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Wifi bluetooth based combined positioning algorithm

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Abstract

Nowadays positioning have become very important for many services (Localization based services) and positioning have become more accurate, despite, there are some territories that basic positioning systems like GPS or even hybrid ones like GPS-WiFi or GPS-WiFi-gsm can't cover, specially indoor enviroments. In this paper we propose a positioning method merging WLAN and Bluetooth technologies based on trilateration technique. Simulated sceneario demostrate accuracy gains, even when we use a high signal attenuation parameter. A simulated sceneario taken from a real home with the real WLAN and Bluetooth stations validates our WLAN-Bluetooth method. Firstly we calculate each equation from each available station, then we decide how to overdetermine the generated equation system in a reason of 4 to 1 (4 equations for one unknown) and finally solve the system using mathematical methods. This work is a step more to better position in indoor enviroments and localization based services.

Keywords: Bluetooth, Positioning, WiFi, fusion.

1. Introduction

In recent years the location capabilities have become important for users [1] given the emergence of many services that rely on it, from entertainment to personal security services and others. The use of wireless has increased dramatically in recent years, this also caused by the increase of mobile devices capable of using these technologies, such as smartphones.

The estimation of the user's position is typically obtained with trilateration distance of at least three measures from three stations. The best example of this is the localization based on GPS, which is the obvious

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choice for outdoor use, but given the weakness in indoor environments have been several approaches using mostly indoors distributed technologies such as RFID, FG, WiFi and Bluetooth [2].

The aim of this paper is to present an algorithm that uses WLAN and Bluethooth technologies for indoor position merging the two signal types. Our goal is to develop a method that improves multilateration overdeterminig the system of equations in a reason of 4 to 1 (4 equations for one unknown) obtained from known stations.

This paper is organized as follow. A theoretical background for this work and a review of some existing methods for location estimation using bluetooth and WiFi is given in Section 2. In Section 3 we describe and analyze the features of WLAN and Bluetooth technologies in location systems. Section 4 presents our contribution and algorithm to merge data from bluetooth and WLAN and overdetermine the generated equation system in a reason of 4 to 1. Experimental results are presented in Section 5. Finally, Section 6 contains the conclusion and presents some future work to do.

2. Background and Current State of the Art

2.1. Trilateration

Trilateraion is a method that computes a node position by intersecting 3 circles. The position of the 3 references nodes must be known and the distance to each of them. Multilateraion is similar to trilateration, but 4 or more references are requiered[2].

2.2. RSSI

Received Signal Strength Indication (RSSI) is a measure of the strength of received radio signal. Typically for a wireless device RSSI is used as the reference for determining the optimal radius for a specific link [3].

2.3. RSS

Received Signal Strength.

2.4. Related Works

Given the importance in these days of the indoor location, there is a lot of work on the subject using wireless technologies such as bluetooth, WiFi, RFID, etc. and different approaches to tackle the problem depending on the transmitters. For example, the Bluetooth Triangulator[3] bases the location on 3 bluetooth signals and trilateration to determine an area where the device is located but given the exclusive use of bluetooth technology remains accurate. There are also systems with only the use of bluetooth transmitters but using more complex algorithms in order to calculate the position of the device as it does in [4] where bluetooth transmitters are in a known distribution and a previously trained neural network to calculate the position. Having to train previously a network requires a previous work not easy in most of the interiors, particle filtering used in [5] is a proposal that avoids require extensive prior knowledge but the complexity lies in filtering particles and the computation cost, however, the use of more complex algorithms lets you get a more accurate position of the device. One interesting approach is the used one in [6] that uses the RSSI information between several fixed wireless beacons to improve the reliability of a Bluetooth positioning system and this information is used to calibrate the sensor responses. Many approaches use fingerprint to estimate the position like in [7], [8]

There is another approach that, given the availability of sensing devices that have both, Bluetooth and WiFi, and a GPS, take full advantage of the existence of signals in the indoor environment as the method proposed in[9] which is based on the prior existence of RSSI Bluetooth and RSS WiFi maps, a known distribution of Bluetooth stations and other from WiFi stations. Another fusion method used in [1] is very interesting because of its simplicity, which since the GPS in a indoor environment has trouble getting the 4 signals required to solve the system of equations, aims to complement these equations with force signals from an Access Point, if the number of visible satellites is less than four, completes the set of equations with equations of WiFi, a similar methodology to that is used in this work which will complete the set of equations with the available signals in the environment.

