WiFi Based Indoor Positioning System

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April 16, 2015

Abstract

Global Positioning System is the most prominent contribution in determining position of user and in routing him to his destination. This system uses satellites to triangulate the location of the GPS device. Though this system has made a good impression in terms of accuracy and is the preferred location based system for outdoor positioning, when it comes to indoor environment, GPS has proved to be inefficient. The reason for its inefficiency is that in order for GPS to perform a triangulation, the device needs to be in line-of-sight from the satellites. Moreover, GPS system has a low precision which make it not suitable for indoor areas. Therefore, when it comes to indoor positioning system, other alternatives such as Bluetooth, WiFi, RFID and Infrared are more preferable. This project proposes to implement a mobile application which will be able to estimate the position of a user within a building using WiFi technology.

1 Problem Definition

Design and implement a mobile application which will be able to estimate the position of a user within a building using WiFi signals.

2 Motivation

WiFi can serve as a potential candidate as an alternative to GPS as it is commonly found in buildings. The strength of radio signals emanating from WiFi routers is inversely proportional to distance, this fact can be used to calculate an approximate location of user in a closed environment. Such a system would be useful for navigation inside malls, locating users inside a building etc.

3 Related Works

Rui Zhang et al presents an approach to determine indoor location from within smart phones [1]. The method utilizes the devices accelerometer and gyroscope sensors to recursively calculate the position based on acceleration and angular rate of movement (Pedestrian Dead Reckoning). Calibrating sensors prior to calculation can greatly increase accuracy.

Trehard et al. presents a solution by integrating an anemometer to the smart phone for speed estimation in their approach [2], the orientation information is obtained directly from the smart phone, which will be easily disturbed by local magnetic field and cannot be relied on to achieve high positioning accuracy.

Kim and Kim use geomagnetic field to obtain the position information in [3]. However, the database in respect of geomagnetic field at each location has to be constructed previously.

There is another approach called collaborative positioning, which uses communication to improve positioning accuracy [4]. Collaborative positioning can reduce cumulative positioning error of PDR using communication, when PDR and communication are both enabled in the smart phones. There are several participants who have a Smartphone, walking independently of each other. They conduct PDR to estimate their position but this includes cumulative positioning error. Collaborative positioning has the participants communicate and measure the range between each other and then correct each of their positions to make them consistent with the range information.

4 Design

4.1 Location Fingerprinting

The WiFi network inside a building makes it possible to distinguish different locations as they would receive different strengths from various routers. The received signal strengths thus act as a fingerprint for a location. Location fingerprinting based positioning systems usually works in two phases : calibration and positioning.

In calibration phase, several positions inside a building are chosen and RSS values from the different access points are recorded. Each of the n measurements become a part of a radio map and is a tuple

$$(q_i, r_i) \qquad i = 1, 2, ..., n$$

where

$$q_i = (x_i, y_i)$$

are the geographical coordinates of the ith location and

$$r_i = (r_{i1}, r_{i2}, ..., r_{im})$$

are the m RSS values from m access points at that location.

In positioning phase, the RSS values are recorded from an unknown location and a location estimator algorithm is used to find its coordinates from the previously created radio map

4.2 Weighted k-Nearest Neighbours (WKNN)

The location estimator algorithm being used is the weighted k Nearest Neighbours Algorithm [5]. It is a two step process:

1. Find out the k nearest neighbours in the radio map

Input : Set of all n readings from calibration phase

$$(q_1, r_1), (q_2, r_2), ..., (q_n, r_n)$$

Reading from current unknown location, r

Output : Set of k nearest points.

Procedure:

Sort the n points in increasing order of Euclidean distance with current reading r. Euclidean distance is calculated by considering the readings as vectors.

Return first k readings in the sorted list

$$(q_1, r_1), (q_2, r_2)...(q_k, r_k)$$

2. Calculate the coordinates of the current unknown location

Input : Set of k nearest points

$$(q_1, r_1), (q_2, r_2)...(q_k, r_k)$$

Output : Coordinate of current unknown location

Procedure:

Calculate coordinates using the formula

$$q = \sum_{j=1}^{k} \frac{w_j q_j}{\sum_{l=1}^{k} w_l}$$

Where all weights are nonnegative

$$w_j = d^{-1}_{(r_i, r)}$$

d is the Euclidean distance between the readings.

q_j is the coordinates of the j^{th} location

WKNN has one tuning parameter, the number of nearest neighbours considered (k), which is used to control the locality of the location calculation. When k = 1, the algorithm acts as a simple look-up table. For larger values, the location will be estimated to be somewhere in-between the calibration points.

