Application of WiFi-based Indoor Positioning System in Handheld Directory System

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Abstract: - The purpose of this paper is to introduce a handheld indoor directory system which built on WiFi-based positioning techniques. The whole system consists of three modules, namely mobile phone module, Kiosks module, and Website and Database module. The mobile phone module is the main frontend module which installed on users' mobile devices, whereas the Kiosks and website are to provide supports and maintenances to the main module. User can download maps and application from the Kiosks or website. On the other hand, administrator uses the website to manage the database. The proposed system is aimed to provide a new ways of providing indoor floor directory, which offers capabilities to retrieve customizable information, to navigate interactively, to enable location-awareness computing and most importantly the portability of the directory system. Additionally, the proposed system is designated to cater for the needs of visually challenged persons by incorporating screen reader and improved accessibility.

Key-Words: - WiFi Positioning, WLAN positioning, Navigation system, Mobile Application, Visually impaired

1 Introduction

Navigation has always been an issue, especially when a person is in an unfamiliar area. Directories and maps are the vital facilities which assist visitors to reach their desired destination or to have a feel of the building layout. A common form of directories is in the form of a physical board, placed in the strategic positions which highly visible to the visitors.

It is usual that vast numbers of information and labels are shown on the directory boards. However, humans have the cognitive limitations to process huge amount of information. Visitors often need to spend long time to filter out irrelevant labels and information, in order to focus on their point of interests. They might also subject to disruption due to lost trace in the congested directory. At the same time, the physical directory board is subject to the limitation of maximum user at a single point of time. Additionally, the main inefficiency of the conventional directory board is its immobility. Users need to memorize the place of interests, route to reach the place, and it is not uncommon that users need to memorize multiple places and routes.

Approximately 314 million people are visually impaired worldwide, and about 87 percent of the world's visually impaired live in developing countries [1]. Despite of the high distribution of visually impaired persons in developing countries, the indoor facilities to assist the group is much less sophisticated compared to developed countries. The Visually challenged persons often encounter tougher issues when they newly arrive at a building. Moreover, they are almost impossible to use the conventional directory, as it does not provide the accessibility for those visually challenged. For instance, the fonts used in the directory are often small and enriched with different colors and a style in order to make the directory has more attractive appearance [2].

In relevant to aforementioned issues, an interactive and customizable directory which has the portability to be carried around would be much appreciated. Furthermore, the implementation cost of the new directory must be considerable low, in order to allow it being widely adopted and beneficial to larger groups of user. Therefore, the purpose of this paper is to introduce a handheld directory system, which allows users to use their mobile device as an interactive and customizable indoor directory. The proposed floor directory system is built on WiFi-based positioning techniques to provide the capability of real time positioning, interactive navigation, and the provision of location-triggered information. Furthermore, a kiosk with touch screen acts as a part of the whole system which not only to allows users to download maps of the area through Bluetooth, but to cater for the needs of users whose mobile device does not support WiFi connection. Additionally, the proposed floor directory system caters for the needs of visually challenged persons by incorporating dedicated features and functionalities such as screen reader and legibility of the interfaces.

Next section of this paper presents and discusses various positioning techniques. Then, the discussion narrowed down to WiFi-based positioning and various wireless positioning techniques, which form the foundation of this research. Section 3 presents the proposed directory system in terms of its overall architecture and system design. Section 4 presents the implementation of the proposed system

2 Literature Review

2.1 WiFi-based Positioning System

In order to remedy the shortfall of GPS technology, many researchers have proposed alternate indoor navigation systems, e.g. ultrasonic-based system, pseudo-satellite technology, Bluetooth, RFID-based system, wireless signal positioning, TV signal positioning, and IP address positioning [3]. However, most of these positioning systems rely on proprietary infrastructure and often entail expensive deployment [4]. As a kind of the alternate navigation system developed, WLAN-based positioning system has received much attention recently. The scope of this paper is focus on the WLAN-based positioning system, which also refers as WiFi-based positioning system.

