unable to determine the 3D objects whether are viewable or blocked from user viewpoint. Thus, a feasible culling algorithm is integrated to prevent the unseen 3D objects from rendering into the graphic pipeline.

3.1. Culling Algorithm

PDA used up lots of the processing time and memory just to render a large scale of complex 3D scenes to the screen. Static allocation of tracking system can accept the large-scale visualization time as time is not

an issue for such system. Our system is designed in the way such that continuous updating of 3D scene are the main advantages for the PDA mobile. In completing the culling algorithm, the 3D modelled 3D scenes are separated into few cells (rooms) to be rendered instead of the whole scene at a time. Technically, culling algorithm is performed in three phases. Cell-to-cell visibility indicates which cell to be rendered according to the user's current position. Next, cell-to-object visibility determines all the 3D objects that are located in that particular cell. Finally, object-to-object visibility culled the unseen 3D objects based on the user's current viewpoint. Fig. 2 depicts the output obtained after performing the culling algorithm on 3D scene.
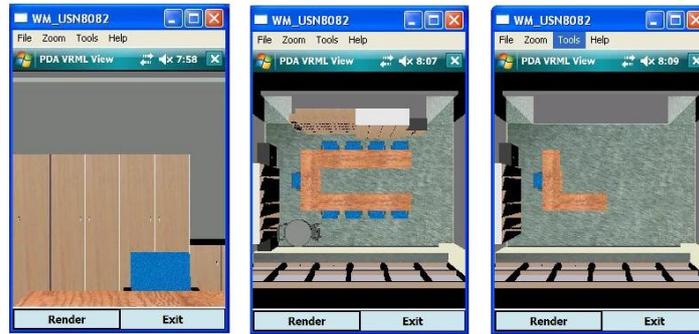

Fig. 2: Comparison of 3D scene with and without performing culling algorithm.

4. Indoor Location-awareness System

The optimization of RSSI signals on the existing WLAN suffered from the elimination of ray. Weak signals are unable to contribute for the distance and position calculation. Thus, a radiolocation device (CC2431 Chipcon [7], Norway) run on the IEEE 802.15.4 standard estimates the location based on transmitted and received signal strength between blind node and reference nodes. By default, the blind node gathered the acquired information from all the responding reference nodes, read out the position from CC2431 location engine and transmit to the base station. But, location engine provides high level of inaccuracy for calculated position. Instead of utilizing the position obtained, our paper focuses on estimate the user's location based on raw RSSI signals.

Received Packet from Blind Nodes
(RSSIi, Xi, Yi)

Distance Estimation

RSSI Smoothing Algorithm

- Estimation

$$R_{est(i)} = R_{pred(i)} + a(R_{meas(i)} - R_{pred(i)})$$

$$V_{est(i)} = V_{pred(i)} + \frac{b}{T_s}(R_{meas(i)} - R_{pred(i)})$$

- Prediction

$$R_{pred(i+1)} = R_{est(i)} + V_{est(i)}T_s$$

$$V_{pred(i+1)} = V_{est(i)}$$

- Distance Estimation

$$D = 10^{\frac{(RSSI-A)}{10n}}$$

Position Estimation
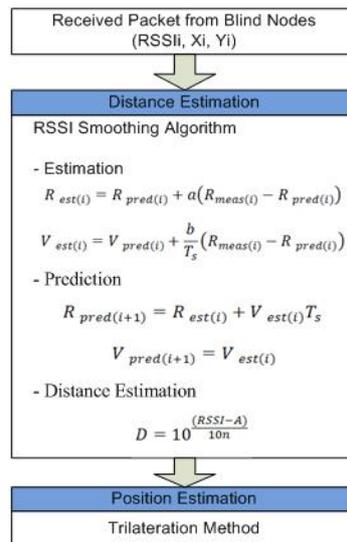
Trilateration Method

Fig. 3: RSSI smoothing algorithm.

