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Indoor Wireless Localization using Haversine Formula

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Abstract: Indoor wireless Localization is essential for most of the critical environment or infrastructure created by man. Technological growth in the areas of wireless communication access techniques, high speed information processing and security has made to connect most of the day-to-day usable things, place and situations to be connected to the internet, named as Internet of Things(IOT).Using such IOT infrastructure providing an accurate or high precision localization is a smart and challenging issue. In this paper, we have proposed mapping model for locating a static or a mobile electronic communicable gadgets or the things to which such electronic gadgets are connected. Here, 4-way mapping includes the planning and positioning of wireless AP building layout, GPS co-ordinate and the signal power between the electronic gadget and access point. The methodology uses Haversine formula for measurement and estimation of distance with improved efficiency in localization. Implementation model includes signal measurements with wifi position, GPS values and building layout to identify the precise location for different scenarios is considered and evaluated the performance of the system and found that the results are more efficient compared to other methodologies.

Keywords: Localization, Haversine, GPS (Global positioning system)

1. INTRODUCTION

Location systems are one of the most promising fields in mobile computing. Location systems allow developing location-aware applications. The most common location systems is Global positioning system (GPS) technology—now found in everything from cars to wristwatches—has become increasingly popular over the past few years for tracking location. But it has its limits—most notably, roofs, walls and floors that shield satellite signals and keep them from locating GPS receivers indoors.

With the increase in mobile computing devices and wireless LANs, it has become important to determine the location of a device at any point in time in terms of safety and providing efficient services. Several applications can be conceived of that can use this information. Detecting the location is one of the first step towards building context sensitive smart devices. This information can then be used in indoor positioning environment like museums, banks, shopping malls to provide context sensitive information based on the user location. People spend most of their time indoors (80-90%), in offices, shopping malls, hospitals, metros, museums, etc., hence the possibility to determine locations and trajectories of people and objects inside buildings and other closed structures becomes increasingly important.

For advanced indoor LBSs supporting museum/fair guides, fire rescues, emergency management, or simply ordinary businesses, quality and effectiveness of services demand knowing immediately where people and resources are inside buildings and other complexes and how to navigate to certain locations.

It is of great importance to provide seamless integration and handover of different localization technologies while users move from open space to various closed environments and vice-versa, and efficient adaptation of indoor LBSs to changing environments, contexts and situations.

GPS is world widely used to track the location of the objects or people in outdoor environment. It is widely used in commercial and personal applications. Although GPS have attracted numerous popular outdoor applications, since its accuracy in indoor environments is considerably degraded new technologies have emerged for indoor geolocation. It is not accurate inside the building due to many obstacles like walls, metals which will absorb the strength of the signal. In order to overcome this problem, indoor wireless localization [1] is very much required. Here, we are using Haversine formula to locate people inside building or organisation.

The scope of this paper is to find the location or object inside the building with better accuracy using wifi signals and Haversine formula. The motivation for this experiment is around 80-90% of his time a person spends inside the building and it makes localization important. In section 2, we have discussed the previously available techniques for indoor localization. In section 3, we have discussed our proposed methodology. In section 4, we have shown how to carry out this experiment and listed the results and error rate. In section 5, we have concluded with future enhancements.

2. BACKGROUND AND RELATED WORKS

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Lot of research is being undertaken in this domain to find a more viable solution of location positioning. Different positioning techniques have been used to determine the location of a user.

1) Triangulation

The triangulation [2] location sensing technique uses the geometric properties of triangles to compute object location, using distance measurements and angulation, using primarily angle or bearing measurements.

Lateration: Lateration computes the position of an object by measuring its distance from multiple reference distance measurements from 3 non-collinear points as shown below. But in 3-D, distance measurements from 4 non-coplanar points are required.

