Project

On

Infrastructure Free Indoor Localization System

Submitted in partial fulfilment of the degree of

Master of Computer Application

By

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TO WHOM IT MAY CONCERN

This is to clarify that the project entitled ***"Infrastructure Free Indoor Localization System"*** *has been completed by* ***Ankit Padia.*** *This work is carried out under the supervision of* ***Dr. Sarbani Roy*** *in partial fulfilment for the award of the degree of* ***Master of Computer Application*** *of the department of* ***Computer Science and Engineering, Jadavpur University,*** *during the session 2018-19. The project report has been approved as it satisfies the academic requirements in respect of project work prescribed for the said degree.*

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CERTIFICATE OF APPROVAL

This is to clarify that the project entitled ***"Infrastructure Free Indoor Localization System"*** *has been completed by* ***Ankit Padia.*** *This work is carried out under the supervision of* ***Dr. Sarbani Roy*** *in partial fulfilment for the award of the degree of* ***Master of Computer Application*** *of the department of* ***Computer Science and Engineering, Jadavpur University,*** *during the session 2018-19. The project report has been approved as it satisfies the academic requirements in respect of project work prescribed for the said degree.*

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Candidate's Name **:** Ankit Padia
Exam Roll No **:** MCA 196002
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CONTENTS

Abstract

Indoor Localization requires the continuous tracking of user's position and his/her surroundings for the purpose of dynamically planning and follow a route to the user's intended destination. The Global Positioning System (GPS) made the task of navigating outdoors relatively straightforward, but due to lack of signal reception inside buildings, navigating in an indoor environment has become a very challenging task. However, increasing smartphone capabilities have now given rise to a variety of new techniques that can be harnessed to solve this problem of indoor navigation. In this report, we propose a navigation system for smartphones capable of guiding users accurately to their destinations in an unfamiliar indoor environment, without requiring any expensive alterations to the infrastructure or any prior knowledge of the site's layout. Our application incorporates the scanning data from bluetooth device and using those values in the Path-Loss Model to accurately define the target location in an indoor environment applying the Trilateration technique where we use the geometry of circles and solve for the quadratic equations to localise the target.

Chapter 1

Indoor Positioning System

An indoor positioning system (IPS) considers only indoor environments such as inside a building.[1] The location of users or their devices in an indoor location can be determined by an IPS by measuring the location of their mobile devices. Dempsey defines an IPS as a system that continuously and in real-time can determine the position of something or someone in a physical space such as in a hospital, a gymnasium, a school, etc. From this definition, an IPS should work all the time unless the user turns off the system, offer updated position information of the target, estimate positions within a maximum time delay, and cover the expected area the users require to use an IPS. An IPS can provide different kinds of location information for location-based applications required by the users. The absolute location information is provided by some IPSs. Before the position can be estimated, the map of the locating area such as an office, a floor, a building, etc., should be available and saved in the IPS[12]. With respect to the map, the absolute position of a target can be measured and displayed. Usually, the absolute position information with respect to the map of a coverage area is offered by indoor positioning tracking systems and indoor navigation systems, because tracking and guiding services need the exact positions of the targets. The relative position information is another kind of output offered by the IPSs, which measures how different parts of a target move. For example, an IPS which tracks whether the door of a car is closed or not, needs to give the relative position information of the tracked point on the door with respect to the body of the car. The third kind of position information is proximity location information, which specifies a target's location.

1.1 Motivation

We usually find Gps tracking systems to track an android phone location on Gmap but what if we run out of internet connection or Gps. Or what is we want to track our location on a map. Well here we propose a **W**e usually find Gps tracking systems to track an android phone location on Gmap but what if we system that uses bluetooth signals to pinpoint an Android cellular device within the four walls of a room. Here we do not need any internet or gps connection to do so.The system is built to use bluetooth signals and map the signal strength locations so as to inform the user about his/her exact location indoors.

1.2 Contribution

Beacon-based distance measurement approaches are very valuable to estimate users' locations in indoor active media environments given that global positioning system (GPS) cannot be utilized in indoor environments. Traditional approach revises measured beacon distances to improve the accuracy of the measured beacon distances, which assumes that received-signal strength indicator (RSSI) is increased in the proportional to the measured beacon distance. However, RSSI is not increased linearly. Therefore, the errors of the revised distances are invoked. A log-distance path loss model-based relative distance estimation method has been proposed in this paper. By applying a log-distance path loss model, errors that one face when using revised distances can be reduced. In the experiments, the proposed method was compared to the traditional method, which shows the improved result that the accumulated error of the proposed method is decreased to 80% comparing to that of the traditional method.

1.3 Indoor Positioning Technologies

Indoor positioning systems (IPS) use sensors and communication technologies for locating objects in indoor environments. IPS are attracting scientific and enterprise interest because there is a big market opportunity for applying these technologies. Most of the many prior surveys on indoor positioning systems lack a robust classification scheme that would structurally map a wide field such as IPS or omit several crucial technologies or have a limited perspective; ultimately, surveys rapidly lose their usefulness in an area as dynamic as IPS. The aim of this paper is to provide a technological viewpoint of indoor positioning systems, consisting of a wide range of technologies and approaches [9].

1.3.1 Wireless Local Area Network

Wireless local area network (WLAN) technology is used for wireless exchange of data in computer networks, in a limited distance of 20–100 m from access points. WLANs are based on IEEE 802.11 standards (Wi-Fi brand name). They operate in 2.4 or 5 GHz frequency bands and can achieve throughput in excess of 1 Gbit/s. Indoor positioning systems relying on WLAN technology use multiple WLAN access points to determine the target's position in an area. In order to improve accuracy, additional access points must often be added to the existing network. Most common techniques for IPS implemented with WLANs are fingerprinting and signal propagation modelling.