Fig. 3 illustrates the RSSI smoothing algorithm to reduce the RSSI signal fluctuation caused by the environmental factor. Natural of signal behaviour implies that the signal strength varies over time even though target user remains on the same location. Before the smoothing algorithm can be performed, calibration process is conducted to analyze the RSSI signals due to different feature of non-isotropic path loss in different transmission medium and direction. CC2431 computes the RSSI signals (1) with two constant parameter values that obtain during the calibration process where n is the signal propagation

constant or exponent, A is the received signal strength at 1 meter distance. The value d is the distance from the sender that is estimated based on the RSSI signals received.

$$RSSI = -(10 n \log_{10} d + A) \tag{1}$$

$\hat{R}_{est(i)}$ is the ith smoothed estimation range, $\hat{R}_{pred(i)}$ is the ith predicted range while $R_{prev(i)}$ is the ith measured range. $\hat{V}_{est(i)}$ and $\hat{V}_{pred(i)}$ are the ith smoothed estimation range rate and the ith predicted range rate respectively. a and b is the gain constant and T_s is time segment upon the ith update (see Fig. 3).

Trilateration method estimates the final position with at least three reference nodes for the calculation. Our system used up to eight reference nodes at most to calculate the position. Multi-target tracking is identified based on the target node ID instead of naming each of them.

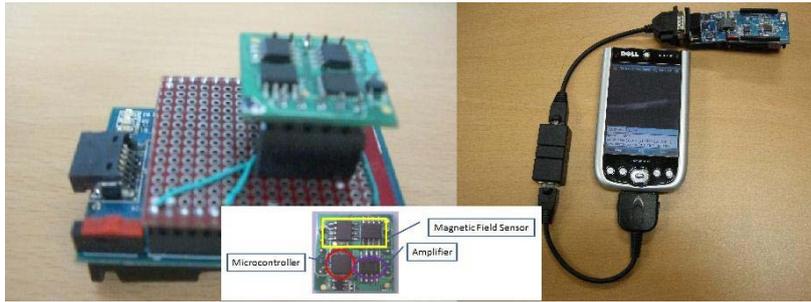## 5. Digital Magnetic Compass (DMC)

Fig. 4: DMC integrated with TIP710GM sensor node and connection of base station to PDA through RS232 serial cable.

DMC serves its purpose as the orientation indicator for 3D scenes, synchronized to the real physical world. Basically, the DMC is built up by 3 parts as shown in Fig. 4. Magnetic field sensors collect the magnetic field data with amplifier that enhances the sensitivity of the sensors. Microcontroller is responsible for internal processing to analysis, process and transfers the data to the integrated TIP710GM sensor node. Size of the DMC is 20mm x 20mm x 2.8mm with 5V energy consumption. A deviation error of 11.5 degree is encounter related to the true north error by the earth magnetic field. Even so, current DMC provides a compensation scheme for variation correction with ±1.5 degree accuracy.

6. Experiment Setup and Result Analysis

First of all, the rendering speed of the 3D virtual world is analyzed as it is the first issue on conducting this research. The comparison is made on few different cells where the position took place in the middle of the cell with viewpoint angle of 140 degree. The table 1 compares the results before and after the culling algorithm is integrated. The rendering speed increase at around 75% to 85% where additional time can be utilized for other processes.

Table 1: Comparison of rendering time before and after culling algorithm is performed.

Cell	Render 3D Duration (Without CA)	Render 3D Duration (With CA)
U801	1 sec	0.2 sec
U802	1 sec	0.2 sec
U803	2 secs	0.5 sec
U804	1 sec	0.2 sec
U805	1 sec	0.2 sec
U806	1 sec	0.2 sec
U807	2 secs	0.5 sec
U808	2 secs	0.5 sec

