Fuzzy Logic Indoor Positioning System

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Abstract — **The GPS system is not valid for positioning indoors, thus positioning systems are designed using Wi-Fi technology that allows location of a device inside buildings. The use of fuzzy logic is argued by the failure to find positioning systems based on this technology, which seeks to observe how their use in this field.**

V. Introduction

The LBSs are location services accessible from mobile devices across mobile networks. These services are used from wide variety of customers, ranging from laptop computers to mobile devices. Any request to these kind of services return the position of a mobile terminal. From these definitions, LBS relies on the use of three Technologies

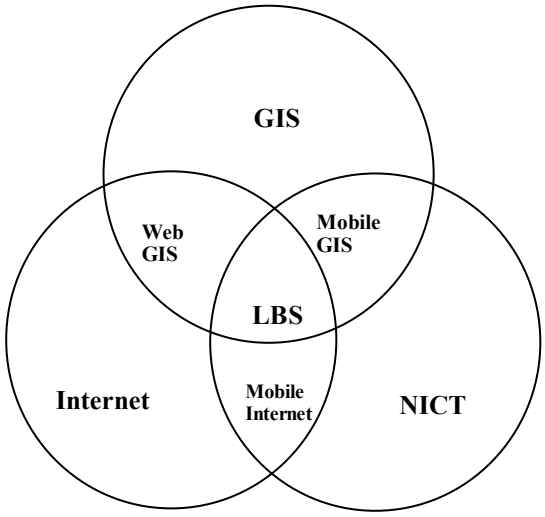


Figura 1. LBS as an intersection of Technologies.

Among the most outstanding characteristics of LBS are:

High performance: It should respond in thousandths of seconds.

Scalable architecture: Support for hundreds of concurrent users and terabytes of information.

Reliable: It must be able to respond the 99,999% of the time.

Fluent: Support for real-time and dynamic information.

Movil: it must be available from any device and it must be accessible from anywhere.

Open: It must to support the usual standard and usual protocols.

Insurance It must safely manage the database and services.

Interoperable: It must be integrated with e-business applications.

VI. Techniques to calculate positions

These techniques are often used in combination with each other:

A. Cell origin (COO).

The identifier of the cell normally is the identifier of the nearest base station. This is known that the position is defined at the perimeter of the base station, which is known his position.

B. Time of arrival (TOA).

If we know the transmission speed of the signal, and the time between sending and receiving the signal, we can calculate the distance. We can know the position on a reference with these data. In this case we require high-precision clocks to calculate signal delay, because this is transmitted at very high-speeds.

C. Difference time of arrival (TDOA) or (E-OTD).

These techniques calculated the distance measuring the time, but it is based on the difference of signals from three base stations, allowing triangularize the position. In the case of TDOA, task "calculating the position" is carried out by the network provider, in the case of E-ODT it is executed by the mobile device.

D. Angle of Arrival (AOA), direction of arrival (DOA):

The use of directional antennas allows mobile devices to detect the angle of arrival of the signal. Because the mobile devices move that is not very accurate. Another possibility is that many base stations have segmented antennae, which divide the circumference of reach of the station at 90, 120 or 180 degrees, depending on the number of segments.

VII. GNNS

The GNSS technology or Global Navigation Satellite System. The breakthrough of this technology is due to the emergence of global positioning remote systems, at an affordable price for the common user.

As reference of this technology is GPS (Global Positioning System) developed by the United States. Although we find other systems such as GLONASS (Global Navigation Satellite System) developed by the Russian Federation and Galileo, developed by the European Union, although it not operational today.

The intention is that all three systems work together to provide better service, taking greater availability and accuracy.

The GPS (global position system or global positioning system) or-Navstar GPS is a GNSS, which determines the position (altitude, latitude and longitude) of an object anywhere in the world by triangulation.

To determine the position of an object are used at least four satellites, those receive the position and a clock signal. The use of more satellites only brings greater precision to the system.

The delay of the signal is calculate by the data obtained, we need the time has been taken to travel from the satellite to the target device, and if we know where the satellite was, we can calculate the position of the device by triangulation.

The two-dimensional triangulation is based in the angle with respect to some points known. In three dimensions to calculate the position we determine the distance from each satellite to the receiver, and once we known the distance to each satellite we can determine the relative position with respect to each satellite, and also we know the position of each of satellites, we can calculate the actual position of the receiver.

The clock of the GPS system has an extreme precision, very similar to the atomic clocks that are in each of the satellite system.