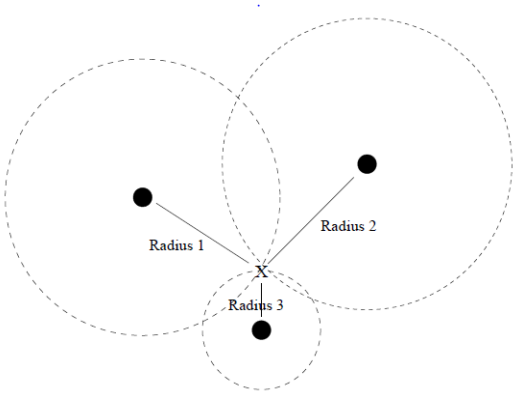

Fig 1: Lateration

There are three general approaches to measuring the distances required by the lateration technique.
Direct: Direct measurements of distances use a physical action or movement. Direct distances measurements are simple to understand but difficult to obtain automatically due to the complexities involved in coordinating physical movement.
Time-of-Flight: Measuring distances from an object to some point P using time-of-flight means measuring the time it takes to travel between the object and point P at a known velocity. The object itself may be moving, the object is approximately stationary and we are instead observing the difference in transmission and arrival time of an emitted signal.

Attenuation: the intensity of an emitted signal decreases as the distance from the emission source increase. The decrease relative to the original intensity is the attenuation. Given a function correlating attenuation and distance for a type of estimate and the original strength of the emission, it's possible to estimate the distance from an object to some point P by measuring the strength of the emission when it reaches P.

Angulation: Angulation is similar to lateration expect, instead of distances, angles are used for determining the position of an object. 2-D angulation requires two angle measurements and one length measurement such as the distances between the reference points as shown in fig below.

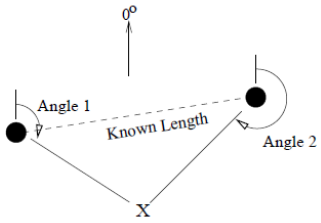

Fig 2: Angulation

2) Scene Analysis

The scene analysis [3] location sensing technique uses features of a scene observed from particular vantage point to draw conclusion about the location of the observer or of objects in the scene. Usually the observed scenes are simplified to obtain features that is are easy to represent and compared.

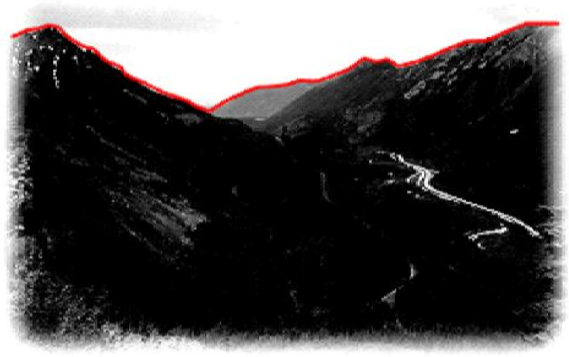

Fig 3: Scene Analysis diagram

Positioning also has been done using different sensing devices however these systems have been very costly. However positioning with Wi-Fi signals have been one of the cheapest. This is because of the ubiquitous availability of Wi-Fi signals in almost all the buildings, so no additional hardware is required to install a positioning system in the buildings.

3. PROPOSED METHODOLOGY

Our experiment uses Wifi access points inside the building assuming that the user whoever enters the building is having laptop or any other electronic gadgets. Initially we are measuring the wifi signal strength which all is available around the user. Then we will consider the access point which is having greater signal strength. Later, by using the Haversine equation or formula, we are going to find the distance between access point and the user and find the location of the user inside the building. The co-ordinates can be found by using the google maps.

We are using 4-way mapping to locate the user inside the building which includes the planning and positioning of wireless AP building layout, GPS co-ordinate and the signal power between the electronic gadget and access point.

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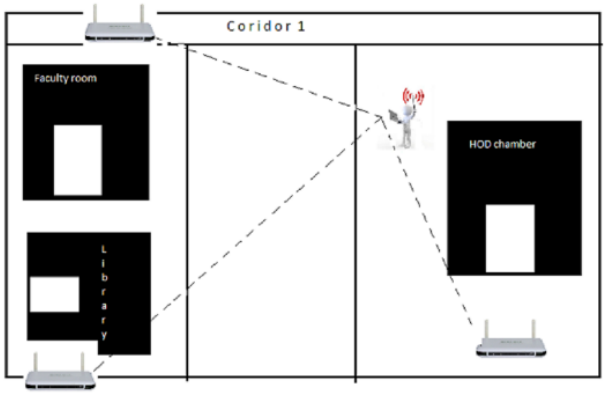

Fig 4: Block diagram

Haversine Formula

The Haversine formula [4] is an important equation in navigation, which uses latitudes and longitudes. The Haversine formula is also called as "Great circle Distances". It was invented by Prof. James Inman in the year 1835. It is based on spherical trigonometry.