Compared to these other positioning systems, wireless positioning system (WPS) that based on Wireless Local Area Network (WLAN) infrastructure has certain advantages, including availability and readiness of infrastructure, low deployment cost, easy to implement, and signal stability. Currently, given that many buildings are equipped with WLAN access points (shopping malls, universities, office buildings, airports, etc.), WLAN based positioning system has become practical to use these access points (usually in the form of wireless routers) to determine user location in these indoor environments [4]. In other words, the WLAN based positioning system utilizes the existing communication equipment, thus significantly reduce the implementation efforts and costs. Major part of the positioning system can be implemented in software.

Moveover, provided that most of the mobile device such as cell phones are enabled with wireless radio communication network interfaces (such as Wi-Fi), protocols which to provide location estimation based on the received signal strength indication (RSSI) of wireless access points are becoming more-and-more popular, precise, and sophisticated.

Additionally, WLAN is also known as a stable system due to its robust Radio Frequency (RF) signal propagation compared with the other systems. For instance, the performance of video or IR-based positioning systems is negatively affected by line-of-sight (LOS) obstructions or light conditions, such as fluorescent lighting or direct sunlight [5].

2.2 Wireless Positioning Techniques

There are numbers of techniques have been developed by researchers to determine or estimate the position of the mobile device by different properties of signal from the WLAN Access Points (APs). Bose and Heng summarized various WLAN-based positioning techniques into Cell Identity (Cell-ID), Time of Arrival (TOA), Time Difference of Arrival (TDOA), Angle of Arrival (AOA), and signal strength based method [6].

Cell identity (Cell-ID) makes use of the radio coverage of an identified cell to indicate the location of a mobile device. It does not require complex operation such as time synchronization and multiple Access Points. The main shortcoming of this technique is its accuracy since usually the coverage of a cell is wide and due to its simplicity. Moreover, the presence of high rise buildings and many stationary points in an urban setting make this method inaccurate due to multi-path propagation and signal reflection [7].

In Angel of Arrival (AOA), the position of the mobile device is determined by the direction of incoming signals from other transmitters whose locations are known. Triangulation technique is used to compute the location of the measured mobile device. However, a special antenna array is required on the AP and be capable of mounting them under static conditions [5].

Time of Arrival (TOA) measures a distance using the travel time of a radio signal from a transmitter to a receiver. Once the distances from a mobile device to three stationary devices are estimated, the position of the mobile device with respect to the stationary devices can easily be determined using the intersecting circles of trilateration. Its application requires very accurate and tight time synchronization of the transmitter and receiver, which is difficult to achieve for close ranges [8, 9].

As a remedy to the shortfall of TOA, Time Difference of Arrival (TDOA) was developed, which utilizes the time difference between receiver and two or more receivers [6]. Thus, TOA require time synchronization between transmitters and receivers, whereas TDOA only requires synchronization between receivers.

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Signal Strength based technique uses the signal attenuation property of the radio wave – Received Signal Strength Indication (RSSI) to measure the distance from a receiver to transmitter using the distance-to-signal-strength relationship. One common approach of RSSI-based system is fingerprint approach, which entails two phases: a training phase and a tracking phase. In the training phase, the received signal strength information is filtered, interpolated, and eventually stored in a database as sample points. In the tracking phase, the position is determined by comparison with the received signal strength sample points stored in the database [10]. The accuracy of this system is a function of the sample points' sampling space, an estimation method and the structure of the database. However, such a method requires the time consuming survey procedure

3. Handheld Indoor Directory System

3.1 System Overview

The proposed interactive floor directory system, named "Guide Phone", is a solution to provide floor directory and indoor navigation services, by utilizing mobile phone itself as both an interactive directory panel and as a signal processing device for navigational purpose. In other words, the proposed solution intended to change the conventional way of providing indoor directory, which usually in the form of physical directory board located inside a building. The purpose of Guide Phone is to provide interactive, portable, customizable ways to navigate within an indoor environment. The following subsections present the features of the proposed "Guide Phone".