1.3.2 Radio-Frequency Identification

Radio-frequency identification (RFID) is a technology that uses radio waves to store and retrieve data between a reader and a tag. RFID readers are able to read data emitted from RFID tags. RFID is a cheap and flexible wireless technology that already found widespread usage in identification of objects (inventory, personnel, animals etc.), but it can also be used to determine position of an object in a mapped area. There are two types of RFID technologies. One is the passive RFID where the tracked tag is a receiver. The working range of passive RFID systems is short (1–2 m). They work in several frequency bands (usually LF:125-134kHz, HF and NFC: 13.56 MHz, UHF: 865–960 MHz) and their price is low. The tag modulates and reflects a signal back to the transmitter and does not require a power source for its operation. The other RFID type is active RFID, where tracked device is a transmitter. Active RFID systems can cover longer distances (10–100 m) and usually operate in the 433 MHz or 915 MHz frequency bands. Their price is higher than the price of passive RFIDs. The device acts as a ‘beacon’ and periodically transmits signals containing ID, or some other data, to readers. RFID usually uses proximity techniques to detect weather a target is in range of a reference point.

1.3.3 Ultrasonic System

Ultrasonic positioning systems use sound frequencies above the upper audible limit of human hearing (usually around 40 kHz). Such systems determine target's position by measuring the time needed for a signal to travel from a transmitter to receivers. Audible sound IPSs work on similar principles but ultrasonic systems are more convenient since they are not intrusive to people who are using (or are surrounded by) the system. A disadvantage of the technology is that new infrastructure, in form of sensors and transmitters, is needed in every room where the system is used.

1.3.4 Bluetooth Technology

Bluetooth technology is used to transfer data over short distances (10-100m, with Bluetooth 2.0). It is defined in IEEE 802.15.1 as a form of a Wireless personal area network (WPAN) and works in 2.4 GHz frequency band with data transfer rates of 1–3 Mbit/s. The main purpose of the Bluetooth technology is to create a simple wireless communication that doesn't require LOS. Because of Bluetooth's low price and complexity, today, this technology is present in most smartphones and wireless computer peripherals.

iBeacon by Apple is a technology standard that uses Bluetooth Low Energy (BLE) for proximity measuring. One of iBeacon's purposes is to enable users to locate products in stores by telling them proximity to the wanted item or a shelf. The system can also be used for indoor positioning by distributing beacons on predetermined fixed points in an area and then triangulating position with usage of multiple proximity measurements. Beacons transmit signals, while an application installed on portable devices determine proximity of each beacon: immediate (less than 50cm), near (between 50 cm and 3 m) and far (3–30 m). iBeacon applications are available on both Android and iOS.

1.3.5 Inertial Sensor

Inertial sensors, such as accelerometers and gyroscopes, in combination with other sensors (e.g. compass) can be used to determine a target's speed and direction. When speed and direction are obtained, having knowledge of initial position, we can estimate the future position – dead reckoning technique. An advantage of this technology is that most modem smartphones have all the sensors necessary for dead reckoning. A disadvantage is the accumulation of errors in cases where small deviations in calculation of direction can cause large errors in estimation of position as long distances are travelled. To reduce the error accumulation, a lot of dead reckoning based IPSs also use particle filtering (PF) algorithms. Inertial technology IPSs are usually used in combination with some other technologies (i.e. WLAN, Bluetooth, RF).

Application of IPS

➢ Indoor Navigation

The position monitoring and tracking systems in hospitals are such examples. The IPS should provide the room where a patient is. Thus location-based applications in hospital can monitor whether the patient enters a correct room for diagnoses or operations.[12]

➢ Personnel Tracking

The position monitoring and tracking systems in hospitals are such examples. The IPS should provide the room where a patient is. Thus location-based applications in hospital can monitor whether the patient enters a correct room for diagnoses or operations as shown in Figure 1.

➢ Rescue Operation

Indoor location data is critical in emergency situations. Command centers need to find their operational forces. Rescuers need to find potential victims to save lives in case of calamities like earthquake, landslide or a fire outbreak. In emergency scenarios, the fast conduction of victims to exit (evacuation) and the precise monitoring of the rescuers' position are both important to reducing deaths and injuries [12].

➢ Autonomous Robot Navigation

Robot localization means how much a robot is able to establish its own location and orientation within the frame of reference. For path planning, one needs to determine the robot's current location and a goal location, within the same coordinate system. Map building can be in the form of a metric map or any notation describing position coordinates in the robot's frame of reference.[8]

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Figure 1: Indoor Navigation Sketch[9]

Chapter 2

Bluetooth Based Positioning System

2.1 Log Distance Path Loss Model

The **log-distance path loss model** is a radio propagation model that predicts the path loss a signal encounters inside a building or densely populated areas over distance.[10]

One can extend the log distance path loss model to the Friis free space model. One can predict the loss of propagation for a wider range of environments, whereas, the Friis free space model is restricted to cases where the path between the transmitter and the receiver is without obstruction. The model encompasses random shadowing effects due to signal blockage by solid objects. As such, one can also refer to it as log normal shadowing model.

