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Ultra-wideband (UWB) precise location problem under signal interference based on Shark optimization algorithm

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Keywords: Positioning, UWB, Kmeans, Radar map, Matching algorithm, Shark optimization, Least square method.

Abstract: In indoor positioning applications, UWB technology can achieve centimeter-level positioning accuracy, and has good resistance to multipath interference and weakness, as well as strong penetration. However, due to the complex and changeable indoor environment, UWB communication signals are easily blocked. Although UWB technology has penetration capability, it still produces errors. When there is strong interference, abnormal fluctuations of data will occur, and indoor positioning cannot be basically completed, or even serious accidents will occur. Therefore, the problem of ultra-wideband (UWB) precise location under signal interference becomes an urgent problem to be solved. An algorithm is established to find the correct distance between the "abnormal data" processed by the minimum sum of absolute distance differences and "normal data". Optimal target optimization A model based on shark optimization and UWB localization based on least square method are used to establish a comparison model, using shark optimization model can better calculate the exact location of Tag point.

1. Introduction

There are many methods for UWB positioning technology [1-3]. This paper only considers the ranging principle based on Time of Flight (TOF), which is one of the most common positioning methods in UWB positioning method. TOF[8] ranging technology is a two-way ranging technology, which calculates the signal in the flight time of two modules, multiplied by the speed of light to find the distance between two modules, the distance must have different degrees of error, but its accuracy has been relatively high.

In indoor positioning applications, UWB technology can achieve centimeter-level positioning accuracy (generally referring to 2-dimensional planar positioning), and has good resistance to multipath interference and weak performance, as well as strong penetration ability. However, due to the complex and changeable indoor environment, UWB communication signals are easily blocked. Although UWB technology has penetration capability, it still produces errors. When there is strong interference, abnormal fluctuations (usually time delay) will occur in data, and indoor positioning cannot be basically completed, or even serious accidents will occur. Therefore, the problem of ultra-wideband (UWB) precise location under signal interference becomes an urgent problem to be solved.

2. Data cleaning

2.1 Background of the study area

For outlier processing [4], two methods are generally adopted. One is n standard deviations; The other is the boxline test. The judgment formula of standard deviation method is: where is the sample mean and is the sample standard deviation; when n=2, the observation that meets the condition is the outlier; when n=3, the observation that meets the condition is the extreme outlier; The judgment formula of the boxplot is or, where Q1 is the lower quartile (25%), Q3 is the upper quartile (75%), and IQR is the quartile difference (the difference between the upper quartile and the lower quartile). When n=1.5, the observation that meets the condition is an outlier; when n=3, the observation that meets the condition is an extreme outlier[9].

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}\left(x_i - \overline{x}\right)^2}{n}} \tag{1}$$

Table 1: Comparison of statistical description of base station outliers before and after processing

A0	**count**	**mean**	**std**	**min**	**25%**	**50%**	**75%**	**max**
Before	275	4899.02	17.55	4850	4890	4910	4910	4940
After	264	4900.38	15.86	4870	4890	4910	4910	4930
A1	**count**	**mean**	**std**	**min**	**25%**	**50%**	**75%**	**max**
Before	264	5327.05	10.52	5300	5320	5330	5330	5350
After	256	5327.11	9.71	5310	5320	5330	5330	5340
A2	**count**	**mean**	**std**	**min**	**25%**	**50%**	**75%**	**max**
Before	256	2030.16	10.40	2010	2020	2030	2040	2060
After	255	2030.04	10.26	2010	2020	2030	20440	2050
A3	**count**	**mean**	**std**	**min**	**25%**	**50%**	**75%**	**max**
Before	255	2858.59	248.54	70	2880	2880	2880	2900
After	253	2880.63	7.74	2860	2880	2880	2880	2900

3. Location model and calculation

3.1 Geometric modeling solution

After obtaining the distance between the unknown point and the four base stations, all that remains is to solve for the coordinates of the unknown point. Known from geometry knowledge through the known location of the base station as the center of the circle, distance as a multiple round by round radius to point, two round pitch is more than two round radius difference, it will meet in one or two points, then four round if intersection, there will always be one of the intersection area, so we ask for solution of the unknown points is to four known points as the center of the circle, The intersection area of the four circles drawn with the distance between them and the unknown point as the radius is the approximate position of the unknown point [5-7].

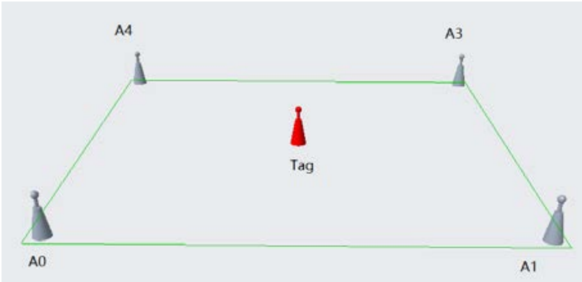

Figure 1: Indoor base stations are distributed in different horizontal planes

Based on geometric knowledge, the model is established to solve the problem. The coordinates of the four base station points (X1, y1, z1)(X2, y2, z2)(x3, y3, z3)(x4, y4, z4) and the distance to the unknown point (x, y, z) R1, R2, R3, R4 are known, so the four-point positioning uses the matrix to solve the equation:

$$\begin{aligned}(x-x_1)^2+(y-y_1)^2+(z-z_1)^2&=R_1^{\,2}\\(x-x_2)^2+(y-y_2)^2+(z-z_2)^2&=R_2^{\,2}\\(x-x_3)^2+(y-y_3)^2+(z-z_3)^2&=R_3^{\,2}\\(x-x_4)^2+(y-y_4)^2+(z-z_4)^2&=R_4^{\,2}\end{aligned} \tag{2}$$