Measurement of Distances in spherical trigonometry is based on solving spherical triangles whose sides form arcs of great circles.

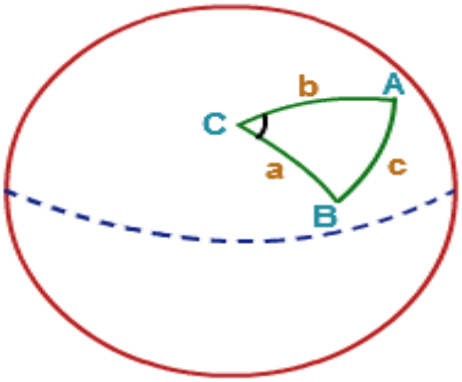

Fig 5: Spherical triangle

In the figure, great circle arcs form the sides of spherical triangle and where two arcs intersect, a spherical angle is formed. In other words, the arc lengths are a measure of the angel they subtend at the center of the sphere and the spherical angles between the arcs a measure of the angle at which the planes that form the arcs intersect.
Haversine formula is given by

Haversin (d/r) = haversin $(\emptyset_2-\emptyset_1)$ + $\cos(\emptyset_1)$ $\cos(\emptyset_2)$ haversin $(\lambda_2-\lambda_1)$

where,

haversine(x) = 1-cos (x)/2

- d is the distance between the two points
- r is the radius of the sphere,
- ϕ_1, ϕ_2: latitude of point 1 and latitude of point 2
- λ_1, λ_2: longitude of point 1 and longitude of point2

Step 1: Express location co-ordinates in decimal format
Step 2: Express West Longitudes and south latitudes as negative values otherwise positive.
Step 3: Express Location coordinates as radians
Step 4: Determine the initial latitude and initial longitude
Step 5: Calculate the total distance from to the optimal location using the haversine formula.

4. EXPERIMENT SETUP

The project is carried out in our college building where indoor positioning is expected. Consider a user with the laptop enters the building and he wants to know his position where exactly he is. We have a small piece of c# code to measure the signal strength of wifi access points. As soon as the user runs the code, the signal strength of each wifi access points will be displayed in the user laptop. We will get the SSID, signal strength and MAC address of each individual access points as shown in the below figure.

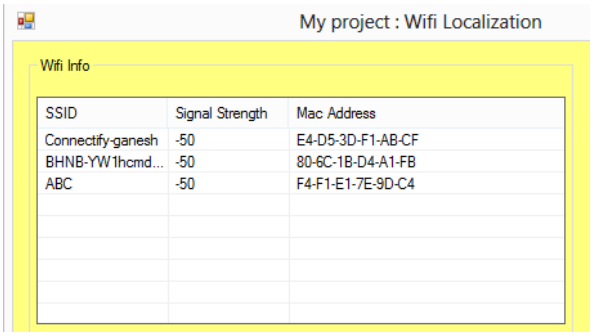

Fig 6: List of wifi signals strength

The user will get to know to which wifi AP he is nearer to. The coordinates of all the wifi access points should be pre recorded in the website or database of the organisation. Now by using the GPS, the person can calculate his present coordinates. So the user will come to know the coordinates of both wifi AP as well as his coordinates. Now by using the Haversine formula, the user can calculate his distance from his current place to wifi AP. Hence there by, we can locate where exactly the person is standing inside the building.

For instance, Consider user with a laptop enters the building and he wants to know his location. He runs the application or code in his laptop to check the available Wifi AP and calculates the signal strength of all AP. The figure is shown below.

