Object location indoors

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1 Abstract

keywords:BLE RSSI location Android
This paper is aimed at introducing the algorithm of indoor object location based on BLE technology, and some details in implementation process.

2 Background of Issue

Some electronic devices that have a tiny outlook could be hard to find when users place them arbitrarily after usage.If users cannot find them timely, troubles may appear.To avoid these troubles happening, we try to utilize BLE(bluetooth Low Energy) technology to locate such tiny object with help of Android mobile devices.

3 What's BLE?

BLE, abbreviation of Bluetooth Low Energy, is a wireless personal area network technologyaimed at novel applications in the healthcare, fitness, beacons,security, and home entertainment industries.Compared to Classic Bluetooth, Bluetooth Smart is intended to provide considerably reduced power consumption and cost while maintaining a similar communication range.[1]

4 Work Arrangement

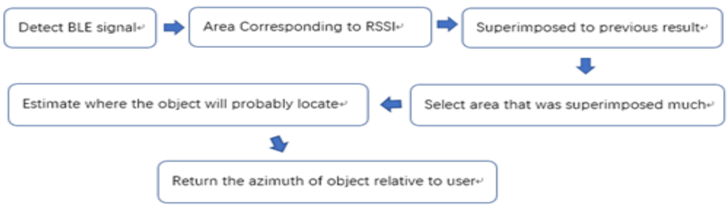
This project was raised by Dr.Xinyu Tong, and was carried out by Yexin Yang, in IEEE class, and me.
Yexin Yang is responsible for controlling sensors on mobile device, using bluetooth sensor on mobile phone to catch BLE signal sent by the object, and gyroscope to determine which direction the user is facing.
My work is to design an algorithm to handle data collected by sensors, and give the most probably position that the object locates.

5 Overview of Algorithm

Due to the diversity of indoor surroundings, signal would be received after several reflection, diffraction and scattering.As a result, RSSI(Received Signal Strength Indication) is not so stable, so that RSSI value could have a fluctuation even if user is under the same condition.Therefore, RSSI value cannot act as an exact known volume.

Thus I choose the algorithm as follows: regard the position of user as reference point, assume RSSI value is r_i, then the object could cause a RSSI at user's position equivalent to r_i in multiple location. So, given a specific RSSI value, a series of possible location corresponding to it constitute an area,assumed as S_i.Then according to different RSSI values $r_1, r_2, r_3, ..., r_n$ detected in different position, the corresponding possible area $S_1, S_2, S_3, ..., S_n$ could be obtained.These areas would overlap.The more times overlap happens in some position, then the higher chance the object will have to locate in that position.

The process of this algorithm could be expressed as graph 5.1.



Graph 5.1 Algorithm Process

6 RSSI line – mathematical model build

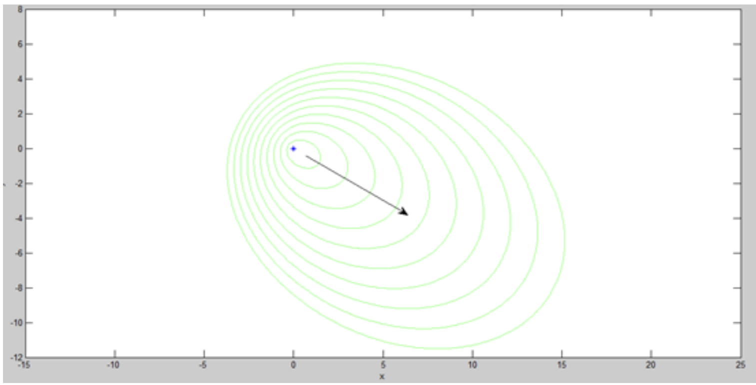
After some experiment of BLE signal detection, we found that in condition that the distance between user and signal source is fixed, RSSI tend to decrease with increasing of the angle of user's orientation and direction of the source.When user face the source, the strongest signal can be detected; while the weakest signal can be detected when user turns his back towards the source.Then we can infer that, for a specific RSSI value, when the source is in front of user, the distance would be longest, while the source is in back of user, the distance would be shortest.

similar to contour line, we define a concept, RSSI line.Under ideal conditions that RSSI value would not fluctuate, when user's orientation and position is fixed, the source in any position on the same RSSI line will produce equivalent RSSI value at user's postion.

considering the characteristic mentioned above, a model made up by ellipse come into my mind naturally.