In fig. 5, the RSSI signals fluctuation received from the different reference nodes are reduced by applying the RSSI smoothing algorithm. RSSI fluctuation still exists, but it somehow minimizes the error rate to an acceptable range. Finally, the fig. 6 depicts the results obtained by locating the two targets at the same time in real-time condition. It shows that by targeting two or more users, the error increase rapidly as more signals are intercepting with each others in a single room.
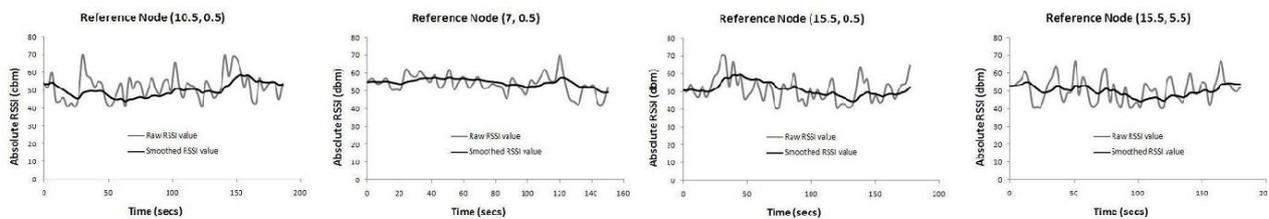
Fig. 5: RSSI smoothing algorithm to reduce the signal fluctuation in indoor environment.
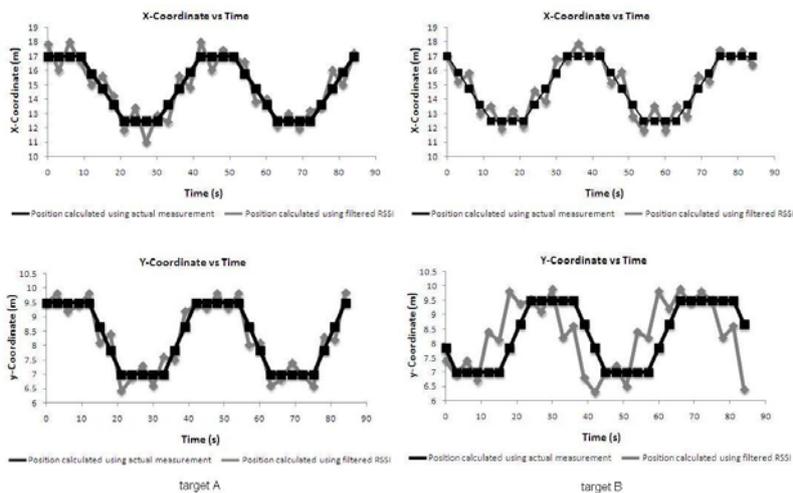

Fig. 6: Position estimation for 2 different targets in real-time situation.

7. Conclusion

3D virtual world distinguished from the old style 2D flat representation is that user tends to recognize the objects around the nearby area to search for the route to destination. Therefore, it proven that the 3D provides more useful information that benefit to mobile user. Nevertheless, our system managed to decrease the rendering time of 3D visualization on low power processing PDA. Accuracy refinement algorithm too possesses the ability to increase the accuracy of estimated position. Less complicated but flexible accuracy refinement algorithm is needed to compete with the PDA processing time.

8. References

[1] Jiung-Yao Huang, Chung-Hsien Tsai. Improve GPS Positioning Accuracy with Context Awareness. *Ubi-Media Computing, 2008 First IEEE International Conference on.* July-Aug. 2008, pp. 94-99.

[2] R. Want, A. Hopper, V. Falcao, and J. Gibbons. The Active Badge Location System. *ACM Transactions on Information Systems 10(1)*. January 1992, pp. 91-102.

[3] Burigat S., and Chittaro L.. Location-aware Visualization of VRML Models in GPS-based Mobile Guides. *Proceeding s of the 10th International Conference on 3D Web Technology ACM Press, New York*. 2005, pp. 57-64.

[4] F. Lassabe, P. Canalda, P. Chatonnay, F. Spies. A Friss-based Calibrated Model for WiFi Terminals Positioning. *In Proceedings of the Sixth IEEE International Symposium on a World of Wireless Proceedings of the Fourth Annual IEEE International Conference on Pervasive Computing and Communications Workshops (PERCOM'06).* 2006.

[5] Pocket Cortona – ParallelGraphics. http://www.parallelgraphics.com/products/cortonace/.

[6] CFCOM Odyssey - http://www.odyssysoftware.com/products/developertools/CFCOM/tabid/75/Default.aspx.

[7] CC2431 Development Kit User Manual – http://focus.ti.com/docs/toolsw/folders/print/cc2431dk.html.