The ***path-loss exponent (PLE)*** values are given in the following Table, for reference purposes only. They should not necessarily be associated with the actual environment we are trying to model. Usually, PLE is considered to be known ***a-priori***, but mostly that is not the case. Care must be taken to estimate the PLE for the given environment before design and modelling. Equating the empirically observed values over several time instants give us an estimate of the PLE, to the established theoretical values as shown in Figure 2.[6]

Environment	**Path Loss Exponent (n)**
Free Space	2
Urban area cellular radio	2.7 to 3.5
Shadowed urban cellular radio	3 to 5
Inside a building - line-of-sight	1.6 to 1.8
Obstructed in building	4 to 6
Obstructed in factory	2 to 3

Figure 2 :Table showing PLE for different environment

Path Loss depends on the environment i.e. on where the transmitter and receiver are located. Path loss models are developed via numerical methods and empirical approximations of measured data from channel sounding experiments. Generally speaking, propagation path loss is an increasing function of both frequency and distance:
Pl=10log10(16π2dnλ2)

where P_l is the average propagation path loss, d is the distance between the transmitter and receiver, n is the path loss exponent (varying between 2 for free space and 6 for obstructions in building propagation), and λ is the free space wavelength defined as the ratio of the speed of light in meter per second to the carrier frequency in Hertz.[7]

2.2 RSSI Based Path Loss Model

The positioning accuracy is affected by the complex noise present in the measured (by intelligent terminal) RSSI. Bluetooth systems can seldom transmit signals with fixed power - This results in time-varying characteristics of RSSI. Furthermore, the indoor electromagnetic environment is complex, including the likes of multipath fading and noise[10]. Upon testing the RSSI fluctuation of two Bluetooth beacons manufactured by different companies, as shown in Figure 3, it is clear that due to the instability of the Bluetooth system, both of the RSSI values are time-dependent and the maximum fluctuation value is approximately 10 dBm. A sliding or average filter is usually applied for decreasing the random fluctuation of the RSSI and improve the positioning accuracy. But, the frequency setting of Bluetooth can be kept low so as to reduce power consumption. Relying on multiple RSSI values to smooth means an increase in latency. Implementation of a RSSI-based low-latency, high-precision positioning system is thus, hampered. [6]

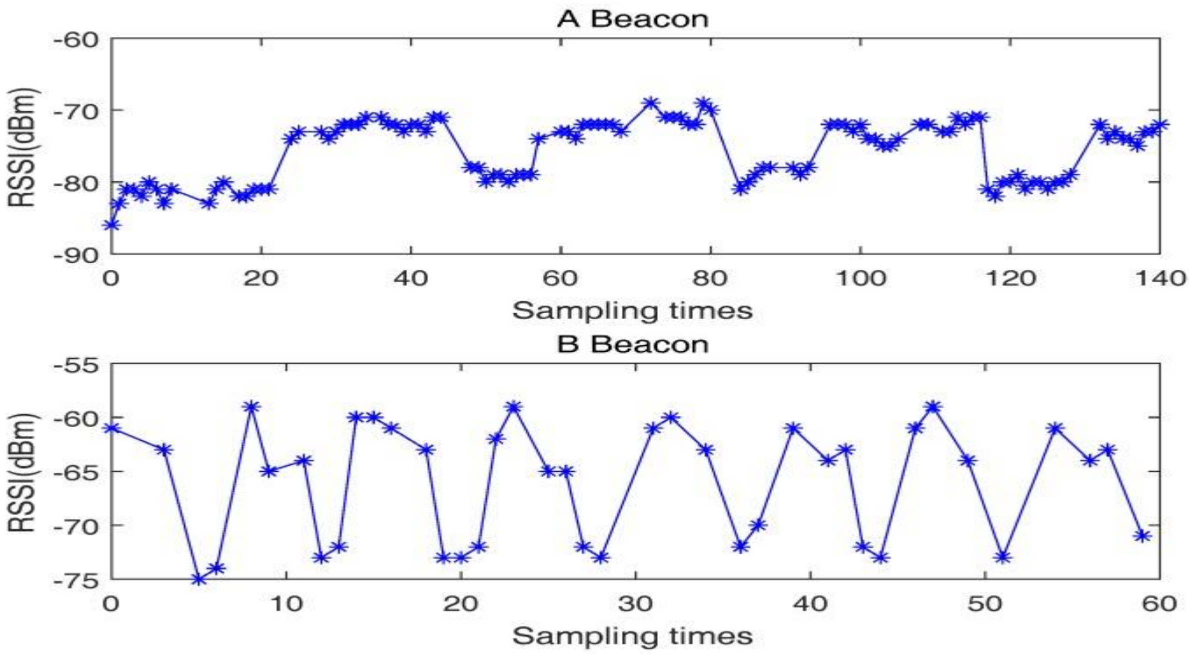

Figure 3 :Bluetooth Signal Strength[13]

RSSI Distance Model

Common propagation path-loss models include models like the logarithmic distance path-loss model and the free space propagation model. Studies have shown that the channel fading characteristic follows a lognormal distribution. One generally uses the logarithmic distance path-loss model to measure RSSI distance[13]. It is expressed as

$$\mathrm{RSSI} = -10\mathrm{n}\log\left(\frac{d}{d_0}\right) + \mathrm{A} + X_{\sigma} \tag{1}$$

where d is the distance between the transmitter and the receiver, and n is a path-loss parameter related to the specific wireless transmission environment. The more obstacles there are, the larger n will be. A is the RSSI with distance d_0 from the transmitter. X_σ is a Gaussian-distribution random variable with mean 0 and variance σ^2.