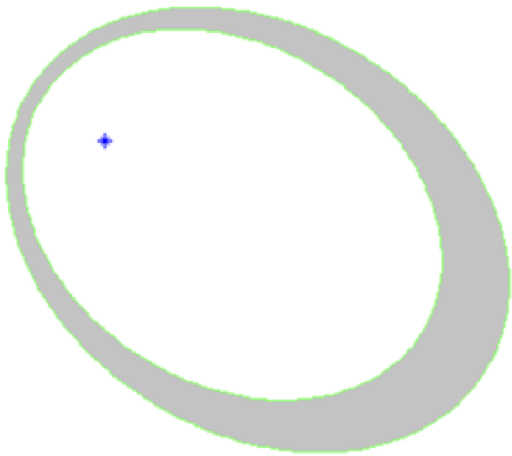
according to the second definition of ellipse, the ratio of the distance between a point on the ellipse and a focal point to the distance between this point and the directrix is a constant, which is defined as eccentricity e.Therefore, the longer

the distance between a point on the ellipse and the directrix is, the longer the distance between that point and the focal point will be. This characteristic coincide with the RSSI line mentioned above. So we can use a set of ellipses that have a common focal point to fit the RSSI line approximately.
After several trials, the set of ellipses show on graph 6.1 could fit the RSSI characteristic better, in which "*" represent the position of user, the arrow indicate the orientation of user.



Graph 6.1 the set of ellipses to fit the RSSI line

This set of ellipses have the following characteristic:
Characteristic 6.1: Each ellipse have a common focal point which represents the position of user;
Characteristic 6.2: The ratio of semi-minor axis b to semi-major axis a is a constant k.That means, the shape of the ellipses is fixed.The parameter k will be determined by experiment.
Characteristic 6.3: See from the user's position, RSSI increase regularly along a certain direction. Consequently, under ideal condition, when user's position and orientation is fixed, the ellipse will be determined only by RSSI.If considering the fluctuation of RSSI, for a certain RSSI value, possible range will expand to an oval ring area as graph 6.2.



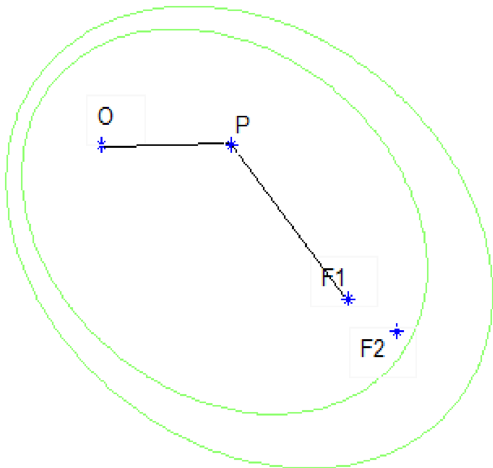
Graph 6.2 ring area corresponding to a certain RSSI

7 Matlab simulation

Matlab code is easy to program and debug, so in order to decrease potential problems that may appear in Android application, I decide to simulate the algorithm on Matlab first.
To implement traversal of 2D-space, the space should be divided into small square grid and be represented by 2D-array, that is to say, the space should be discretized.
Information collected by sensors contains user's current position (x_i, y_i), RSSI value r_i, and the orientation of user θ.
As mentioned earlier, possible area of source could be determined with RSSI, user's position and user's orientation, and this area is bounded by two ellipse.To judge whether a point P is in the area, we only need to judge whether the relationship in following formula is satisfied.

