Error Compensation Method for TOF Ranging and Positioning

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Abstract. In order to solve the problem of indoor target movement autonomous positioning error accumulation, this paper proposes a method of the RSST assisted positioning error compensation. In the first place, the identification card position is determined using optimizing the distance and orientation between the main station and the auxiliary station. Secondly, the Auxiliary correction of time positioning error is proceeding by RSSI measured value. Finally, the singular data are corrected and least squares processed through multiple measurements to reduce the influence of measurement data fluctuation on positioning. Practical application has been carried out in the corridor environment consisting of 1 main station,2 auxiliary stations and 20 terminal nodes and the direct-vision distance is 200m. The results show that the method reduces the errors of environment, scattering and system. Compared with the positioning error of point-to-point ranging in the corridor environment, the error decreases from 12m to 3m by 75%. Compared with the corridor environment 1, the location error of main station and auxiliary station is reduced from 15m to 3m by 80%.

Keywords: Master orientation; Singular data compensation; Auxiliary orientation.

1. Introduction

Indoor positioning is important in fire-rescue and equipment maintenance[1].Some methods use vibration sensor to determine the target position, the advantage is to overcome the blocking problem, but because of the sensor sensitivity is not high, positioning error is large. Mems sensor positioning [2] has the advantage of independent positioning and does not rely on the source equipment. However, the drift error of Mems sensors is large, so the error cannot be corrected by itself, and the positioning distance is very limited.

There are wireless positioning methods based on the main station and auxiliary station to achieve high accuracy of positioning, but the indoor environment is complex, blocking is inevitable, direct vision distance is close, scattering is serious and other factors also seriously affect the positioning error. The compensation method proposed in this paper not only reduces the communication overhead of the JN5148 nodes [3], but also reduces the error caused by wall scattering and delay, and realizes the accurate positioning of indoor person and device[4].

2. TOF Ranging Positioning Method

2.1 Related Concept Definition

Definition (1)(positioning identification card)

The positioning identification card is composed of a TOF ranging and positioning device and is connected with the positioning target.

Definition (2)(positioning auxiliary station)

The positioning auxiliary station is composed of TOF ranging and positioning device, which communicates with the positioning identification card and the positioning main station to realize the ranging of the positioning identification card.

Definition (3)(positioning master station)

Master orientation process the ranging and time-stamp data of the auxiliary station and the identification card, and calculating the relative position of the identification card[5].

2.2 TOF Ranging Positioning Method

As shown in figure 1, the relative position of the labeling card is calculated according to the distance between the labeling card and the main station and the auxiliary station.

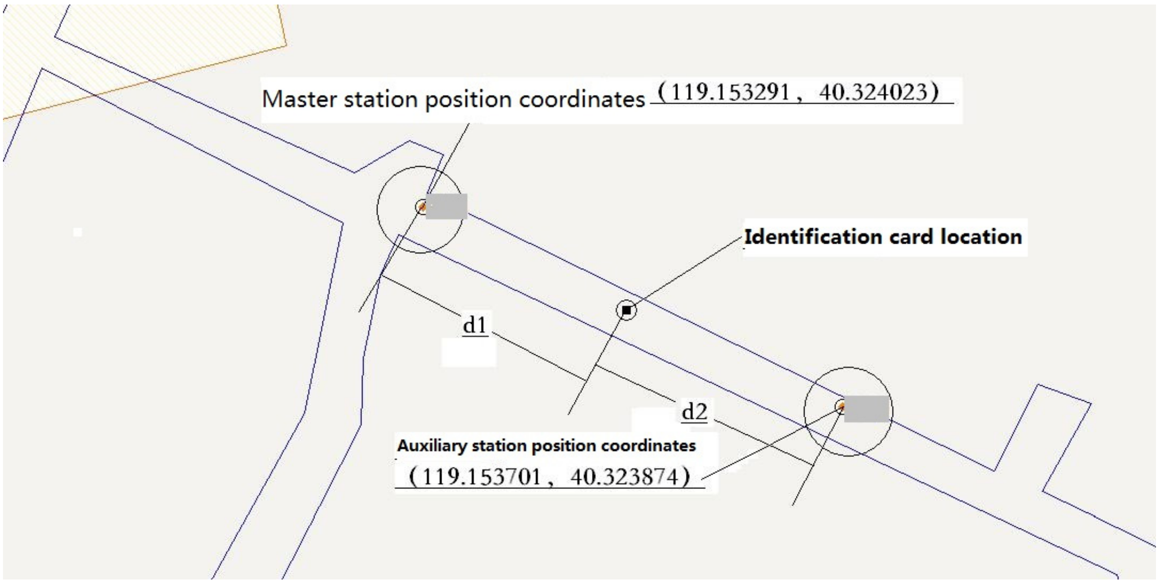

Figure 1. location diagram of main station, auxiliary station and identification card

The specific method is as follows: in the figure, the roadway can be directly seen, the main station and the auxiliary station are fixed, and the sign card moves in the roadway.At the beginning of the measurement, the auxiliary station sends its own measurement data and time stamp to the main station according to the measured distance from the identification card. When the main station receives the data, it measures the distance from the identification card and makes a time stamp.

3. Error Compensation for TOF Ranging and Positioning

3.1 TOF Ranging and Positioning Error

By the 1.2 method, the experiment was proceeding in the corridor environment according to the marked position in figure 1. The error between the measured positioning data and the actual position of the target was within the range of 15-22m, with an average value of about 18m. The identification card was fixed at the same position, and the floating of the positioning error data was irregular.