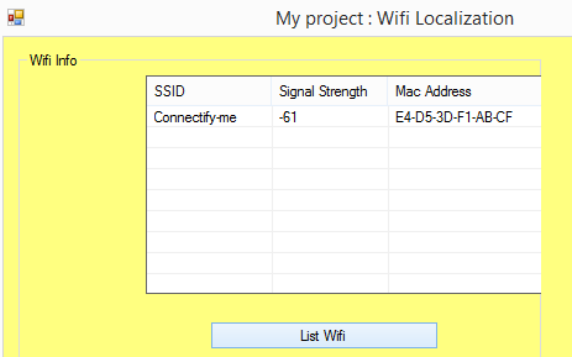

Fig 7: List of Wifi signal strength

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Now the AP with name Connectify-me is nearer to the user. As wifi AP are static and the places where they are installed are prior known to user, he can say he is somewhere near to that AP. But to know from what distance exactly he is away from that AP, we are using Haversine formula to calculate the distance between user and wifi AP.

Haversine formula calculates the distance based on the co-ordinates. Let the latitude and longitude of wifi AP be 13.027698^0 and 77.556768^0 respectively and that of user will be 13.027739^0 and 77.556133^0 and the user is required to enter this co-ordinates in dialog box of distance calculator.

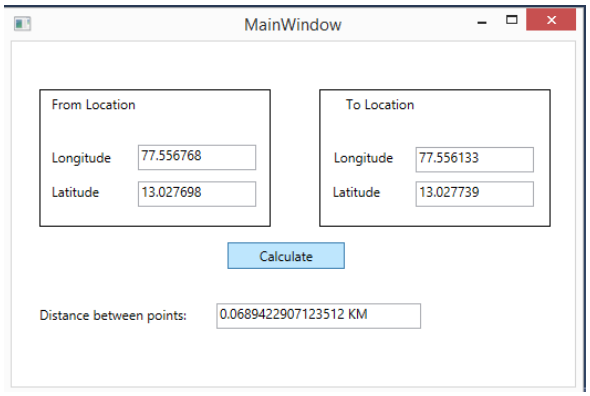

Fig 8 : Calculating distance between 2 points

This gives the distance between the wifi AP and user, and it is 0.068km or 68m.

4.1 Resolving Conflicts when 2 Access points have same signal strength:

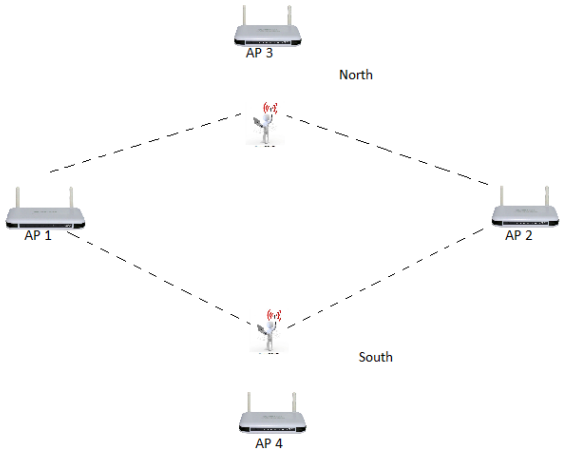

Fig 9: Conflict when 2 AP have same strength

Consider a special case, where there arises a conflict of determining position of user when 2 Access points have same signal strength as shown in the fig 9. The Access points AP1 and AP2 have same strength and cannot determine whether the user is in North or South. In this situation we use one more Access point to locate the user (Either AP3 or AP4). If the user receives more signal strength from AP3, we can say he is in North side. If the user receives more signal strength from AP4, we can say that user is in South side. In this way, we resolve the conflict of 2 Access points having same signal strength.

5. RESULTS

The Haversine formula gives the most accurate result and the error rate is very small, which is negligible.
The survey of the above experiment is shown in the below table.