3.1.1 Interactivity

Guide Phone is coined as interactive directory system, given that it capable of providing richer information contents, rather than just static information as in the conventional directory board. Additionally, users can request only the information which is in their interests. In other words, information is tailored and customized according to personal needs. For instance, users can search a specific location by name, level, or other characteristics. Richer information such as products, contacts, and direction can be provided to users. This implies significant time savings, enhanced user satisfaction and improved efficiency.

3.1.2 Location-Awareness Information

As the Guide Phone use WLAN-based positioning technique, it able to provide location–awareness information to users. As the most fundamental function, users can track their current location in the map. In advance, customized information can be sent to user when they are in certain positions, to provide further description or relevant information regarding the current surroundings. Specifically, shopping mall or commercial building can capture the benefit of this functionality to customize their advertisements and to increase the flow of crowd into their premises.

3.1.3 Not Required to Connect to Access Points

Apart from that, the positioning technique does not require the mobile device to connect to a wireless access point (AP) such as wireless router, but only need to detect the signal transmitted from the access points. This feature is valuable given the reason that it is common that most of the APs are encrypted with passwords, thus make the positioning system which require connection to the APs infeasible. Nevertheless, Guide Phone only needs to detect the strength of the wireless signal in order to estimate the location of the users.

3.1.4 Flexible and Self-Contained

Flexibility represents the capability of Guide Phone to use different maps with minimal efforts by downloading the map of particular building from the Kiosk provided or the management website. In other words, the capability of the Guide Phone is expandable to cover any new building or place. The Guide Phone is a self-contented system when it is in action. The sensor, signal processing application, database are all included in the mobile phone. Thus, the phone application can operate independently without request any service from server.

3.2 Overall Architecture

The whole "Guide Phone" system consists of three main modules, namely mobile phone module, Kiosk module, and Website and Database module, as illustrated in Fig. 1.

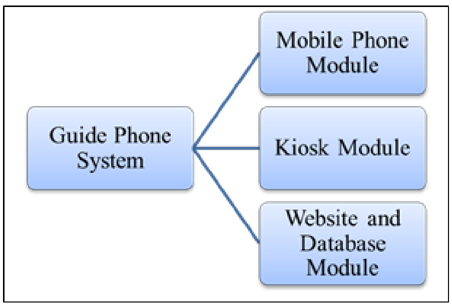

Fig. 1 Main Modules of Guide Phone System

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3.2.1 Mobile Phone Module

Mobile Phone module is the application which installed on the users' mobile device. The purpose, input, operation, and output of the module are indicated as in Table 1.

Table 1 Description of Mobile Phone Module

Purpose • To enable searching of lots/rooms by user • To determine current location of user • To provide sufficient information of a lot/room.
Inputs • User's search request would be needed in order to perform the search functions. • 3 MAC address, latitudes, longitudes and signal strengths will be needed to calculate the current location of the user using triangulation. • User's selection of the lot/room will determine the result of the full details of the lot/room.
Operations • Database and query function A mobile database is stored internally in the mobile phone and contains all the data similar to the database of the web and the kiosk, which contain the maps and layout data. Users define the criteria used to search or filter the destination of interests. • Wi-Fi detection function To detect the available access points for triangulation purposes. It also includes functions to determine the access points with the strongest signal strength. • Triangulation function Consists of functions and algorithms to carry out triangulation based on the coordinates given in order to calculate the current location of the user based on the strength of wireless signals. • Location mapping function Location mapping consists of functions which enables the exact location of the user to be displayed in the form of an image so that the user can navigate around the area. Basically it displays the results of triangulation.
Outputs • List of search results. • The user's current location on a map. • Details on a lot/room selected by the user.

3.2.2 Kiosk Module

As part of the whole Guide Phone system, touch sensitive kiosks are provided in the building. Users can download the Guide Phone application and maps of the building from the Kiosk through Bluetooth or USB connection. Moreover, the Kiosks act as complementary facilities to cater for the needs of users whose mobile device does not has WiFi adapter. It provides the identical functions available to Mobile Phone module, with exception of the positioning tracking system. This is due to the reason that as the Kiosks are fixed in certain location, it does not make sense to provide the real-time positioning function.