For convenience of calculation, d_0 usually takes a value of 1 meter. Since X_σ has a mean of 0, the distance-loss model can be obtained with

$$\overline{RSSI} = -10\mathrm{n}\log(\mathrm{d}) + \overline{A} \tag{2}$$

where $\overline{A}$ is the average measured RSSI when the received node is 1 meter away from the transmit node which is related to the RF circuits of Bluetooth nodes. By gathering the RSSI values for Bluetooth beacons at different distances and using the least squares algorithm to fit the parameters, we can obtain the RSSI distance model[10].
From (2), we see that one needs to precisely estimate the parameters A and n to improve the ranging accuracy. Parameter n is related to the wireless transmission environment and can be obtained by fitting a large number of experimental measurements. A is determined by the Bluetooth transmit power. As far as an ideal scenario goes, the value of A for a single Bluetooth beacon should be constant. In reality, the Bluetooth transmit power possesses characteristics that varies with time. The complex indoor environment makes it difficult to calculate the relationship between RSSI and the distance, to sufficient precision, by using the logarithmic distance loss model. Fitting of the RSSI distance model has been accomplished by neural networks. However, since the BP neural network is prone to converging to a local minimum point, it is difficult to obtain a good indoor RSSI distance model. The particle swarm optimization algorithm (PSO) can be used to optimize the weights and thresholds of the BP neural network and can effectively prevent the BP neural network from falling into the local optimal solution and decrease the time for convergence.

2.3 RSSI Real-Time Correction Algorithm

For reduction of the positioning error caused by RSSI fluctuation, we monitored the RSSI fluctuation in real-time through the Bluetooth gateway and compensated for the RSSI measured by the blind nodes. Our system model is shown in Figure 4, where B_1, B_2, B_3 and B_4 are the Bluetooth anchor nodes, M is a Bluetooth gateway, and N is a blind node (usually a user or mobile terminal).

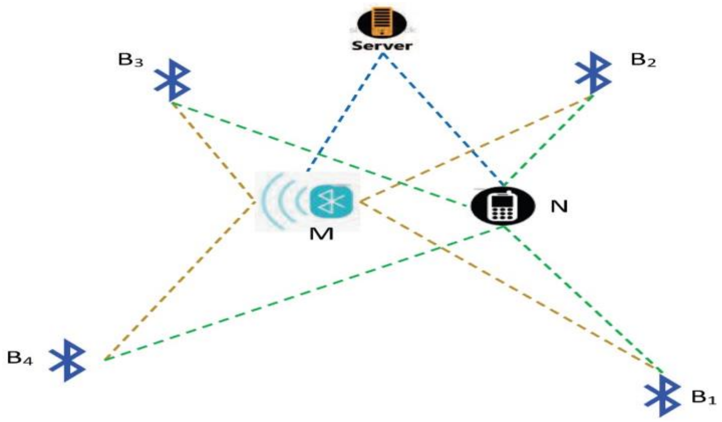

Figure 4 :Diagram of Indoor Positioning by Bluetooth nodes with Received Signal Strength Indication (RSSI) [10]

In the offline phase, the average RSSI is recorded at different distances, and the corresponding average RSSI distance model can be obtained by curve fitting as

$$\overline{RSSI} = -10\text{n}\log(\text{d}) + \overline{A_l} \tag{3}$$

where A_l is the average RSSI at a distance of 1 m from B_l. Since *M*, *N*, and *B* are in a relatively small range, we can assume that the transmission environment among them is approximately the same, which means that the loss parameter (*n*) is the same. In this way, *n* and $\overline{A_l}$ are determined.

In the online phase, the server records R_{Ml} and takes the average time taken to achieve the average signal strength ($\overline{R_{Ml}}$) at regular intervals. Based on equ (3), we obtain

$$\overline{R_{Ml}} = -10\text{n}\log(d_l) + \overline{A_l} \tag{4}$$

Assume the distance between gateway *M* and Bluetooth node B_l (l = 1, 2, 3, 4) is d_l. First, *M* collects the RSSI R_{Ml} of the surrounding Bluetooth node (B_l) and uploads them to the server through a wired or wireless Internet interface in real-time. The real-time RSSI distance model is

$$R_{Ml} = -10n\log(d_l) + A_l \tag{5}$$

where A_l is the RSSI at a distance of 1 m from B_l.

Similarly, for the blind node (*N*) to be located, the average signal strength (R_{Nl}) of node B_l and the real-time signal strength (R_{Nl}) are represented as follows:

$$\overline{R_{Nl}} = -10\text{n}\log(d_{Nl}) + \overline{A_l} \tag{6}$$

$$R_{Nl} = -10\text{n}\log(d_{Nl}) + A_l \tag{7}$$

Using (4) and (5), we obtain

$$R_{Ml} - \overline{R_{Ml}} = A_l - \overline{A_l} = \Delta A_l \tag{8}$$

where ΔA_l represents the real-time fluctuation of the Bluetooth system which we call the RSSI correction offset.

Combining (6) and (7) gives

$$R_{Nl} - \overline{R_{Nl}} = A_l - \overline{A_l}$$

$$R_{Nl} = \Delta A_l + \overline{R_{Nl}} \tag{9}$$

Further, the corrected RSSI $\widetilde{R_{Nl}}$ is obtained as

$$\widetilde{R_{Nl}} = R_{Nl} - \Delta A_l$$

$$= -10\text{n}\log(d_{Nl}) + \overline{A_l} \tag{10}$$

which is also the real-time path-loss model.

Through the above algorithm, we can eliminate the error caused by the fluctuation of Bluetooth transmit power and get a more accurate RSSI distance model. It is crucial for precise indoor positioning.