Transpose both sides of the above equation into a linear equation:

$$\begin{aligned}x_1x+y_1y+z_1z-0.5R^2&=0.5(x_1^2+y_1^2+z_1^2-R_1^2)\\x_2x+y_2y+z_2z-0.5R^2&=0.5(x_2^2+y_2^2+z_2^2-R_2^2)\\x_3x+y_3y+z_3z-0.5R^2&=0.5(x_3^2+y_3^2+z_3^2-R_3^2)\\x_4x+y_4y+z_4z-0.5R^2&=0.5(x_4^2+y_4^2+z_4^2-R_4^2)\end{aligned} \tag{3}$$

This can be converted to matrix multiplication:

$$\begin{bmatrix}2(x_1-x_2) & 2(y_1-y_2) & 2(z_1-z_2)\\2(x_1-x_3) & 2(y_1-y_3) & 2(z_1-z_2)\\2(x_1-x_4) & 2(y_1-y_4) & 2(z_1-z_2)\end{bmatrix}\begin{bmatrix}x\\y\\z\end{bmatrix}=\begin{bmatrix}\lambda_1\\\lambda_2\\\lambda_3\end{bmatrix} \tag{4}$$

Then you solve for A inverse, multiply both sides of this equation by x, y, z, and you get the coordinates of the unknown point.

In the experiment, MATLAB matrix operation was used to calculate the target coordinates, and the results are shown in Figure 2.

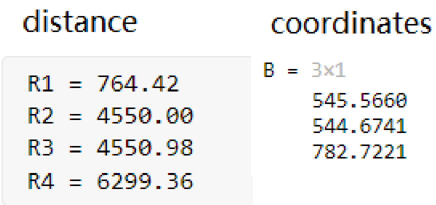

Figure 2: Distance and coordinates

3.2 Modeling and calculation of shark optimization algorithm

The shark optimization algorithm model is used to calculate the target coordinates, and the results are shown in Figure 3.

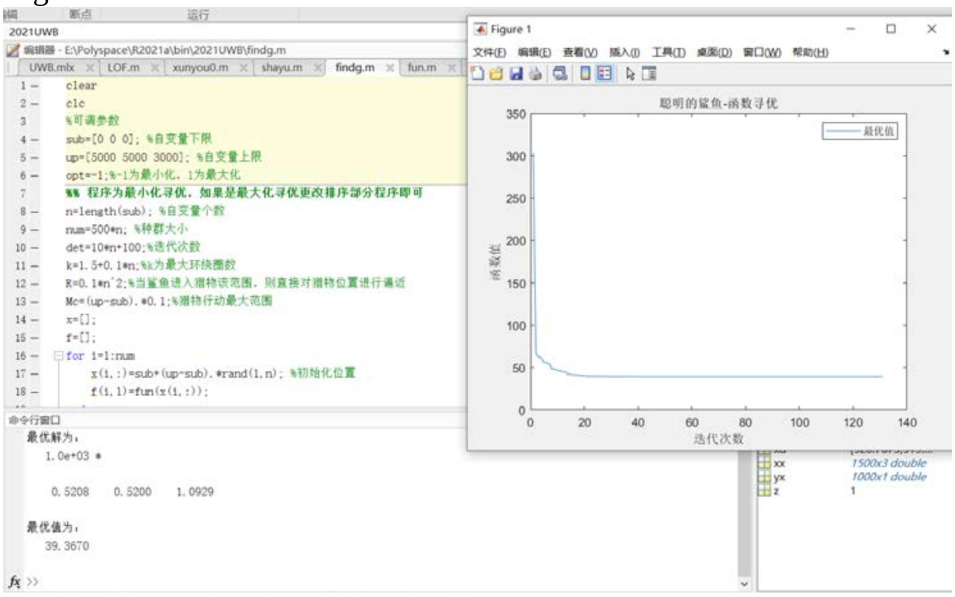

Figure 3 Shark search for optimal coordinates

Table 2: Accurate positioning of normal data

Normal data	**1**	**2**	**3**	**4**	**5**
x	1178.70	3174.96	2737.81	2448.70	1479.72
y	677.79	1715.39	1167.05	1007.65	2542.09
z	691.19	763.00	808.56	2277.75	2133.94

Table 3: Accurate location of abnormal data

Abnormal data	**1**	**2**	**3**	**4**	**5**
x	2027.83	4282.52	1943.23	3657.92	4703.79
y	725.11	1663.01	1007.00	2115.28	2016.68
z	1087.84	669.17	2629.86	2501.42	970.28

4. Conclusions and Discussion

The data at the center point of the clustering result is the exact value. An algorithm is established for 5 groups of "abnormal data" to find the correct distance between the "abnormal data" processed by the minimum sum of absolute distance differences and "normal data". Optimal target optimization A model based on shark optimization and UWB localization based on least square method are used to establish a comparison model, using shark optimization model can better calculate the exact location of Tag point.

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