TOF ranging error is mainly related to the corridor environment, wall scattering and JN5148 module itself.When the JN5148 modules communicate with each other, the flight time of the signals in the air is extremely short. Due to the protocol relationship, if the calculation is not accurate, the error will be large.Wall scattering and complex corridor environment will change the communication path and affect the positioning error.

3.2 Error Compensation Methods for TOF Ranging and Positioning

(1) Main station, auxiliary station to determine the azimuth error compensation

One auxiliary station is added on the basis of one main station and one auxiliary station in 1.2. Each node position is determined dynamically according to the actual environment to ensure that the main station and auxiliary station are not in a straight line. The optimal communication and transit position of the main station and auxiliary station in the roadway is ensured through multiple measurements.

System at the beginning, as long as the identity card and two auxiliary station communication range, two auxiliary station according to the measured distance with id card, the distance measurement data and time-stamp sent to the host at the same time, the master station received two auxiliary station data, measuring the distance and id card with yourself, and time-stamp, then according to the three groups of distance data, three time stamps and advocate complementary station geometric location to determine the orientation and the relative position of identity card data.
This way can reduce the measurement errors caused by the wall scattering and the complex corridor environment.

(2) Auxiliary error compensation for RSSI positioning

The relation between the node RSSI value and the distance between nodes can be expressed by formula 1 [6]:

$$P_r(dBm) = A - 10.n\lg r \tag{1}$$

A and n are obtained by power measurement and actual communication distance fitting.

Because of identity card mobile node continuity and RSSI of node localization is given priority to with time positioning, positioning the auxiliary method, the orientation of time and RSSI is obtained by multiple measuring two sets of data, according to the accuracy requirement set allowed variance range, make time for their positioning data points, by comparing the time RSSI two sets of data variance, variance smaller location data as a fixed location data.

(3) Least squares error compensation

Above, the time-stamp and RSSI value are used to correct the singular value of TOF ranging data to reduce the error accumulation.

On this basis,Quadratic error correction is performed[7].

Suppose xi represents the corrected measurement distance after intensity compensation, yi represents the actual distance, then:

$$y = a + bx + \varepsilon \tag{2}$$

$\varepsilon \sim$ N(0, δ^2).

So there's an error $\left(Y_i - a - bX_i\right)$, $i = 1, 2, \cdots, n$,Sum the error squared to obtain:

$$Q(a,b) = \sum_{i=1}^{n}\left(Y_i - a - bX_i\right)^2 \tag{3}$$

Then:

$$\begin{cases} \dfrac{\partial Q(a,b)}{\partial a} = 2\sum_{i=1}^{n}\left(Y_i - a - bX_i\right) = 0, \\ \dfrac{\partial Q(a,b)}{\partial b} = \sum_{i=1}^{n}(-X_i)\left(Y_i - a - bX_i\right) = 0, \end{cases} \tag{4}$$

By sorting, the binary quadratic equations of a and b can be obtained:

$$\begin{cases} \sum_{i=1}^{n} Y_i = na + b\sum_{i=1}^{n} X_i \\ \sum_{i=1}^{n} X_i Y_i = a\sum_{i=1}^{n} X_i + b\sum_{i=1}^{n} X_i^2 \end{cases} \tag{5}$$

Solve the system, get:

$$\begin{cases} \hat{b} = \dfrac{\sum_{i=1}^{n} X_i Y_i - n\overline{X}\cdot\overline{Y}}{\sum_{i=1}^{n} X_i^2 - n\overline{X}^2} \\ \hat{a} = \overline{Y} - \hat{b}\overline{X} \end{cases} \tag{6}$$

The corrected actual distance is obtained as follows:

$$\hat{Y} = \hat{a} + \hat{b}X \tag{7}$$

The actual distance can be estimated according to the measured distance corrected after intensity compensation according to 7.

4. Application Example

4.1 Application Environment and Testing Methods

Application environment: as shown in figure 1, it is an unobstructed network environment with direct vision distance of 200m, consisting of 1 main station, 2 auxiliary stations and 20 identification CARDS.

Test method: mobile positioning test was carried out on 20 identification CARDS in the application environment, and the recorded time value was tested every one meter for 20 times. The measured distance was calculated according to the TOF ranging method, and the singular value was corrected with the RSSI strength value. Three groups of distance data and three groups of time-stamps were obtained, and error compensation was conducted according to the method in 2.2.

4.2 Test Result

Compared with the point-to-point network communication in the corridor environment, the communication overhead is dispersed from 2 to 4 nodes. For each node, the communication overhead is reduced by 50%, and the ranging and positioning error is reduced by 75% from 12m to 3m.Compared with the corridor environment 1 for the main station and the auxiliary station, the communication overhead is dispersed from 3 to 4 nodes. For each node, the communication overhead is reduced by 25%, and the ranging and positioning error is reduced by 80% from 15m to 3m.

4.3 Interpretation of Result

The positioning method and application test of the system are carried out under the environment of slow movement of identification card nodes. By analyzing the causes of positioning error and the compensation method, the communication overhead and location error of the system are reduced.Since the auxiliary station is added, the measurement error caused by the node movement is compensated by the time difference of the measurement of the two auxiliary stations, which provides the basis for accurate positioning.The influence of singular data on location error is eliminated by RSSI compensation and least square regression analysis.

5. Conclusion

To compensate for metope scattering and the corridor environment complex change communication path effect the positioning error of the system, the article puts forward a kind of TOF ranging positioning error compensation method, through the study of the optimization of the main and auxiliary station location, using RSSI strength value, correction of TOF range value, and using the least squares regression analysis was carried out on the measurement data, reduces the communication overhead and information system ranging positioning error. In order to further improve the accuracy of the system, the error compensation method should be considered in the next step when the number of identification CARDS increases and the speed increases.

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