Indoor Positioning With Opportunistic Navigation in Android Smartphones

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***Abstract*— This paper aims to introduce an android application that positions a user in an indoor environment and allows him to navigate opportunistically through the indoor space. RSSI (Received Signal Strength Indication) technique together with trilateration is proposed to cater this solution. In a typical scenario, when a user walks inside a building, a smartphone client conducts a single communication with our server to receive the RSS radiomap and is then able to position itself independently using the observed RSS values. Opportunistic Navigation is then enabled that allows the user to navigate himself.**

Keywords—RSS fingerprints, radiomap, trilaterate

I. INTRODUCTION

Context-aware computing is one of the building blocks of ubiquitous and pervasive wireless computing. Location awareness is the key capability of context-aware computing. A system deployed to determine or estimate the location of an entity is called a position location system or positioning system [1].

The success of outdoor positioning and applications based on the global positioning system (GPS) provides an incentive to the research and development of indoor positioning systems. Unfortunately, the GPS system cannot be used effectively inside buildings and in dense urban areas due to its weak signal reception when there are no lines-of-sight. This has motivated research over the last 15 years and has led to the development of several indoor positioning systems.

The typical behavior of people in a space filled with points of interest is one of browsing or exploring. People generally enter a space with an ill-defined goal such as “enjoy the art collection.” In the space, they will generally browse in order to find pieces that interest them. These users navigate a space by wandering around and searching for pieces that interest them. Once a piece is identified as one that is of interest to the user, generally the user will engage in some sort of interaction with the piece, such as requesting more information. We call such a method of navigating a space opportunistic navigation [2]. Users are opportunistically moving through a space; taking advantage of any opportunities to view pieces which interest them. It is the responsibility of the designers of systems which assist in navigation to ensure that their system allows for such a behavior.

Location fingerprinting, which utilizes radio signals, is a technique that identifies the location of a user by characterizing the radio signal environment of the user. A majority of previous localization approaches employ Received Signal Strength (RSS) as a metric for location determination. RSS fingerprints can be easily obtained for most off-the-shelf equipments. In these methods, localization is divided into two phases: training and serving. In the first phase, traditional methods involve a site survey process, in which engineers record the RSS fingerprints (e.g., WiFi signal strengths from multiple Access Points, APs) at every position of an interesting area and accordingly build a fingerprint database. Next in the serving phase, when a user sends a location query with its current RSS fingerprint, localization algorithms retrieve the fingerprint database and return the matched fingerprints as well as corresponding locations.

In this paper, we present an android application that positions the user in an indoor environment and allows user to opportunistically navigate through the indoor space. We use the RSS fingerprinting approach for localization and enable opportunistic navigation via numbers overlaid on the floorplan map.

II. RELATED WORK

A. Indoor Positioning

In the literature of indoor localization, a well-known research direction, many techniques have been proposed in the past two decades. There are some existing precise indoor localization techniques, however, they require specialized infrastructure and hardwares. Active Badge [3] use infra-red transceivers to range distance and performs localization. SNUGL [4] can achieve centimeter lever accuracy using pseudolites system. Cricket [5] performs localization using ultrasound, and LANDMARC [6] uses RFID array to detection people movement. These precise indoor localization systems are hindered by the system cost and the requirement of additional localization hardware.

EZ [7] proposed a crowdsensing based indoor localization, which exploited the possibility of automatically establishing the mapping between fingerprint set and floor plan. Acoustic ranging (AR) assisted Wi-Fi positioning was recently developed to provide distance estimation between two users.

B. Opportunistic Navigation

The field of device-assisted navigation has seen numerous projects in the past and will no doubt continue to be a hot area

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of research. Location-Based Notification Systems like the GUIDE project [8] provide a real world application designed to guide tourists around the city of Lancaster. Tourists using the system are guided around the city by their virtual companion. The system points out and identifies nearby landmarks which the user may be interested in.

The Cyberguide project, detailed in [9], is a location-based notification system developed at Georgia Tech. It is a family of prototype systems, consisting of both an indoor and outdoor model. Both projects were designed to guide visitors around their respective spaces.

Another project in the field of location-based notification services is the Marble Museum project described in [10]. It is a navigational assistant available for use by visitors to the Marble Museum in Carrara. Visitors walk through the museum with a PDA and are made aware of nearby pieces of art and can request further information.

III. SYSTEM ARCHITECTURE

In this section we present the overall vision of the system as shown in Fig. 1. The working process consists of two phases: training and serving.

During the training phase (radiomap construction), a number of RSS fingerprints are collected a priori at some predefined reference locations using a commercial device. All raw fingerprints are preprocessed in the preprocessing module. Each RSS fingerprint is then associated with the respective local coordinates and stored in the so called radiomap in the server.