With the information gathered by the GPS receiver calculates the distance that separates the satellites, by the time that takes to the signal to reach the receiver and knowing the speed of transmission of the signal.

The GPS system raises some drawbacks in terms of positioning, but includes:

A. *Selective Availability:*
The U.S. defence department keeps the possibility of including some degree of error in calculating the position, which can range from 10-100 meters. At present they are not using this feature, although there is nothing that will forbid.

B. *Topology-satellite receiver:*
Recipients must consider the geometry receptor-visible satellites used in the calculation of distances, since a certain spatial configuration can increase or decrease the accuracy of the measures.

C. Aspects atmospheric disturbance and Ionospheric meteorological phenomena:
Both affect the dissemination and propagation of electromagnetic signals between satellites and devices (receivers).

But without a doubt, the biggest drawback of the GPS system is that it doesn't works like a internal system, because it needs to have direct visibility between the receiver and each of the satellites used, so you have to find alternative techniques positioning.

VIII. WIFI

The mobile wireless networks using electromagnetic waves to send information from one place to another. Although this type of technology takes several decades used for specific applications, has recently experienced a boom due to technological improvements already existing lower prices.

A breakdown of these networks is: Wireless Wide Area Networks (WMAN) ej. GSM and UMTS, Wireless Local Area Networks (WLAN) ej. IEEE 802.11, and Wireless Personal Area Networks (WPAN) - ie. Bluetooth

Technology		Long.Max	Speed (Mbps)	Frequency
WMAN	GSM	100m – 35Kn	0.009 – 0.014	~900 MHz,
	GPRS		0.160	
	UTMS (G3)		2.0	
WLAN	Ultra-Wideband	10m	100	~2.4 y 5 GHz
	IEEE 802.11a	50m	54	
	IEEE 802.11b	100m	11	
WPAN	Bluetooth	10m	1	~2.4 GHz
	Homero	50m	10	
	IrDA	1 – 1.5m	1 - 16	

IX. Indoor Positioning System (WLAN)

A WLAN is a data communications system that transmits and receives data using electromagnetic waves (although it is also possible with infrared light), instead of twisted pair, coaxial or fiber optics used in conventional LANs, and provides wireless connectivity within an area of coverage.

There are three types of typical configurations

A. Peer to peer or ad-hoc networks:
It consists of a network of two or more mobile handsets equipped with the corresponding wireless network card, so that communication is established between the nodes, communicating directly with each other.

B. Infrastructure Mode:
They have more scope than the ad-hoc networks, but its implementation is necessary for the installation of an access point.

C. MultiNetwork:
Allow link various networks (WLAN and / or WMAN) among themselves, for them relies on the use of directional antennas, which give visibility outside closed environments.

Co.	Standard	Frec.	Physic Level	V. Max.	Date
IEEE	802.11b	2,4 GHz	DSSS	11 Mbit/s	2001
IEEE	802.11a	5 GHz	OFDM	54 Mbit/s	2002
IEEE	802.11g	2,4 GHz	OFDM/ DSSS	54 Mbit/s	Fin 2002
ETSI	HiperLAN2	5 GHz	OFDM	54 Mbit/s	2003
ETSI / IEEE	5GHz Unified Protocol (5-UP)	5 GHz	OFDM	108 Mbit/ s	2003
Bluetoo th SIG	Bluetooth	2,4 GHz	DSSS/ FHSS	0,721 Mbit/s	2002

X. Calculation Of The Position Through the RSS

The location through Wireless networks can be carried out in different ways:

A. *Vector Power*
The signal information of the access points as laid down in the training of the devices is stored in a database (vector where each cell contains the power that comes from each user to access point).

B. *Triangulation of Power*
The customer receives the signal of three access points and provided an estimated current position through a system of equations .

C. *Heuristic*
It is not only whether a system by itself, but is more a complement to two previous ones. There are several possibilities for its implementation: Near, close neighbours (K-times Proximidada), theory of Bayes or neural networks.

XI. Statement of the Problem

As mentioned, the GPS system is not valid for positioning indoors, thus positioning systems are designed Wi-Fi that allows location of any device inside a building.

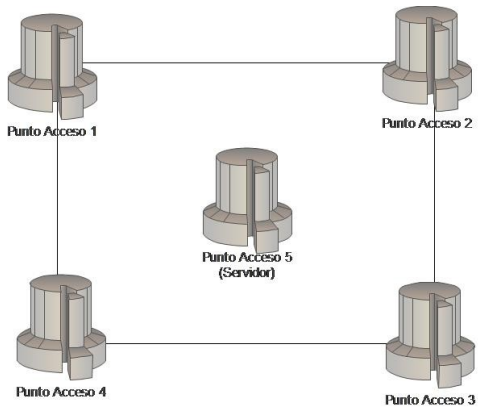
The use of fuzzy logic is argued by the failure to find positioning systems based on this technology, which seeks to observe how their use in this field.