Chapter 3

TRILATERATION

In geometry, **trilateration** uses the geometry of circles, spheres or triangles to determine absolute or relative locations of points. Apart from the mathematical intrigue, trilateration also has practical applications in surveying and navigation, including in GPS. Unlike triangulation, one does not need to measure angles. In planar geometry, it is known that if a point lies on two circles, then the circles' centers and the two radii provide adequate information for narrowing down the possible locations to two. Additional information may decrease the possibilities down to one unique solution. In 3D geometry, when it is known that a point lies on the surfaces of three spheres, then the centers of the three spheres along with their radii provide adequate information for narrowing down the possible locations to no more than two. Here, we describe a method to determine the intersections of three sphere surfaces, given the centers and radii of the three spheres.[12]

3.1 **Bluetooth Trilateration**

Even though one does not need to measure angles, trilateration is a sophisticated version of triangulation. Data from a single Bluetooth device provides a general location of a point within a large circular area on the Earth's surface. Adding data from a second Bluetooth device allows to narrow the specific location of that point down to a region where the two areas of satellite data overlap. Adding data from a third provides an accurate position of the point on the map.

At least three Bluetooth devices are required for an accurate calculation of position. Data from a fourth device—or even more than four devices—further enhance the precision of the point's location [5].

Upon estimating the distance from the sender and each receiver, the position of the BLE device needs to be estimated next. As we stated before, mathematical trilateration is not always possible since there is not always a single intersection of the three estimations but rather an area of possible locations. In this paper we present a method that calculates the location by trusting more in the measurements from the devices that are estimated to be closer to the sender.

We can use it with L receivers, L being greater or equal to 3 as we need at least three distances for trilateration. When more receivers are placed, we consider only the three receivers whose calculated distance to the sender is the smallest, according to our approach of trusting more the devices closer to the sender. The use of more than three receivers improves the accuracy of the system.[14]

Circles intersect at one single point: The ideal case is shown in Figure 3, where all the circles intersect in one point.

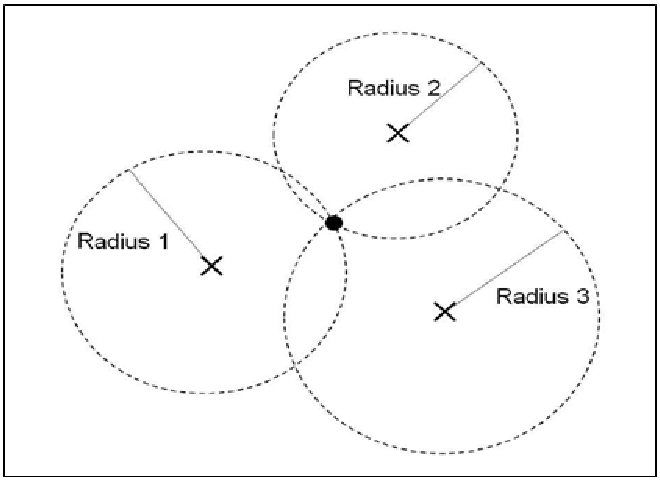

Figure 5 : Trilateration : 3 circle intersection[13]

We can see in Figure 5 that circles C1, C2 and C3 intersect at point P. For these circles, we have
the following set of equations:

$$r_1^2 = (x - x_1)^2 + (y - y_1)^2 \qquad (11)$$
$$r_2^2 = (x - x_2)^2 + (y - y_2)^2 \qquad (12)$$
$$r_3^2 = (x - x_3)^2 + (y - y_3)^2 \qquad (13)$$

where $r1$, $r2$ and $r3$ are the radius of the circles C_1, C_2 and C_3 respectively, and the tuples (x_1, y_1),
(x_2, y_2), and (x_3, y_3), are the centre of the same circles. In the case we have L receivers, the set of 3
equations become a set of L equations from which we take the three equations related to the receivers closer to the sender.
When the three circles intersect in one point, the set of equations in (9) can be solved, leading to
one single point P = (x, y) given by:

$$x = \frac{\begin{vmatrix} (y_2^2 - y_1^2) + \ (x_2^2 - x_1^2) + (r_1^2 - r_2^2) & (y_1 - y_2) \\ (y_3^2 - y_2^2) + \ (x_3^2 - x_2^2) + (r_2^2 - r_3^2) & (y_2 - y_3) \end{vmatrix}}{\begin{vmatrix} (x_1 - \ x_2) & (y_1 - \ y_2) \\ (x_2 - \ x_3) & (y_2 - \ y_3) \end{vmatrix}} \qquad (14)$$

$$y = \frac{\begin{vmatrix} (x_2^2 - x_1^2) + \ (y_2^2 - y_1^2) + (r_1^2 - r_2^2) & (x_1 - x_2) \\ (x_3^2 - x_2^2) + \ (y_3^2 - y_2^2) + (r_2^2 - r_3^2) & (x_2 - x_3) \end{vmatrix}}{\begin{vmatrix} (y_1 - \ y_2) & (x_1 - \ x_2) \\ (y_2 - \ y_3) & (x_2 - \ x_3) \end{vmatrix}} \qquad (15)$$

Chapter 4

Experimental Setup

In a room of 200 x 200 cm, we have chosen three distinct known points A,B,C

A (10,130)

B (30,60)

C (130,10)

We have arbitrary placed the object in the above said room which we want to localise.

Now, we have to follow the steps below :

- Firstly, we have to find the RSSI values for the bluetooth signals at the three known points. This can be done using an android application called ‘Bluetooth Signals’ which helps to find the RSSI values for a distant device connected via bluetooth.

- Then we have to find the estimated distance based on the RSSI values from the said three points using equation (10).

- Taking the estimated distance as the radius and the vertices of the known points as the centre we draw a geometric circle at the three given known points.

- Using the equations of the circle framed above and upon solving them we the get the vertices to the destined object we want to find out.

The above approach is accurate when there exists a common point of intersection for the three geometric circles drawn on the three points.