Sl. no	Location(Wifi)		Location(User)		Distance	Place
	Lat	Long	Lat	Long		
	13.030210	77.564016	13.032133	77.564108	21.5 m	HOD chamber
2	13.030201	77.564019	13.030110	77.564055	10m	Faculty room 1
3	13.030210	77.564016	13.031836	77.565206	22m	Faculty room 2
4	13.030210	77.564016	13.032186	77.56479	23m	Faculty room 3
5	13.030201	77.564019	13.030658	77.564232	50m	Dept of E&E

Fig 10 : Table of list of survey

Sl.no	Place	Actual distance	Calculated Distance	Error rate
1	HOD chamber	21.497m	21.5m	0.03m
2	Faculty room 1	9.995m	10m	0.05m
3	Faculty room 2	21.997m	22m	0.03m
4	Faculty room 3	22.996m	23m	0.04m
5	Dept of E&E	49.997m	50m	0.03m

Fig 11: Table of error rate

6. GRAPHS

The graphical results of the above results is shown in the below figure.

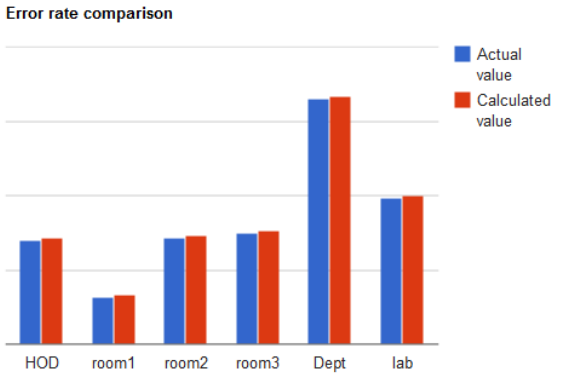

Fig 12: Error rate comparison

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We have plotted a graph of signal variation how it varies over a certain distance.

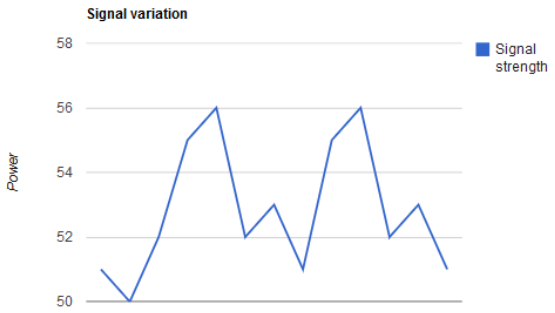

Fig 13: Signal variation

7. CONCLUSION

There are many methodologies present now days for indoor localization. But using wifi signals for locating the people or object inside the building is very efficient as there will be no much loss in the signal propagation. By using Haversine formula to calculate the distance between 2 places by considering the latitude and longitude of those places is very accurate. Hence it is very effective to use the wifi signals and Haversine formula together for localization purpose, which will be helpful in the future for indoor localization.

This indoor localization methodology helps in future to disseminate the user pattern, interaction details, gives alarm for the dumb people about the steps or about infrastructure and can also be useful in indicating highly in toxic region.

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BIOGRAPIES

DR.VIJAYA KUMAR B. P. Received his Ph. D degree from the Department of Electrical Communication Engineering, Indian Institute of Science (IISc), Bangalore in 2003, M. Tech degree in Computer Science and Technology from Indian Institute of Technology, IITR, with honors in 1992 and Bachelors degree in Electronics and Communications from Mysore University with Distinction in the year 1987. He is currently heading the Department of Information Science and Engineering, M.S.Ramaiah Institute of Technology, Bangalore, Karnataka, where he is involved in research and teaching. His major areas of research are Computational Intelligence applications in Mobile, Adhoc and Sensor networks. He is having 25 years of Teaching and 12 years Research experience. He has published around 65 papers which include journals, conferences and project proposals. His name is listed in Marquis Who's Who in the World, and Marquis Who's Who in Asia, 2012. He is a Senior Member of International Association of Computer Science and Information Technology (SMIACSIT), IEEE Member and Life member of India Society for Technical Education (LMISTE).

The paper has been written by **Ganesh L,** pursuing Master of technology in Software Engineering in the prestigious M.S.Ramaiah Institute of Technology, Bangalore. The main idea and proper guidance is given by Dr. Vijaya Kumar B P, our beloved HOD, Dept of ISE. Without his guidance and support, it was impossible for me to carry out this experiment. His novelty and ideas helped me lot to get proper knowledge in Indoor localization. I hereby thank Dr. Vijaya Kumar B P for helping me and guiding me.