3. WLAN and Bluetooth location systems

In this section is described and analyzed the performance of using just WLAN or Bluetooth stations.

3.1. WLAN

The indoor location is complex because the structures cause many side effects on the signal that are far from making it a perfect signal due to the reflection, absorption and multipath [9] Therefore, many techniques that use the WLAN as a signal for localization require very sophisticated algorithms, prior knowledge of the environment and sometimes special-purpose hardware for localization.

The proposed technique for this analysis is the multilateration, simulating an RSS reading to determine the distance to the WLAN base which is being taken with a signal attenuation parameter introduced to simulate different environments and losses signal due to the structure simulated. This technique does not require any specialized hardware so it can be simulated without problems.

First verifies the existence of at least 3 WLAN base stations at the scope of the simulated device that is looking to locate, once you verified this algebraic transformation is performed as proposed by Dan Kalman in [10] to simplify the process of solving the system of equations generated by 3 or more mixed signals, once you have this system is solved using the mathematical tool Least Squares and finally the minimized system its solved by the Kramer method.

Once this methodology was designed to solve the WLAN system proceeded to perform 400 simulations for each of the combinations (a total of 3600 simulations) forming the system of equations with 3, 4 and 8 base stations on the scope and varying the attenuation parameter from a 1 to a maximum of 15, 30 and 45 percent at random for each of the simulations.

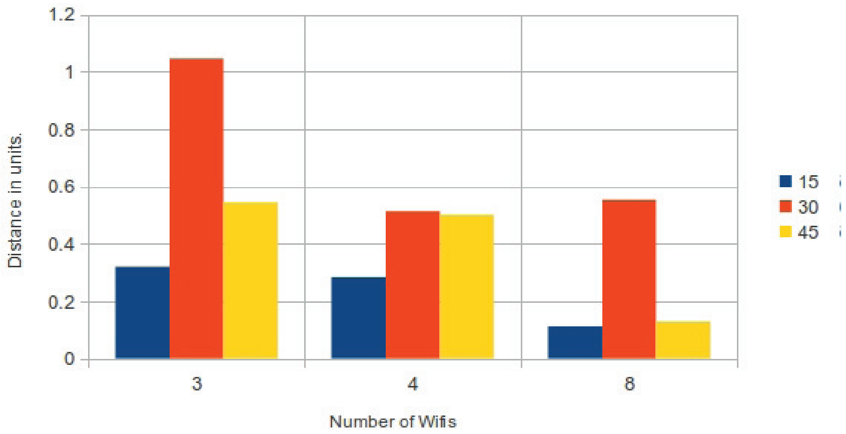


Fig. 1. Euclidiane distance in units from the exact location of the device with 3,4 and 8 WLAN signals and 15, 30 and 45 percent signal attenuation parameter

Figure 1 shows the behavior of simulated WLAN multilateration in the proposed cases, the distance obtained with respect to the coordinates where the object to locate actually is, is calculated using Euclidean distance with coordinates x and y, as we consider error. We note that while the attenuation parameter increases the error increases and similarly for the case of 3 base stations and 4 base stations wich have a higher error than the case of 8 available base stations.

3.2. Bluetooth

Given the rise of personal networks, mostly by the smartphones, Bluetooth technology is widely disseminated in any form and this makes it a technology that is also commonly found indoors, which has allowed in recent years the exploration of techniques for location based on this technology.

