WIFI BASED INDOOR POSITIONING SYSTEM

A THESIS
Submitted by

AJNAS KT B110403CS
and
JAZEEM MUHAMED BASHEER B110152CS

In partial fulfilment for the award of the degree of

BACHELOR OF TECHNOLOGY
IN
COMPUTER SCIENCE AND ENGINEERING

Under the guidance of
Dr. VINOD PATHARI

DEPARTMENT OF COMPUTER ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT
NIT CAMPUS PO, CALICUT
KERALA, INDIA 673601

May 15, 2015

ACKNOWLEDGEMENTS

We wish to express our profound gratitude to Dr.Vinod Pathari, Associate Professor, Department of Computer Science and Engineering , National Institute of Technology, Calicut for his constructive criticism and valuable suggestions throughout the course of the project.

We also take this opportunity to thank Abdul Nazeer, Head of Department, CSE for providing us the venues to improve our work.

We would also express our gratitude to all the Faculty members of Computer Science and Engineering Department, National Institute of Technology, Calicut, for their thoughts and valuations on our project.

AJNAS KT

JAZEEM MUHAMED BASHEER

DECLARATION

"I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgment has been made in the text".

Place:
Date:

Signature :
Name :
Reg.No:

CERTIFICATE

This is to certify that the thesis entitled: "**WIFI BASED INDOOR POSITIONING SYSTEM**" *submitted by Sri* ***AJNAS KT*** *and Sri* ***JAZEEM MUHAMED BASHEER*** *to National Institute of Technology Calicut towards partial fulfillment of the requirements for the award of Degree of Bachelor of Technology in Computer Science Engineering is a bonafide record of the work carried out by him/her under my/our supervision and guidance.*

Signed by Thesis Supervisor(s) with name(s) and date

Place:
Date:

Signature of Head of the Department

Office Seal

Contents

Abstract

Almost everybody relies on Global Positioning System for providing location information, weather forecast and navigation. GPS enabled devices can determine location by connecting to four or more satellites. The system works with remarkable accuracy in outdoor environments and provide crucial information to users worldwide. The need for unobstructive line of sight connection with satellites make GPS inefficient in indoor conditions. Positioning and navigation are being a real need for indoor spaces as buildings with as much as over 3 million sq ft floor areas are constructed around the world. Alternate systems for GPS are being researched and developed for indoor spaces using popular wireless technologies such as Bluetooth, Wifi, RFID and Infrared. 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.

Figures

Figure

Chapter 1

Problem Definition

To build a mobile application which will be able to estimate, store and display the latest position of a user inside a building using WiFi technology.

The application should work in two phases, one for calibration and the other for positioning.

Calibration module learns about the WiFi access points and their signal strengths inside the building in different distinguishable positions. This data learned will be in sync with a server database to make it available for other users as well.

Positioning module uses the already learned data available in the server database to find the user's current position. Both the phases should work independently. This enables a normal user to locate his position without going through calibration phase. The latest location of the user will be sent back to the server and would be available for display.

Chapter 2

Literature Survey

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. proposes another method by making use of an anemometer present in the smart phone for estimating device speeds [2]. This data coupled with orientation of device obtained from the local magnetic field readings increases the accuracy of positioning.

Kim and Kim use geomagnetic field to obtain the position information in [3]. This requires a table to be constructed beforehand connecting each position with its geomagnetic field reading.

Collaborative positioning uses messages between devices to increase accuracy [4]. This approach can be done as an extension to Pedestrian Dead Reckoning, but can decrease cumulative error every device correcting each other. These devices start by working independently using PDR.

Chapter 3

Design

3.1 System Overview

The system has two independent phases as displayed in the figure 3.1. The two phases being the calibration phase and positioning phase. The calibration phase scans the Radio Signal Strengths (RSS) values of wifi access points for different positions inside the building and later this data is updated to the server database. During the positioning phase, the RSS Values obtained from the unknown position are used in the position estimator algorithm to obtain an estimate position of the user.

3.2 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.

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

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

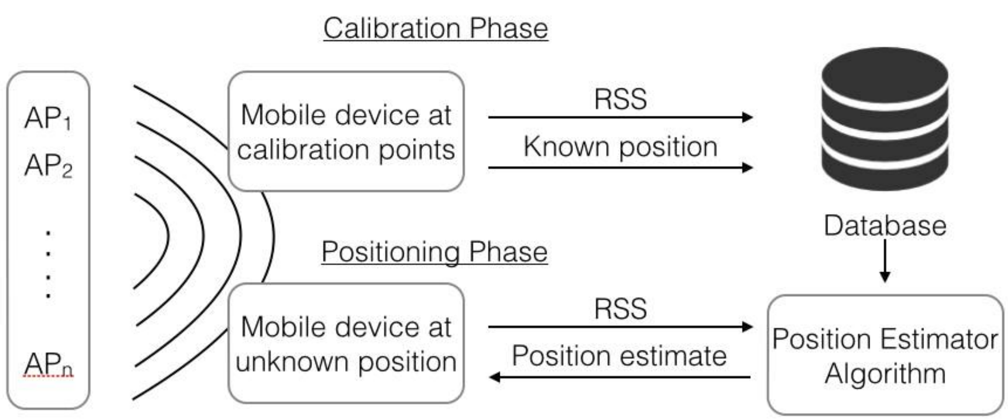

Figure 3.1: High level system overview

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.