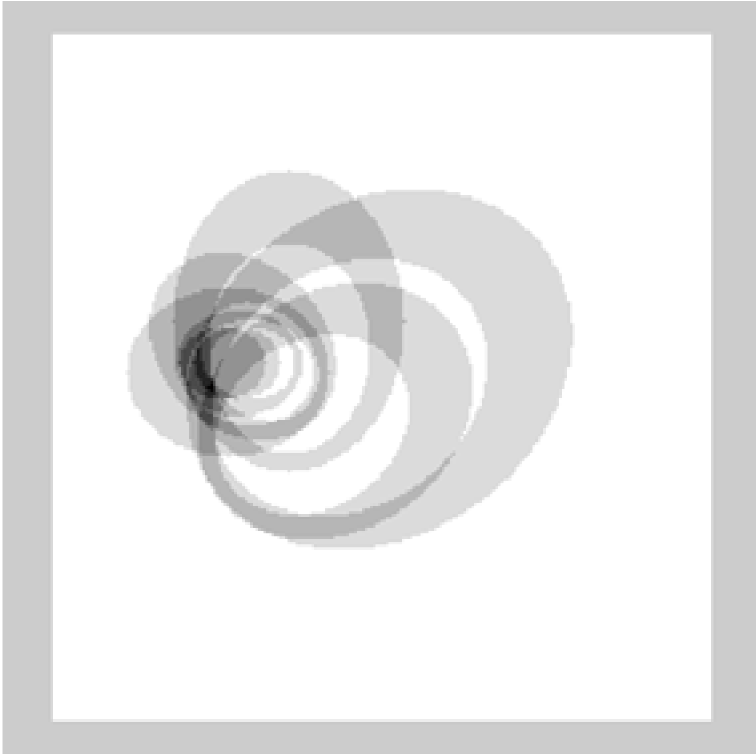
$$|PO| + |PF_1| > 2a_1 \quad and \quad |PO| + |PF_2| < 2a_2 \tag{1}$$

Among them, O is the common focal point of two ellipse and represent user's position; F_1,F_2 represent the other focal point of the two ellipse respectively; a_1,a_2 represent the semi-major axis length, as shown in graph 7.1.



Graph 7.1 relationship judgement of point and target area

Meanwhile, according to Characteristic 6.2, $\frac{b}{a} = k$, then semi-focal-length $c = a\sqrt{1-k^2}$.Therefore, the function to determine the oval ring area just need to return a_1 and a_2. Every time when mobile device detect target BLE signal, traversal on the search space will be executed once. If a point coordinated (i,j) satisfy the relationship in fomular (1), the count number at (i,j) in the array restoring the result will add 1, in order to implement the overlap of multiple area corresponding to BLE signal detection. Use graph 7.2 to display the overlapping extent graphically, in which the depth of shadow at a point represent the extent of overlapping taking place there, scilicet, the possibility that the object locates there.



Graph 7.2 graphical simulation result

Subsequent work is to return the azimuth of area where overlaps much. In that area with lillte overlapping has no reference value, a threshold is set to filter coordinate. Then take the weighted average of every point above the threshold, regarding the overlap times as weight.

$$\bar{x} = \frac{\sum iA(i,j)}{\sum A(i,j)} \qquad A(i,j) > threshold \tag{2}$$

$$\bar{y} = \frac{\sum jA(i,j)}{\sum A(i,j)} \qquad A(i,j) > threshold \tag{3}$$

$A(i,j)$ represent overlap times in coordinate (i,j), and $(\bar{x},\bar{y})$ is coordinate of the position we need. With the coordinate, we can use inverse trigonometric function to calculate the azimuth of the object.

8 Implementation on Android

Based on the application implemented by Yexin Yang, rewrite the algorithm above into a function with java at AndroidStudio.Every time when BLE signal is detected, the function will be called and return the probable position of the object base on input parameter, including RSSI, position and orientation. How to get current position of user is still under development.

9 future work

This project is still incomplete.In future work, we will perfect it from aspects following:
1) Get the position of user precisely;
2) Add User Interface to instruct user;
3) Revise the math model to make it more accurate.
4) Improve the operating efficiency and optimize memory.

Reference

[1] Bluetooth Low Energy - Wikipedia
https://en.wikipedia.org/wiki/Bluetooth_low_energy