Now suppose that we don’t have a common point of intersection for the three points.

In that scenario we have found the intersecting points of the 3 circles taking two circles each and then taking the nearest three points which form the smallest triangle of the 6 intersection points we find the centroid of the triangle which gives the position of the object.

Calculation for Localization (Common Point of Intersection)

Data Set Reading

We have taken three points A (20,100) , B (150,30) , C(180,190) and measured the TxPower and RSS values using Bluetooth Sensor (Mobile device taken in this scenario).

1st Set

				TxPower	RSS			DIST	MEAN	MODE
POINT A	X	Y		-66	-67			112.2018	112.926	112.2018
	20	100		-66	-68			125.8925		
				-66	-66			100		
				-66	-65			89.12509		
				-66	-68			125.8925		
				-66	-67			112.2018		
				-66	-67			112.2018		
				-66	-68			125.8925		

Figure 6: Calculation of Tx Power & RSS value for Point A

				TxPower	RSS			DIST	MEAN	MODE
POINT B	X	Y		-66	-68			125.8925	138.6312	141.2538
	150	30		-66	-69			141.2538		
				-66	-69			141.2538		
				-66	-68			125.8925		
				-66	-70			158.4893		
				-66	-69			141.2538		
				-66	-69			141.2538		
				-66	-68			125.8925		
				-66	-69			141.2538		
				-66	-69			141.2538		
				-66	-69			141.2538		

Figure 7: Calculation of Tx Power & RSS value for Point B

				TxPower	RSS			DIST	MEAN	MODE
POINT C	X	Y		-66	-65			89.12509	93.88373	89.12509
	180	190		-66	-64			79.43282		
				-66	-64			79.43282		
				-66	-66			100		
				-66	-70			158.4893		
				-66	-65			89.12509		
				-66	-66			100		
				-66	-65			89.12509		
				-66	-64			79.43282		
				-66	-65			89.12509		
				-66	-64			79.43282		

Figure 8: Calculation of Tx Power & RSS value for Point C

From the above tables we see that we have a set of values for the distance and so we take a mode and a mean value in order to solve in the set of equations.

	Mode	Mean
r_1	112.2018	112.9260
r_2	141.2580	138.6312
r_3	89.12509	93.8837

Now using the values of r_1 , r_2 , r_3 (individually for both mode & mean) and putting these values in the equation no. (14) & (15) we get the value of x & y .

On solving for the equation in the excel sheet we get the position of point using the Mode Value

$$x = 106.9763$$

$$y = 158.4086$$

On solving for the equation in the excel sheet we get the position of point using the Mean Value

$$x = 107.6572$$

$$y = 153.2657$$

Original Position of the Bluetooth Device taken

$$x = 100.0$$

$$y = 160.0$$

Pseudo Code for Localisation (Generalised Case)

Approach

- To find if intersection point is present or not.
- If intersection point is present, find the points.
- Find coordinates for smallest triangle from intersecting points
- Find the centroid

Init: container inp1,inp2,inp3 // container type variable to store intersecting coordinates of each intersecting circles.

inp1=FindIntersectionPoints(x_1,y_1,x_2,y_2,r_1,r_2) // Finds intersecting points between circles c1 and c2

print intersecting coordinates.

inp2=FindIntersectionPoints(x_2,y_2,x_3,y_3,r_2,r_3) // Finds intersecting points between circles c2 and c3

print intersecting coordinates.

inp3=FindIntersectionPoints(x_1,y_1,x_3,y_3,r_1,r_3) // Finds intersecting points between circles c1 and c3

print intersecting coordinates.

Taking one of the coordinates of inp1 as a pivot point find the index number of the smallest distance formed between choosen inp1 coodinate and inp2 coordinates and choosen inp1 coodinate and inp3 coordinates.

Index1=FindSmallestDistance(one of the coordinates of inp1, inp2)

Index2=FindSmallestDistance(one of the coordinates of inp1, inp3)

Using the Index numbers find the area for both the inp1 coodinates with respect to indexed inp2 and inp3 coordinates.

If area 1 > area 2

the smallest triangle formed by using the coordinates used to find area 2.

Find the centroid.

Print the coordinates and centroid

End if

else

the smallest triangle formed by using the coordinates used to find area 1.

Find the centroid.

Print the coordinates and centroid.

End else

User Input:

20 100 // Centre of Circle C_1

112.2018 // Radius of C_1

150 30 // Centre of Circle C_2

141.2538 // Radius of C_2

180 190 // Centre of Circle C_3

89.12509 // Radius of C_3

Output:

Radius of c1 circle : 112.202 and center(x,y) :20, 100

Radius of c2 circle : 141.254 and center(x,y) :150, 30

Radius of c3 circle : 89.1251 and center(x,y) :180, 190

c1 and c2 intersection points : 110.925, 165.742 : 15.1652, -12.0976

c1 and c3 intersection points : 90.9274, 186.94 : 131.131, 115.468

c2 and c3 intersection points : 95.904, 160.485 : 247.691, 132.025

Co-ordinate of smallest area's triangle area(x,y) :

90.9274, 186.94

95.904, 160.485

110.925, 165.742

Centroid = (99.3, 171)

So, the original position is (100,160) and the position we got on solving from this experiment is (99.3,171)

Error:

To find the error we have to find the distance between the Original Position and the Obtained Position

So, the error is $\sqrt{(99.3 - 100)^2 + (171 - 160)^2} = \sqrt{121.49}$

$= 11.02$ cm

Thus, we can say that our obtained position is accurate up to ~ 11 cm

Now we take 3 more different position sets of A,B,C to estimate the error of finding the position of the object keeping it at the same location.