In addition one of the advantages we found in the use of this technology is simplicity, the whole system focusing on the design of the driver and diffuse the rules governing it. The solution therefore is about our way of thinking and reasoning.

Let's build on systems DOT, which is responsible for calculating the position of the device is the provider, in our case one of the access points at their disposal. In addition the system will make use of a fuzzy controller for calculating the region where the device was found. One characteristic of our system is that positioning by region, bounded by the number of access points used, and not one based on positioning coordinates.

Our physical environment of development will be an enclosed area with square or rectangular shape with 5 access points, located one on each corner and one in the center of campus. The latter is considered as central server with the aim to be responsible for calculating the position.

The graphic location would be as follows:



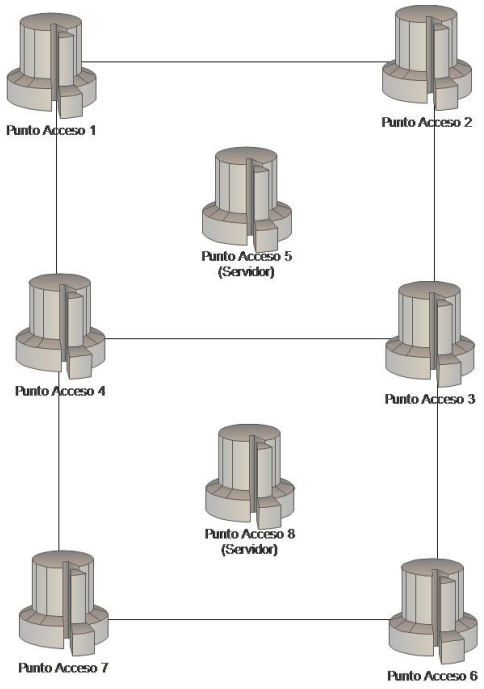
In the event that compound is too big, will require an expansion of the system, which will be incorporated into another server and so many access points as necessary, bearing in mind that all access points can be reused for the new server .

Although such systems can incorporate a training system, which is to undertake measures prior to the signal received from a few known points, indicating that when the system receives the signal level of each access point, the device is found in that particular position. But our goal is to eliminate this phase of training, through the ability of different access points to be among them.

As position of access points is fixed and known, each access point system to inform the signal strength from each other access points. The system can estimate the position of the client device within the square using this information and processing signal delays existing on each access point located anywhere on the plant.

This simplification, implies that the system will not be as

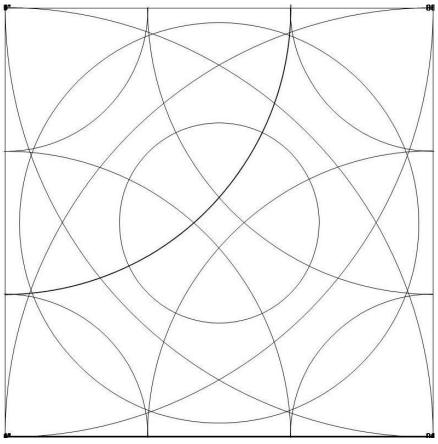
precise as if you use the training system, but on the other hand the system will be more adaptable to changes in the environment.



The position of the client device is calculated by a "central server", thus it is possible releases client device resources thereby the server perform this type of tasks.

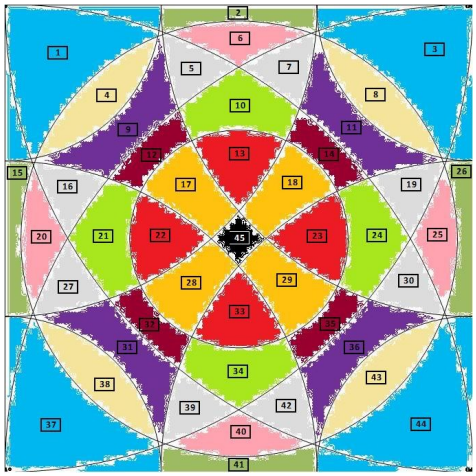
For this functionality you can ask the server at any time if a particular device is located inside the enclosure.