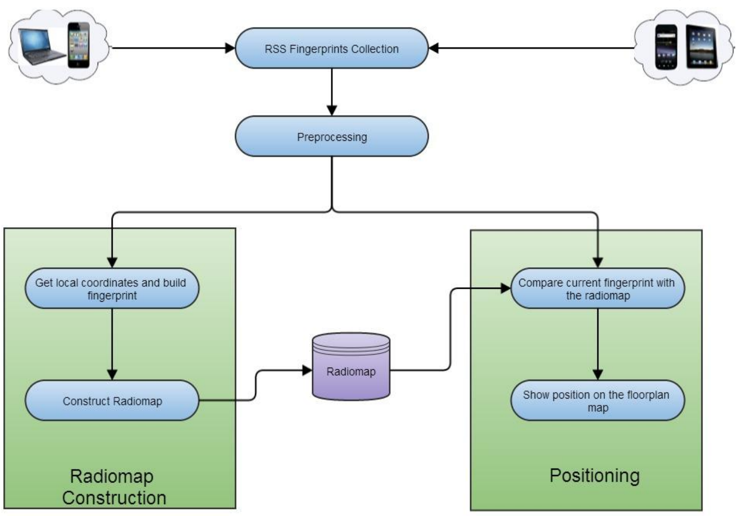

Fig 1. System architecture

In the serving phase (positioning), a user sends a location query with his/her currently measured RSS fingerprint. The positioning application which is a client, connects to the server to download the radiomap and compares the current RSS fingerprint with the fingerprints in the radiomap. The most similar fingerprint is selected and the estimated user's position is shown on the floorplan map.

IV. RADIOMAP CONSTRUCTION

The main objective of the training phase is to construct the radiomap or fingerprint database. An application is developed around the Android RSS API to scan and record RSS values at every location of interests. In the preprocessing module, because the value of RSS is unstable, we find the average of the RSS values collected and associate it with the MAC address of the AP to build the fingerprint. This process is repeated for each and every AP that is heard.

We then trilaterate to get the local coordinates at which the scanning was initiated. The distances (d_1, d_2, d_3) between the local coordinates and the APs (AP_1, AP_2 ,AP_3) required for trilateration are obtained by the Log-distance path loss model. Then three intersecting circles with radius (d_1, d_2, d_3) are constructed, the centre of the circles are the locations of the three APs and the intersection of these circles will be the local coordinate (X, Y).

We then store the fingerprint built along with the local coordinates in the database at server which forms the radiomap.

V. LOCATION ESTIMATION

When a user enters with the application installed in his/her phone, the radiomap is downloaded from the server. Then RSS values at his/her position is recorded and preprocessed to get the fingerprint.

The current fingerprint is compared with the fingerprints in the radiomap using Euclidean Distance. If the current fingerprint is S=(s_1, s_2, , , s_n) and the recorded fingerprint is R=(r_1, r_2, , , r_n), then the Euclidean distance is calculated as

$$L = \min dis(S,R), dis(S,R) = \sqrt{\sum_{j=1}^{N}\left(s_j - r_j\right)^2} \quad \text{---- (1)}$$

where s_j is signal strength observed by user form jth AP, r_j is signal strength recorded in database, j=1…N. L is the minimum Euclidean distance between each R in database and S. The smallest Euclidean distance between R and S mean the smallest distance between user current position and reference point recorded in database. So the estimated location is the location corresponding to the smallest RSS Euclidean distance which is recorded in database.

VI. ENABLING OPPORTUNISTIC NAVIGATION

The next phase is to enable opportunistic navigation in the application. A system that supports opportunistic navigation allows users to explore the space on their own, providing relevant information as necessary.

Our application provides navigational information through its use of floorplan map, showing the layout of the region the user is in. By utilizing this floorplan, the application conveys topographical information to the user so that he may determine a path through the space. The application identifies the nearby points of interest via numbers overlaid on the map. The location of the point of interest in the user's region is indicated by the location of the number on the map. Thus opportunistic navigation is enabled in the application.

VII. CONCLUSION

Opportunistic navigation is a natural behavior of humans when presented with a space filled with points of interest. People naturally begin to explore, seeking out objects which merit further inspection. We create a navigational system which allow and encourage this behaviour. The user enters an indoor environment, such as a university campus or a shopping mall, covered by several WLAN APs (Access Points). The user's smartphone obtains the RSS radiomap and parameters from the local distribution server. Then the client positions itself independently using the downloaded radiomap and the currently observed RSS fingerprint. The system also provides the user the points of interest around him and information for the user to choose the points to interact with. It then provides directions to get to the point chosen by the user.

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