2nd Set

				TxPower	RSS			DIST	MEAN	MODE
POINT A	X	Y		-66	-65			89.12509	85.49049	89.12509
	40	100		-66	-64			79.43282		
				-66	-65			89.12509		
				-66	-64			79.43282		
				-66	-65			89.12509		
				-66	-64			79.43282		
				-66	-65			89.12509		
				-66	-65			89.12509		

Figure 9: Calculation of Tx Power & RSS value for Point A

				TxPower	RSS			DIST	MEAN	MODE
POINT B	X	Y		-66	-67			112.2018	112.4725	112.2018
	140	60		-66	-67			112.2018		
				-66	-68			125.8925		
				-66	-67			112.2018		
				-66	-68			125.8925		
				-66	-66			100		
				-66	-67			112.2018		
				-66	-66			100		
				-66	-67			112.2018		
				-66	-67			112.2018		
				-66	-67			112.2018		

Figure 10: Calculation of Tx Power & RSS value for Point B

				TxPower	RSS			DIST	MEAN	MODE
POINT C	X	Y		-66	-63			70.79458	68.78029	70.79458
	165	180		-66	-64			79.43282		
				-66	-62			63.09573		
				-66	-62			63.09573		
				-66	-63			70.79458		
				-66	-63			70.79458		
				-66	-62			63.09573		
				-66	-63			70.79458		
				-66	-63			70.79458		
				-66	-63			70.79458		
				-66	-62			63.09573		

Figure 11: Calculation of Tx Power & RSS value for Point C

3rd Set

				TxPower	RSS			DIST	MEAN	MODE
POINT A	X	Y		-66	-64			79.43282	72.95414	70.79458
	60	100		-66	-63			70.79458		
				-66	-63			70.79458		
				-66	-64			79.43282		
				-66	-63			70.79458		
				-66	-63			70.79458		
				-66	-63			70.79458		
				-66	-63			70.79458		

Figure 12: Calculation of Tx Power & RSS value for Point A

				TxPower	RSS			DIST	MEAN	MODE
POINT B	X	Y		-66	-65			89.12509	84.24507	79.43282
	120	80		-66	-64			79.43282		
				-66	-65			89.12509		
				-66	-66			100		
				-66	-64			79.43282		
				-66	-65			89.12509		
				-66	-66			100		
				-66	-64			79.43282		
				-66	-64			79.43282		
				-66	-63			70.79458		
				-66	-63			70.79458		

Figure 13: Calculation of Tx Power & RSS value for Point B

				TxPower	RSS			DIST	MEAN	MODE
POINT C	X	Y		-66	-61			56.23413	58.31726	56.23413
	155	170		-66	-60			50.11872		
				-66	-60			50.11872		
				-66	-61			56.23413		
				-66	-61			56.23413		
				-66	-62			63.09573		
				-66	-62			63.09573		
				-66	-61			56.23413		
				-66	-61			56.23413		
				-66	-63			70.79458		
				-66	-62			63.09573		

Figure 14: Calculation of Tx Power & RSS value for Point C

4th Set

				TxPower	RSS			DIST	MEAN	MODE
POINT A	X	Y		-66	-65			89.12509	85.77008	89.12509
	80	100		-66	-64			79.43282		
				-66	-66			100		
				-66	-65			89.12509		
				-66	-65			89.12509		
				-66	-64			79.43282		
				-66	-65			89.12509		
				-66	-63			70.79458		

Figure 15: Calculation of Tx Power & RSS value for Point A

				TxPower	RSS			DIST	MEAN	MODE
POINT B	X	Y		-66	-61			56.23413	73.08204	70.79458
	120	80		-66	-62			63.09573		
				-66	-62			63.09573		
				-66	-63			70.79458		
				-66	-63			70.79458		
				-66	-64			79.43282		
				-66	-66			100		
				-66	-64			79.43282		
				-66	-64			79.43282		
				-66	-63			70.79458		
				-66	-63			70.79458		

Figure 16: Calculation of Tx Power & RSS value for Point B

				TxPower	RSS			DIST	MEAN	MODE
POINT C	X	Y		-66	-60			50.11872	44.10917	39.81072
	155	170		-66	-59			44.66836		
				-66	-58			39.81072		
				-66	-61			56.23413		
				-66	-59			44.66836		
				-66	-58			39.81072		
				-66	-58			39.81072		
				-66	-59			44.66836		
				-66	-58			39.81072		
				-66	-60			50.11872		
				-66	-57			35.48134		

Figure 17: Calculation of Tx Power & RSS value for Point C

For the 1st set of Figures 6 to 8 we have already obtained the position at (99.3,171)

Error for the 1st Set : $\sqrt{(99.3-100)^2+(171-160)^2}$ = 11.02 cm

Now, for the 2nd , 3rd and 4th set (Figures 9 to 17) we take the mode values of r_1 , r_2 , r_3 and then put the values in the program to find the data below just like the previous 1st set

Position obtained from the 2nd Set : (97.3,166)

Position obtained from the 3rd Set : (101,158)

Position obtained from the 4th Set : (102,164)

Original Position at (100,160)

Error for the 2nd Set : $\sqrt{(97.3-100)^2+(166-160)^2}$ = 6.58 cm

Error for the 3rd Set : $\sqrt{(101-100)^2+(158-160)^2}$ = 2.24 cm

Error for the 4th Set : $\sqrt{(102-100)^2+(164-160)^2}$ = 4.48 cm

Now we look at the variation of accuracy for the 4 data sets keeping the object position same at (100,160)

Now taking the errors as the radii we draw 4 circles taking the Obtained Position as the centre

to see the variation of accuracy of data when measured from 4 different points for the same object location.