To solve the location based on bluetooth you can use the same principle of trilateration getting the RSSI and Link Quality that even when it is not a measure such as the RSS, through some basic operations can be transformed to a distance approximation.

Several works make use of these methods to develop systems based purely bluetooth using RSSI like [3], [11] and [12].

Since solving a location problem using bluetooths and WLAN can be considered equal for all practical purposes, the methodology used to solve a problem with WLAN base stations was the same as for bluetooths, only adding one more parameter wich is equivalent to the class of Bluetooth, where class 1 has a radius of 100 meters (1 meter equivalent to 1 unit in the simulator), class 2 with a radius of 10 meters and class 3 for a radius of 1 meter.

We chose to use only the class 2 parameter for bluetooths because they are more common on mobile devices and proceeded to perform 400 simulations for each of the combinations (a total of 3600 simulations) forming the system of equations with 3, 4 and 8 stations based on the scope and varying the attenuation parameter from a 1 to a maximum of 15, 30 and 45 percent at random for each of the simulations as well as it was for the system with WLAN base stations. Figure 2 shows the behavior of simulated multilateration

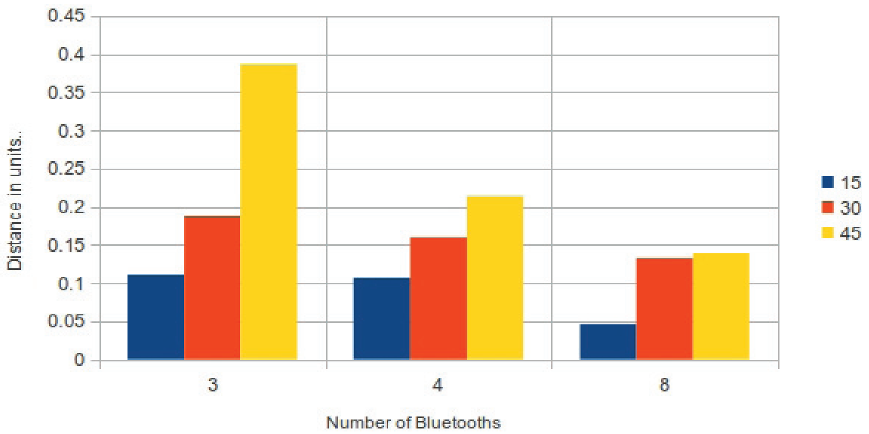


Fig. 2. Euclidiane distance in units from the exact location of the device with 3,4 and 8 Bluetooth signals and 15, 30 and 45 percent signal attenuation parameter

bluetooths class 2 in the proposed cases using the same Euclidean distance as a parameter error. We can see in Figure 2 that while the number of base stations is increasing, the error decreases, and as the attenuation parameter increases similarly the error increases. Besides comparing bluetooths against WLAN stations, the error shows that the error is larger in WLAN, this caused by the fact that bluetooth has a smaller radius, even if the attenuation parameter is greater this error will tend to be smaller .

4. WLAN and Bluetooth Fusion

In this section is described and analyzed the performance of using WLAN and Bluetooth stations and the proposed method.

4.1. Multilateraion and Proposal method

The biggest problem in positioning systems is that not always 3 emitters are visible with enough and clear signal [1]. To tackle this problem have been proposed merging different types of signals to complete

Table 1. WLAN, Bluetooth and Fusion method comparision using 8 base stations

Signal attenuation parameter	WLAN	Bluetooth	Fusion Method
15 percent	0.112 meters	0.045 meters	0.476 meters
30 percent	0.553 meters	0.132 meters	1.124 meters
45 percent	0.128 meters	0.139 meters	1.839 meters

the task of locating, proposals such as [1] that blend the GPS system with WLAN and [9] merging signals from WLAN and Bluetooth are some samples facing this problem using fusion methods.

The proposed method considers that, as trilateration is functional to location systems based on WLAN and Bluetooth, is possible to merge them and get better results than using them independently.