3.3 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

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

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.

Chapter 4

Work Done

4.1 Prototype Android application

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 6 grids as shown in figure 4.1 . 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 calibration phase, the application has the following functionality:

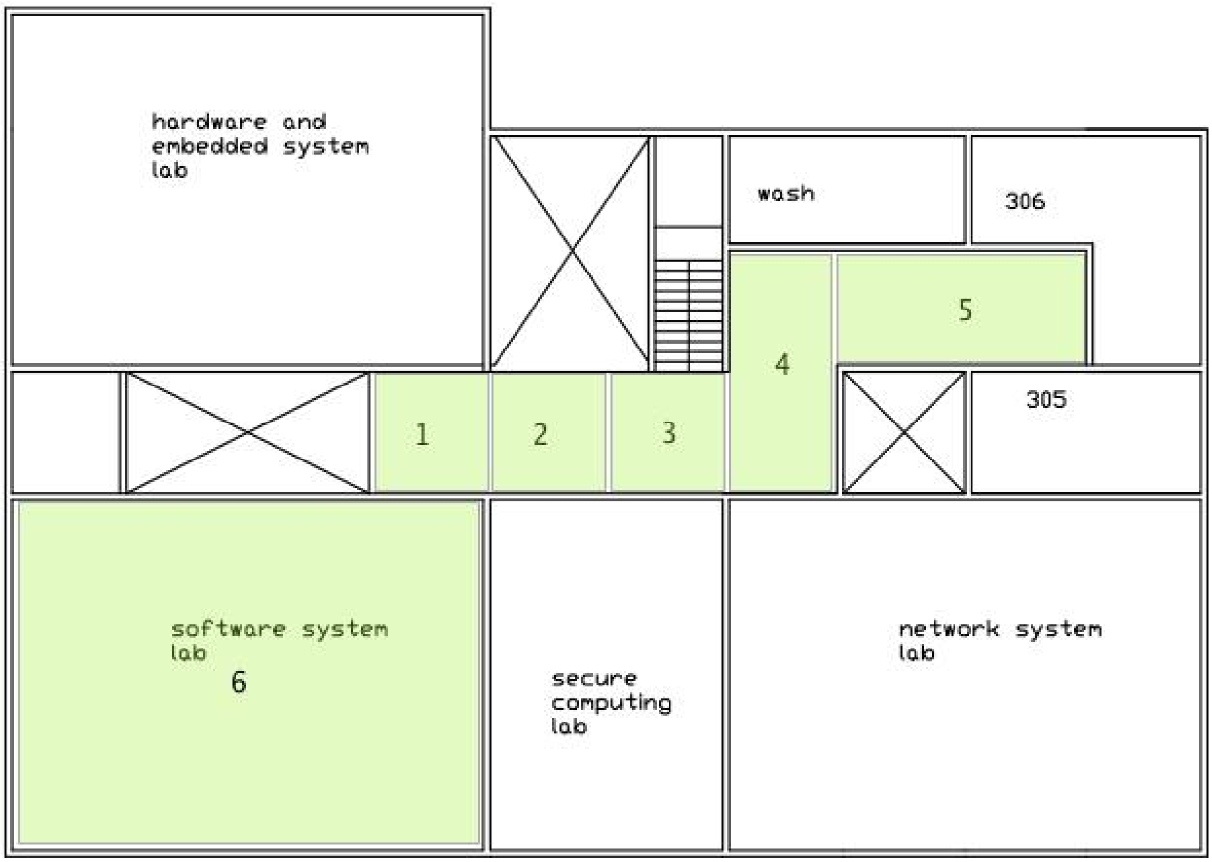

Figure 4.1: Floor map of CSED lab building

(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.

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.

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).

4.2 Backend Server

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.

4.3 Faculty Tracking System

After successful implementation of the prototype android application, a useful practical application was found in the form of a system that could achieve live tracking of various faculty members of the Computer Science and Engineering Department.

The system consists of a modified android application designed for monitoring the wifi signals in the devices vicinity as a background process. The estimated user location is updated to the server regularly whenever the WiFi adapter of the device is turned on.