The variation of colour from deep to lighter describes more accurate data.

We have drawn a circle connecting the points from where the object is measured for each data set in Figure 18.

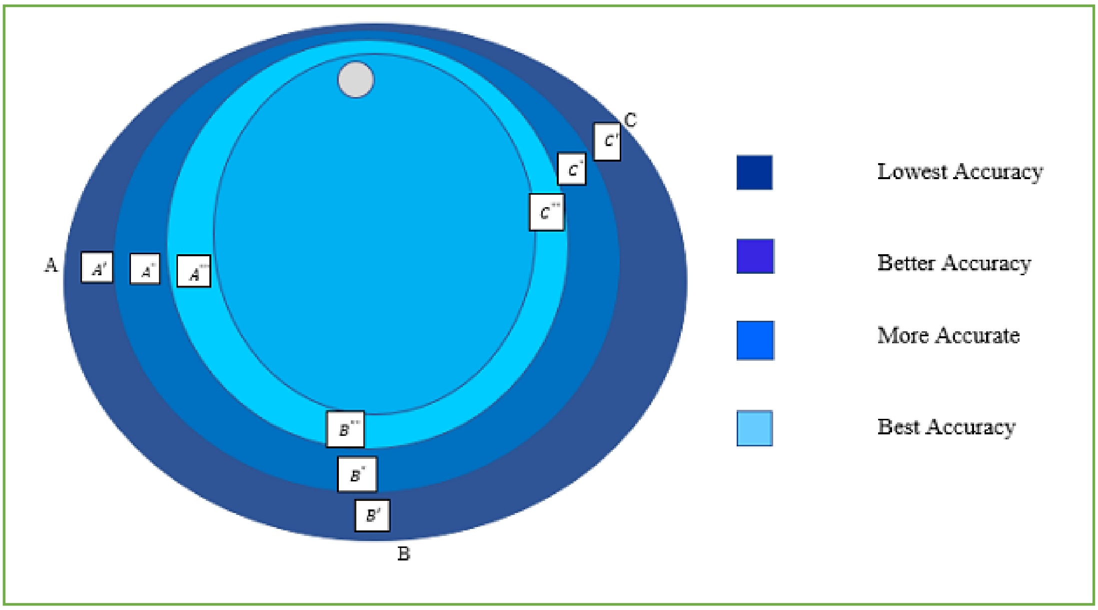

Figure 18: Pie Diagram showing how the accuracy varies when measured from different points

<u>Points from where the Object is measured:</u>

A (20,100)	A’ (40,100)	A” (60,100)	A”” (80,100)
B (150,30)	B’ (140,60)	B” (120,180)	B”” (100,92)
C (180,190)	C’ (165,180)	C” (155,170)	C”” (140,170)

Now, we find values for different object position keeping the object at different locations and then calculating its position :

Original Position	Obtained Position	Error(in cm)
(140,140)	(157.60152.5)	14.62
(200,250)	(205.0,239.2)	12.08
(180,200)	(181.2,210.5)	10.05

So ,Mean Square Error is $\sqrt{14.62^2 + 12.08^2 + 10.05^2}$ = 21.46

Chapter 5

Conclusion

Even though we possess navigation systems for outdoor environments, navigation within buildings still poses a challenge. The main difficulty lies in the fact that one must obtain accurate position information in an easy-to-implement way with minimal infrastructure and one must create indoor maps.

Localization based service is an increasing market. The localization service in indoor environment can not only produce commercial benefit but also improve the life quality for disabled people, and save people's life in emergency circumstances. In this paper, we have summarized the wireless technologies and mathematical techniques that are used in recent literature for indoor localization. Different wireless technologies has its own pros and cons. And based on the characteristics of the wireless technology, they can use same or different mathematical techniques to achieve high accuracy, high precision localization. To improve the performance of indoor localization, multiple wireless technologies and multiple mathematical techniques are integrated.

Our results suggest that our application provides a reasonably accurate and a flexible medium to allow users to navigate indoors without requiring many infrastructural changes. Nevertheless, we also realised that the average accuracy of our application was not satisfactory in certain indoor environments such as libraries and small supermarkets, which typically have narrow aisles. This was largely due our faulty dead reckoning implementation which failed to detect a step when users made a sharp turn. In our evaluation, we managed to suppress this problem to a certain extent by introducing more position markers around the site. Although this improved the accuracy significantly, it resulted in more user interaction. The lighting condition in the site would also largely influence the accuracy and the time taken to decode position markers. This was an important factor to consider when placing position markers. Printing these markers on a mat anti-reflective surface would certainly allow for their successful detection even under bright conditions. However, we had to avoid placing these position markers under low levels of light. The application of obstacle detection to indoor navigation was rather innovative. It allowed the navigation system to assess the surrounding environment up to a certain extent and then verify whether users would be able to walk in a given direction from the current position. Nevertheless, to successfully integrate and test this mechanism, we had to impose an important restriction on the site, i.e. the floor should not have any patterns. Furthermore, the user had to also keep the phone in a set position throughout their entire indoor journey as our algorithm relied upon the constant preview frames received from the smartphone camera. This also significantly increased the battery consumption of the device. Here, we have to agree that the limitations of using this component outweigh the benefits it brings 67 to navigation. A potential solution for the future could be to remove this component completely and instead let users use their intuition to avoid obstacles and at the same time keep up with the given direction hint. To aid navigation further, we could supply our application with an indoor map of the site. Although this goes against one of our key objectives, our qualitative analysis revealed that users actually prefer to know the layout of the site and their current position with respect to their destination.

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