The definition of regions is set from the regions defined by the ranges of each access point, this range has been divided into three, for each access point, giving a map like this:

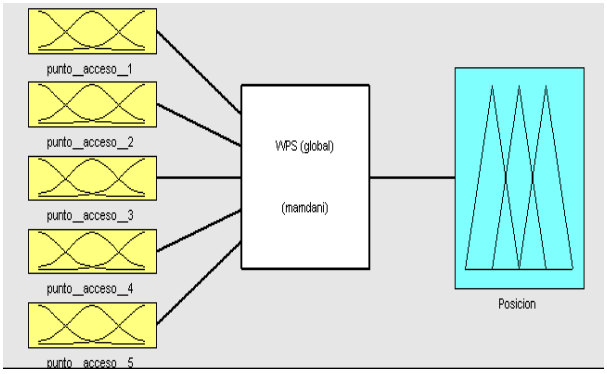


Since the number of regions obtained is very high, we will group the regions depending on the ability to define different regions depending on the divisions established.

Thus we have the following map of regions:



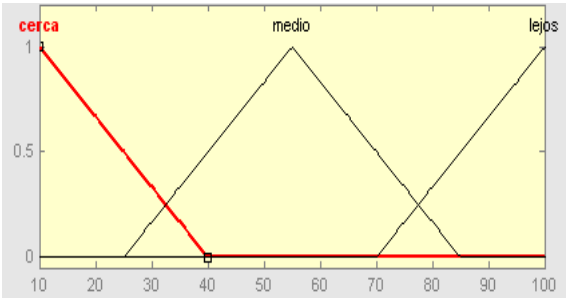
Our system is fundamented in the implementation of a fuzzy controller that is structured as follows:



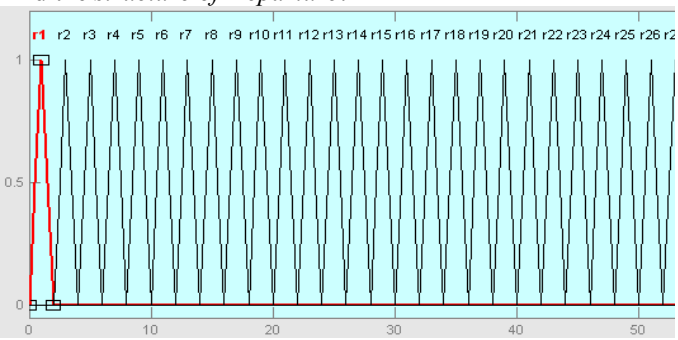
Each of access points will have three variables: Near, Middle and Far. To correspond with the degree of closeness of the device to access point.

Access points are structured as follows:

Access Points:



And the *structure of Departure*:



The output will become one of the possible areas where we can find our device, which will be defined by a fuzzy logic dependent on the input variables.

Functions.
We have four functions to control the system:

1) *Evaluar.* This feature is the entry values signal received from each access point and takes us back the position of the receiver.

```
function out=evaluar(params)
x=readfis('WPS.fis');
out=evalfis(params,x);
```

2) *ModificarPA.* This feature applies to each variable inlet fuzzy controller, representing each of the access points, and adjusts the concepts near, medium and far as signal strength between access points.

```
function modificarPA(imf,params)
   x=readfis('WPS.fis');
   x.input(1).mf(imf).params=params;
   x.input(2).mf(imf).params=params;
   x.input(3).mf(imf).params=params;
   x.input(4).mf(imf).params=params;
   writefis(x,'WPS.fis');
```

1) *ModificarS.* This function is applied to the variable inlet diffuse controller who represents the server, and adjusts the concepts near, medium and away from this, according to Intesa signal received from access points.

```
function modificarS(imf,params)
   x=readfis('WPS.fis');
   x.input(5).mf(imf).params=params;
   writefis(x,'WPS.fis');
```

1) *Modify_range.* This feature allows you to specify the range of each variable inlet controller diffuse.

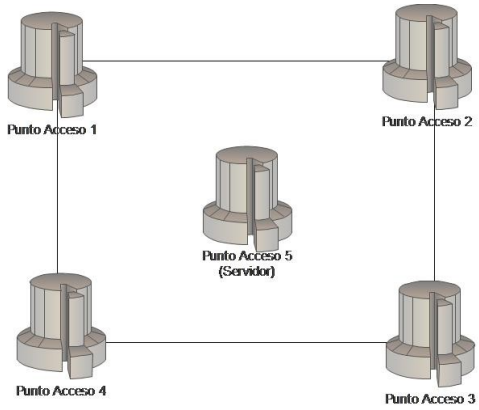
```
function modify_range(ivar,range)
   x=readfis('WPS.fis');
   x.input(var).range=range;
   writefis(x,'WPS.fis');
```

XII. Cases Test

Two scenarios were simulated to verify the results of our system.