A web page is created that shows the latest positions of all devices which are connected to the system. A screenshot of the same is shown in figure 4.2

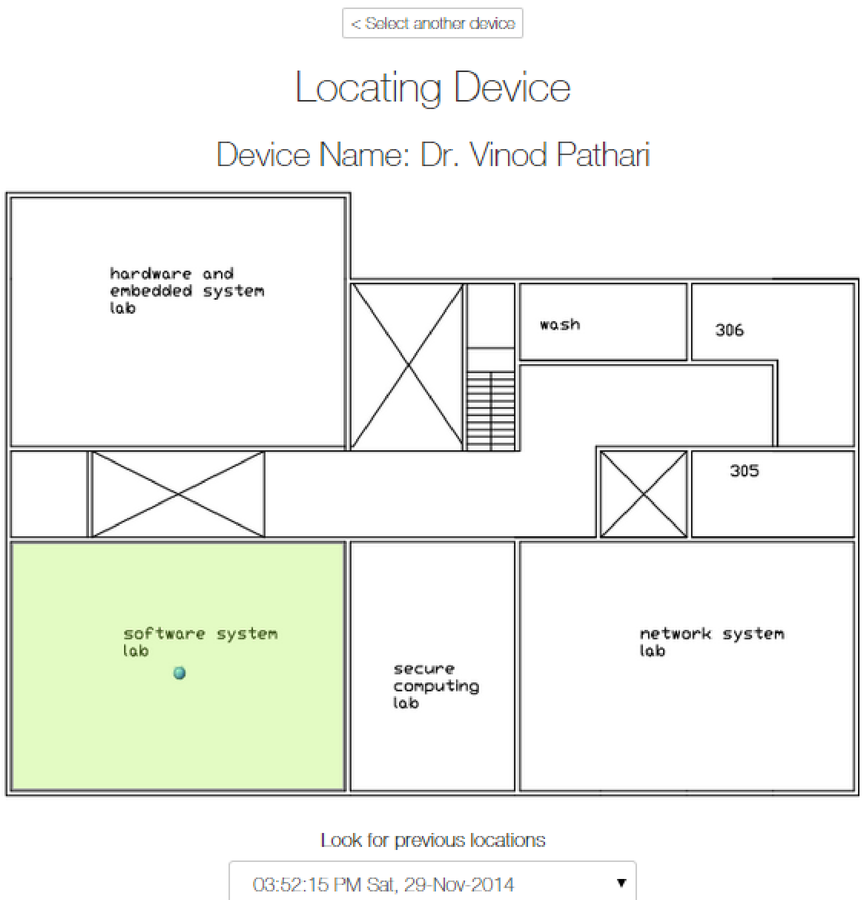

Figure 4.2: Screenshot of web interface

Chapter 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.

5.1 Fluctuating Received Signal Strength (RSS) readings

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

5.2 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.

A provision to choose these 'Friendly WiFis' from the list of available access points is added to the learning phase of the application to solve this issue. The estimator algorithm then filter outs the non reliable access point readings from the calculation.

5.3 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 by the users body obstructing the signals from one particular direction. Orientation specific readings were taken in the calibration phase to counter this factor.

But the desired effect were not seen even after having distinct readings for the 4 cardinal directions. Moreover, this approach proved to be computationally intensive as the application had to calculate the device orientation from the magnetometer and accelerometer sensors periodically.

5.4 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.

5.5 Normalizing RSS Values

The RSS Value obtained at a particular location varies from device to device. This is due to the quality difference in hardware for Android devices. So proper normalization of the readings should be done to get the application to work seamlessly in different devices.

Proper normalization would require the application to be tested on more than 9000 devices that comes preloaded with Android OS in the market.

Chapter 6

Conclusion

The project explored a very practical approach for providing a suitable substitute for GPS that could work in indoor environments. Since it uses WiFi signals for position estimation, the system could be implemented on almost all buildings without additional infrastructure cost.

The application could estimate the user location in favourable conditions with an accuracy of approximately 2 meters.

6.1 Possible Extensions

The system could further be improved by

6.1.1 Navigation Support

The system currently can only calculate position of the user. By adding a navigation module on to the application, the position obtained can be used to guide the user to his preferred location inside the building. This becomes very useful inside large indoor areas like airports.

6.1.2 Augmented Reality Integration

Coupled with an augmented reality module, the application could use the devices camera and orientation sensors to provide user with useful interactive information.

This can be used in shopping malls wherein the user can point his camera to various outlets that surrounds him and see the latest offers.

Bibliography

[1] Rui Zhang, A. Bannoura, F. Hoflinger, L.M. Reindl, and C. Schindelhauer. Indoor localization using a smart phone. In Sensors Applications Symposium (SAS), 2013 IEEE, pages 38–42, Feb 2013.

[2] S. Lamy-Perbal G. Trehard, M. Boukallel. Indoor pedestrian localisation solution based on anemometery sensor integration with a smartphone. In 2012 International Conference on Indoor Positioning and Indoor Navigation (IPIN), November 2012.

[3] E. S. Kim and Y. Kim. Geomagnetism-based indoor location estimation method for future smartphone. In 2012 IPIN, pages 13–15, Nov 2012.

[4] M. Angerman P. Robertson, MG. Puyol. Collaborative pedestrian mapping of buildings using inertial sensors and footslam. In 2011 ION GNSS, 2011.

[5] Vadims uravovs Gints Jkabsons, Vadim Kairish. An analysis of wi-fi based indoor positioning accuracy. In Applied computer systems,Vol.47, Scientific Journal of the Series of Scientific Journal of RTU 2011, pages 131–137, 2011.