The merger of these two signals, given the large number of shared characteristics, may be carried out directly by forming the system of equations generated by the base stations that are reachables at that time. Therefore, the methodology used to solve systems of equations generated for both WLAN and Bluetooth is also applicable to this merger.

400 simulations were performed for each of the combinations (a total of 3600 simulations) using 3 WLAN and 1 Bluetooth, 3 WLAN and 2 Bluetooth and 3 WLAN and 5 Bluetooth base stations respectively and varying the attenuation parameter from a 1 to a maximum of 15, 30 and 45 percent at random for each of the simulations.

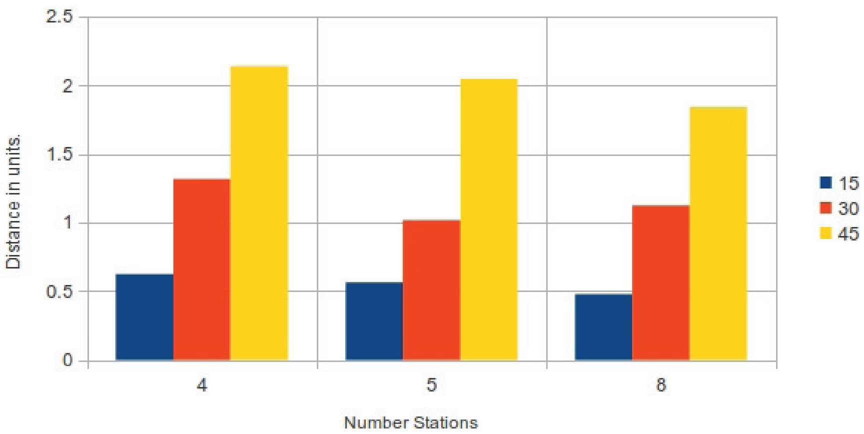


Fig. 3. Euclidiane distance in units from the exact location of the device with 3 WLAN and 1 Bluetooth, 3 WLAN and 2 Bluetooth and 3 WLAN and 5 Bluetooth signals and 15, 30 and 45 percent signal attenuation parameter

Figure 3 shows that the fusion of WLAN with Bluetooth is possible, however, the table 1 shows that the merger itself is the method that generates an larger error , it because is generated by the base station location respect the device to locate and the difference magnitud of the error that can be added to the system from bluetooth and WLAN.

Given the previous observations of individual behavior of the base stations, WLAN and Bluetooth, and the fusion behavior, the following method is proposed to merge the WLAN and Bluetooth available signals:

1. Find the largest number of devices in range.
2. Calculate the distance to each of them.

Table 2. Results comparision

Signal attenuation parameter	WLAN	Bluetooth	Multilateraion	Our proposal
15 percent	Inf.	0.162	0.234 units	0.242 units
30 percent	Inf.	0.398	0.393 units	0.290 units
45 percent	Inf.	0.616	0.501 units	0.438 units

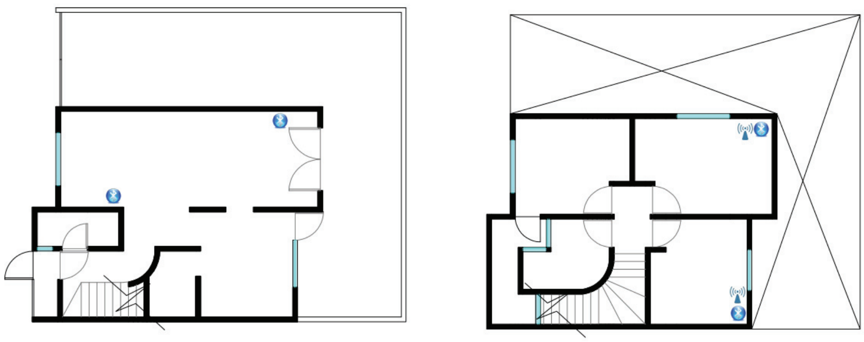
3. Check if the number of equations is equal to or greater than 8, if so skip to step 6, else continue to step 4.
4. Find the equation corresponding to the nearest base station within the set of equations you have.
5. Duplicate the equation as many times as necessary to obtain 8 equations in the system.
6. Solve the system of equations.