3.2.3 Website and Database Module

The website and database can be described as the backend portion of the Guide Phone system. The main purpose of this module is to allow administrators to manage the maps and other data such as location of wireless points, details of rooms or premises, and so on. However, users can access to the frontend of this module to perform the exact same functions of Kiosk module, which are to download map, mobile module application, and search functions.

3.3 Hardware and Software Architecture

Fig. 2 indicates the overall hardware and software architecture of the Guide Phone system.

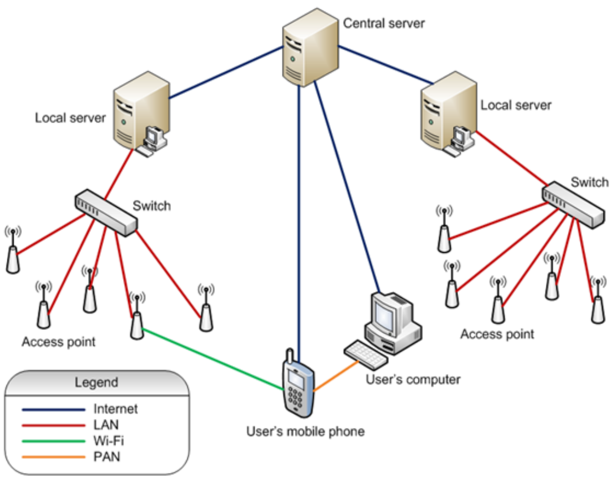

Fig. 2 Overall System Architecture

The central server will be the server hosting the website and database of Guide Phone. The central server will also store the latest Guide Phone application which can be downloaded by the user. The central server will provide access to the data stored to the local servers. The central server will be administered by an administrator who has access to all the local servers as well as the data stored in them.

The local servers reside on the location itself. For example, a shopping complex will have its own local server which will control many access points in the area. Therefore, the more areas implement the Guide Phone, the more local servers will be connected to the central server. The local server will be administered by the area's administrator who can edit and update the details regarding that area only.

The access points function as a guide for triangulation. Each access point will have its own

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location and with this information, triangulation for a user's current location can be determined. The access points can also function as a gateway for users to access the local server to get the Guide Phone application as well as the database and maps of that specific area.

There are two ways for the end user to download the Guide Phone application. One of it would be through direct download whereby the user can connect their phone to the Internet and then download the application to their mobile phones. Another method would be to access the website on the central server using a computer, download the application and transfer the application to the phone. After downloading the application, the user can now use the Guide Phone application.

3.4 Process Flow for End User's Operations

Firstly, a mobile user must turn on his mobile phone's Wi-Fi connectivity. After it is turned on, the user will start the Guide Phone application.

If the application is not yet available in the mobile phone, the user can download the application and the mobile database containing a location's data from the website. After the application is loaded, the user selects the database of his current location. If the database is not available, he can download it. Once the database has been loaded onto the application, the user can now access the functions of the application. The user can choose to search for a lot/room or search for his current location.

If the user wants to search for a lot/room, the user can search either by category, name or level. Once the search is complete, the list of search results will displayed in the user's mobile phone. The user can then select the exact lot/room he was looking for or search again. If the user selects a lot/room, the lot/room details would then be displayed along with the lot/room's picture. After getting the information needed, the user can opt to search for his current location, conduct a search again or end the application.

If the user selects to search for his current location, the application will then detect the access points available in the area and extract 3 access point's MAC address. If the access points cannot be detected, the application will refresh until a few access points are detected. These 3 access points have the strongest signal strength. The MAC address will then be stored into the phone and the mobile database will be accessed to find the coordinates of the access points based on their MAC address. With the coordinates, the current location of the user will be calculated using triangulation. The results will then be displayed to the user. The user can then opt to end the application or continue to browse around the application. The overall system use case diagram is shown in the appendix session, which provides the overall view of the system functionalities.

4 System Implementation

The proposed system has been implemented in a building located in a university. The following shows the user interfaces of the system main modules.

4.1 Interface of Mobile Device Module

The application is developed to run on Windows Mobile, using C# language. Fig. 3 shows one of the main interfaces which users can see the description of the building, and a menu of available actions is provided at the bottom. Fig. 4 illustrates the interface of search by category. Relevant results will be shown according to the category pre-assigned to the rooms.