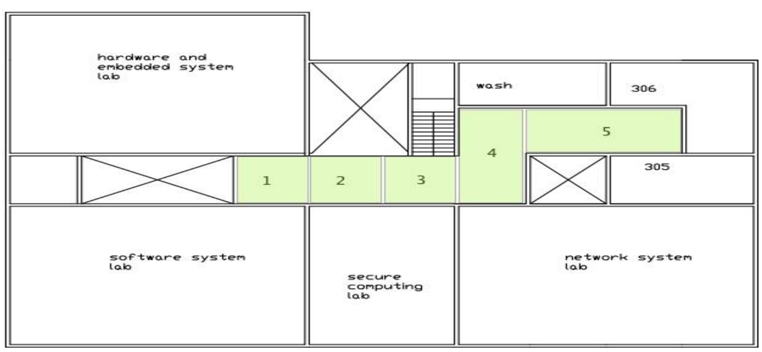

Figure 1

5 Practical Difficulties

Various factors influence the level of accuracy of the system in practice, these were identified and their effects were minimised to the possible extend.

1. Fluctuating Received Signal Strength (RSS) readings

The readings taken from a particular location could fluctuate often and can result in errors. This could be rectified by using the average of several readings from the same location

2. Identifying reliable Access points

The access points considered for positioning purpose should be a permanent part of the structure and ideally be available at all times. Including temporary hotspots into the system should be avoided as they could negatively impact the calculations if they were relocated.

3. Orientation of users

The orientation in which the user holds the smart phone can alter the signal strengths received at that location. This can be accounted to the users body obstructing the signals from one particular direction. Orientation specific readings should be taken in the calibration phase to counter this factor.

4. Proper positioning of Access points

The access points inside a building should be positioned in such a way that each location is uniquely identified in terms of the WiFi fingerprint described earlier. But there is limitation regarding what can be done in this matter.

6 Work Done

To perform the experiments, a prototype Android application of an indoor positioning system that works entirely on the users device (without requirement to have a back-end server) was developed. The application allows determining the position of the device using a prepared radio map and device built-in Wi-Fi chipset. The application works in the two location fingerprinting phases calibration phase and positioning case.

During the calibrations phase, user can select the reliable access points for that particular building. This rules out readings from other access points from being considered for calculation. The experiment was done inside the top floor of CSED Lab building. The floor was divided into 5 grids as shown in Figure 1. In the calibration phase, the available Wi-Fi access point RSSs are measured from different positions in the building. The measurements were taken for a defined period of time 30 seconds (readings became much more consistent then) and after that the average value is calculated and stored into the radio map.

In positioning phase, the application determines the actual position. RSS values of all the sensed APs are measured and compared to the ones in the prepared radio map to get the nearest neighbour. The nearest neighbour will be shown as a coloured grid in the floor map. This method only uses the radio map as a look up table.

In calibration phase, the application has the following functionality:

1. Create/Remove a building
2. View/Add/Remove points to the selected building.
3. Perform fingerprinting by selecting the point from the list.
4. Add/Remove reliable access points from the list of available access points.

Functionality in the positioning phase:

1. Load and view map of the building.
2. Estimate position (in the form of grids as marked in the loaded map).

The readings taken from the calibration phase and the friendly WiFi list are backed up to a server and this enables new users to skip this phase by downloading these already calibrated readings.

At the time of positioning, the WiFi access points in the vicinity of the new device is compared with the saved points to dynamically ascertain the building and floor map to be loaded in the application.

A web page is created that saves the latest positions of all devices and allows users with proper priviledge to view them.

7 Future Work/Conclusion

The RSS Value at a particular location varies from device to device. So proper normalization of the readings should be done to get the application to work seamlessly in different devices.

Orientation specific values should be stored to the database in the calibrations phase. Only the values corresponding to the current orientation of the user (obtained from device sensors) should be considered in the positioning phase.

The second part of WKNN algorithm has to be implemented to get the users coordinates in between the chosen points from calibration phase.

References

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