5. Results

In this section is described and analyzed the performance of our proposal using WLAN and Bluetooth stations.

5.1. Results of the proposed method

The results presented in this paper are based on the simulation of the proposed method in a real distribution of the available devices in a household with devices commonly found indoors.



a) b)

Fig. 4. Real house plans with available WLAN and Bluetooth stations distribution, (a) first floor; (b) second floor

Figure 4 shows the actual distribution planes of the household from which the coordinates data were obtained of the available base stations for the simulation, in which there are 4 bluetooths class 2 and 2 WLAN.

400 simulations were performed for each of the combinations (a total of 1200 simulations) using the 6 available base stations and varying the attenuation parameter from a 1 to a maximum of 15, 30 and 45 percent at random for each of the simulations.

Figure 5 shows that the proposed method can reduce the error significantly compared to the multilateration and Bluetooth for a attenuation parameter of up to 30 or 45 percent, and with the data shown in Table 2 we can compute an error of 26.06 and 12.64 percent lower against multilateration and a 27.13 and 28.89 percent lower against Bluetooth. In the table we can observe that the error with only WLAN is infinite because wth only 2 WLAN base stations it is impossible to find the position of an object.

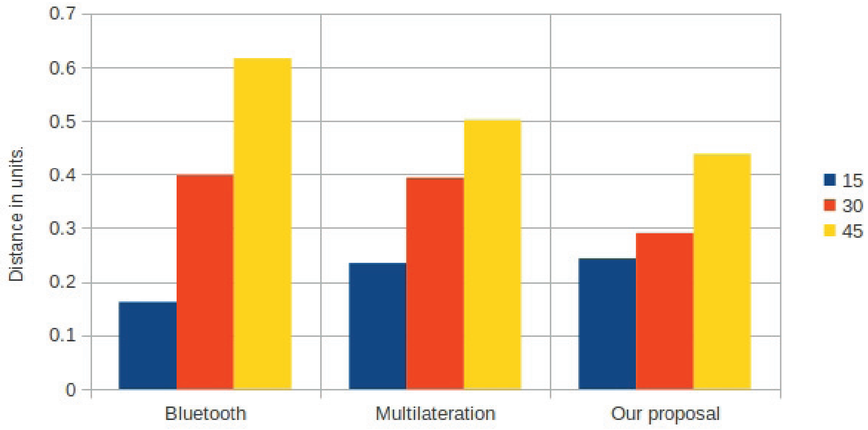


Fig. 5. Euclidiane distance in units from the exact location of the device with normal multilateration and our proposal and 15, 30 and 45 percent signal attenuation parameter

This increase in indoor location in a simulated environment using available resources without special purpose hardware and without prior knowledge developed (requiring only the coordinates of the base stations and in case of bluetooth class parameter) allows indoor improve the provision of location based services in a more effective and efficient way.

6. Conclusions and future work

Simulations of real indoor environment conducted show that the accuracy that presents the proposed method is better than normal multilateration even when you have a attenuation parameter of 45 percent. Also we can conclude that positioning only with WLAN is very complex due it is not common have more than 2 access point and fusioning it with Bluetooth increase the posibility of having more than 2 base stations to calculate the position.

The main idea of the system is to provide a simple method capable of improving indoor location using existing base stations without requiring any further modification or prior knowledge of the interior, only the coordinates of base stations available in the environment.

As future work we propose the real experiment, not just simulated the proposed method, in controlled environments and in the household which the data were taken from the available base stations, as well as add some filtering method to make a better decision to the location of the device in question in an interior, such as Kalman, Particles Filter, Bootstrap and others. It also suggests the fusion of additional sensors such as the pedometer because most of today's smartphones have one built in.

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