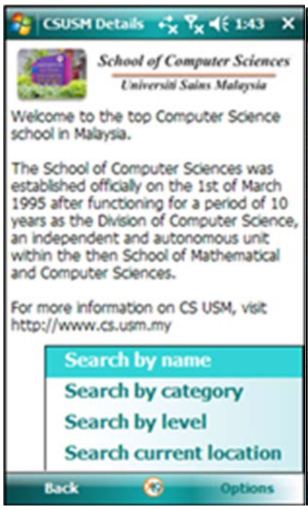

Fig. 3 Main Menu

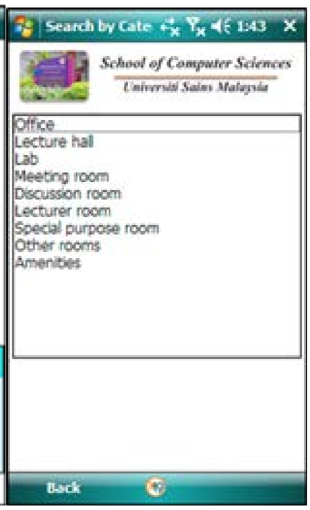

Fig. 4 Search by Category

The option "search by level" implies the function will query the database to retrieve the room which on the level or floor that match the criteria selected by users. With the "search by name", it provide the flexibility for user to customize the search by typing in the keywords that related to the room. The search current location shows the map with the real-time position of users, which shown in Fig. 5. By clicking on the area in the map, user can view the details of the particular selected area, as illustrated in Fig. 6.

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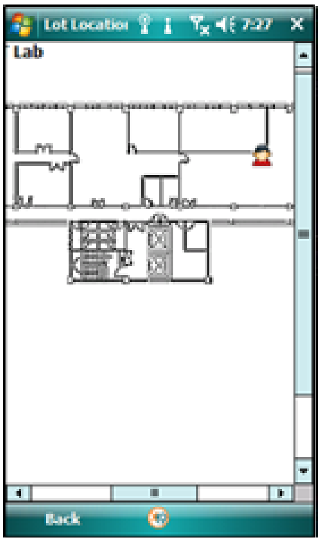

Fig. 5 Current Location

Fig. 6 Details of Location

4.2 Interfaces of Kiosks and Website

The Kiosks and website interfaces which accessible to the users are similar in terms of functionality. Fig. 7 shows a sample of the user interface on Kiosks. The functions available are identical to the functions offered in mobile phone module, with the exception of search by current location.

Fig. 7 User Interface for Kiosk and Website

A user can view the directory for the location. Upon hover over any lots, the area will be highlighted and the name for the lot will appear. User can also click on the lot to view further details. To make the kiosk accessible by even the blind users, a screen reader (NVDA, an open source screen reader for Windows) is used. Alternate texts are used for images to allow blind users to visualize the items which appear on the kiosk screen.

5. Conclusion

Although the implementation involves the most fundamental functionalities, but it is resulted in sufficient data and information for the purpose of assessing the practicality and technical feasibility of the Guide Phone system.

The proposed Guide Phone as a handheld directory system is promising innovation. Provided the pervasiveness of WiFi access points in current buildings such as shopping malls, office and administrative buildings, and tourism spots, the proposed Guide Phone system can be implemented with low cost by utilizing the existing infrastructures. In addition, Smartphones with WiFi adapter have penetrated the market in developing countries than ever before. WiFi or WLAN adapters have become necessities of modern mobile devices which not limited to mobile phone but also other devices such as tablet PC, netbook, and iPod. These imply that the proposed system can be implemented not only in Window Mobile platform, but can be used in other platform in the future.

Nevertheless, one of the limitations of the proposed directory is that the triangulation algorithm used to estimate the position of mobile device requires at least three WiFi access points in order to successfully function. Moreover, more sophisticated functions such as location-specific message, voice guided direction to destination, and inter-users connectivity can be introduced into the Guide Phone system in future.

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APPENDIX – OVERALL USE CASE