Indoor Relative Position Analysis Based on MDS

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1 Abstract

This semester, I choose indoor positioning as my project. This report describes a new type of indoor positioning method. Using the third party wifi of HUAWEI smart home for indoor positioning.

2 Background

2.1 Indoor positioning

To achieve location positioning in the room, mainly using wireless communications, base station positioning, inertial navigation and other integrated technology to form a set of indoor location positioning system. Achieve personnel and objects in the location of monitoring.

2.2 Smart home

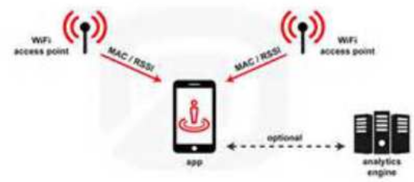
The residence as a platform, using integrated wiring technology, network communications technology, security technology, automatic control technology, audio and video technology will be home life-related facilities integration to bild a highly efficient residential facilities and family planning management system.

2.3 Multidimensional scale(MDS)

A means of visualizing the level of similarity of individual cases of a dataset. It refers to a set of related ordination techniques used in information visualization, in particular to display the information contained in a distance matrix. It is a form of non-linear dimensionality reduction. An MDS algorithm aims to place each object in N-dimensional space such that the between-object distances are preserved as well as possible. Each object is then assigned coordinates in each of the N dimensions. The number of dimensions of an MDS plot N can exceed 2 and is specified a priori. Choosing N=2 optimizes the object locations for a two-dimensional scatterplot.

3 Project work

In this project, the basic principle is same as positioning technology in the wifi technology, that is, through received signal strength indication(RSSI), RSSI localization techniques are based on measuring signal strength from a client device to several different access points, and then combining this information with a propagation model to determine the distance between the client device and the access points. Trilateration(sometimes called multilateration) techniques can be use to calculate the estimated client device position relative to the known position of access points.



Through one of the cheapest and easiest methods to implement, its disadvantage is that it does provide very good accuracy(2-4m), because the RSSI measurements tend to fluctuate according to changes in the environment or multipath fading. If the location measurement is based only on the currently connected wifi access point, without reference to the composition of the surrounding wifi signal strength, wifi positioning is very easy to exist error.

So we use currently popular smart home, by referring to these wifi signal strength, reduce the error. We collect the wifi signal strength from the indoor intelligent devices in the room. In the mobile device and the entire smart home network formed, the collection of wifi strength between any two. Calculated the relative distance between of both by the wifi strength. Through matlab, we use multidimensional scale(MDS) to get the situation of the whole network relative situation, so precise positioning of mobile devices.

First, we need to use the wifi strength of the HUAWEI smart home to calculate the required distance. We implement all the wifi signal strength received by the Andrews and save a txt file containing all the measured data, then we chose an empty outdoor space for the strength test of the HUAWEI mobile wifi and set at a distance of 1m to 10m, with an interval of 1m, 20minutes for each point. We obtained a Gaussian distribution for each integer position and did the matching between the Gaussian images.

To determine the relationship between the intensity and distance of a signal, which requires an understanding of the wave propagation model. In the free space environment, no consideration for blocking and multipath propagation, the distance between the launch and receiver is d, and the receiving power P_r is represented as:

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi d)^2}$$

$P_t$is the launch power; G_t and G_r are emission and receive antenna gain; λ is the wavelength of the wave.

In the real environment, the transmission loss of radio is still relatively large due to the random factors such as multi-diameter, obstruction and diffraction. It is more reasonable to use the log-normal distribution model:

$$P_r(d) = RSSI = 10log\left[\frac{P_r(d_0)}{P}\right] + 20log\left[\frac{d_0}{d}\right] (general\ d_0 = 1)$$

And now we are trying the algorithm of mix the different distances together and distinguish the first half and the second half belong to which integer position. Then the mobile device can obtain the Gaussian distribution of a wifi to estimate the distance.

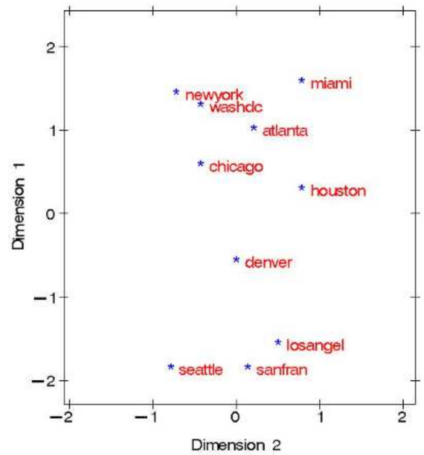
Last, after solving the problem to get the distance through the wifi signal strength, and then we get the relative position information of the entire space after passing the MDS processing by the matrix of the overall distance.

I use a classic example to illustrate the application of MDS, using a perceptive image to show the distance of the U.S. Cities.

	Atlanta	Chicago	Denver	Houston	Los Angeles	Miami	New York	San Francisco	Seattle	Wanshington D.C.
Atlanta	0	.	.	.	.	.	.	.	.	.
Chicago	587	0	.	.	.	.	.	.	.	.
Denver	1212	920	0	.	.	.	.	.	.	.
Houston	701	940	879	0	.	.	.	.	.	.
Los Angeles	1936	1745	831	1374	0	.	.	.	.	.
Miami	604	1188	1726	968	2339	0	.	.	.	.
New York	748	713	1631	1420	2451	1092	0	.	.	.
San Francisco	2139	1858	949	1645	347	2594	2571	0	.	.
Seattle	2182	1737	1021	1891	959	2734	2408	678	0	.
Wanshington D.C.	543	597	1494	1220	2300	923	205	2442	2329	0

Through MDS analysis, we can check the results of analysis by comparing the U.S. Map.

MDS process:



Given the distance between all the network in a matrix, where is the distance between the coordinates of i and j, given by

$$d_{ij} = \sqrt{\left(x_i - x_j\right)^2 + \left(y_i - y_j\right)^2}$$

Now, we want to find the coordinates.

General forms of loss functions called Stress in distance MDS and Strain in classical MDS.

The strain is given by:

$$Strain_D\left(x_1, x_2, ..., x_N\right) = \left(\frac{\Sigma\left(b_{ij} - \langle x_i, x_j\rangle\right)^2}{\Sigma b_{ij}^2}\right)^{1/2}$$

Where b_{ij} are the terms of the matrix defined on step of the following algorithm.

Steps of a MDS algorithm :

MDS uses the fact that the coordinate matrix can be derived by eigenvalue decomposition from $B = XX'$. And the matrix B can be computed from proximity matrix D by using double centering.

1.Set up the squared proximity matrix $D^{(2)} = \left[d_{ij}^2\right]$

2.Apply double centering:$B = -\frac{1}{2}JD^{(2)}$using the centering matrix $J = I - \frac{1}{n}11'$, where n is the number of objects.

3.Determine the m largest eigenvalues $\lambda_1, \lambda_2, ..., \lambda_m$ and corresponding eigenvectors of $e_1, e_2, ..., e_m$ of B(where is the number of dimensions desired for the output).

4.Now,$X = E_m \Lambda_m^{1/2}$, where E_m is the matrix of m eigenvectors and Λ_m is the diagonal matrix of m eigenvalues of B.

We could call MDS function directly in MATLAB to calculation. After that, we will reached a accurate position.

4 Future work

1.solve the problem of indoor multi-diameter effects, obstruction and reflection of obstacles.

2.the operating calculation is large and the mobile device may not be able to handle it.