Test 1.

Scenario unhindered.



Where the values of signal strength are as follows:

	PA-1	PA-2	PA-3	PA-4	PA-5
PA-1	-	-45	-51	-42	-24
PA-2	-45	-	-40	-49	-27
PA-3	-51	-40	-	-47	-26
PA-4	-42	-49	-47	-	-27
PA-5	-24	-27	-26	-27	-

We apply the role of approximation () for adjusting regions.

aproximación (45,42,40,47,24,27,26,27)

After making adjustments in the system, both the range of variables and the variables:

modificarRangos (‘1’,[10,47])
modificarRangos (‘2’,[10,47])
modificarRangos (‘3’,[10,47])
modificarRangos (‘4’,[10,47])
modificarRangos (‘5’,[10,27])

modificarPA (‘1’,[9,10,19])
modificarPA (‘2’,[19,28,38])
modificarPA (‘3’,[38,47,48])

modificarS (‘1’,[9,10,14])
modificarS (‘2’,[14,18,23])
modificarS (‘3’,[23,27,28])

It calculates the position:

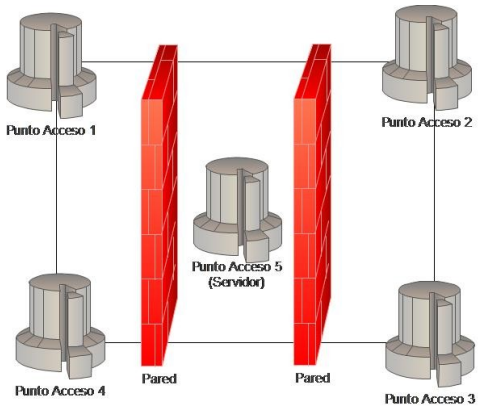
evaluar ([, , , ,])

The results are:

Signal Get					Actual Position	Get Position
PA1	PA2	PA3	PA4	PA5		
27	22	41	50	19	R7	R7
26	39	40	28	18	R21	R21

Test 2.

Scenario unhindered.



Where the values of signal strength are as follows:

	PA-1	PA-2	PA-3	PA-4	PA-5
PA-1	-	-61	-75	-41	-30
PA-2	-61	-	-38	-70	-31
PA-3	-75	-38	-	-57	-30
PA-4	-41	-70	-57	-	-28
PA-5	-30	-31	-30	-28	-

We apply the role of approximation () for adjusting regions.
aproximación (61,41,38,57,30,31,30,28)
After making adjustments in the system, both the range of variables and the variables:

modificarRangos (‘1’,[10,61])
modificarRangos (‘2’,[10,61])
modificarRangos (‘3’,[10,61])
modificarRangos (‘4’,[10,61])
modificarRangos (‘5’,[10,31])

modificarPA (‘1’,[9,10,22])
modificarPA (‘2’,[22,35,49])
modificarPA (‘3’,[49,61,62])

modificarS (‘1’,[9,10,15])
modificarS (‘2’,[15,20,26])
modificarS (‘3’,[26,31,32])

It calculates the position:
evaluar ([, , , ,])
The results are:

Signal Get					Actual Position	Get Position
PA1	PA2	PA3	PA4	PA5		
35	33	57	62	23	R10	R10
37	56	60	35	20	R21	R21

XIII. Conclusion

Among the possibilities for indoor positioning, we found that the positioning based on fuzzy logic takes us back the position of a non-precise, because it is necessary in regions determined beforehand, rather than coordinates or absolute positioning.

The system can be complicated, as much as we want, installing a larger number of access points, which would generate a greater number of regions and smaller area, which we increased the accuracy of our positioning. Once assumed this loss of precision, we note that the system design is simpler and more adaptable that if you use other technologies, since it uses fuzzy logic, similar to human logic, and as a major advantage is that it does not require a training system, making the system itself is adjusted automatically each an interval of time.

As we have found problems that gives us the possibility to use a single controller diffuse to define the regions is very limited, as these must be defined by concentric circles for each access point, not in line with real values obtained. Should you find different intensity values in an access point to various access points, the system will choose the lesser intensity in order to cover all access points involved. Besides this restriction affects the logic of the system, because if a calculation differs slightly from what is established, the result may be a region which is out near the actual position of the object. Therefore, we have achieved a valid positioning system for detecting presence, because if properly defined regions or increasing the number of access points the location of the receiver can be sufficiently accurate for this type of application.

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