Study of Mobile Robot positioning based on Ultra-Wideband System

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Abstract

In order to achieve high precision indoor positioning, UWB positioning scheme was proposed. This positioning system was based on the combination of DS-TWR algorithm and TDOA algorithm, which eliminated the problem of time desynchronization between positioning base stations and tag.The collected outlier data was filtered to remove signals disturbed by noise. The Kalman filtering was introduced for predictive estimation of localization data. The experimental results showed that the root-mean-square error in the X-axis direction and Y-axis direction after Kalman filtering was controlled within 10 cm, which improved about 5 cm compared with the actual measurement positioning error.

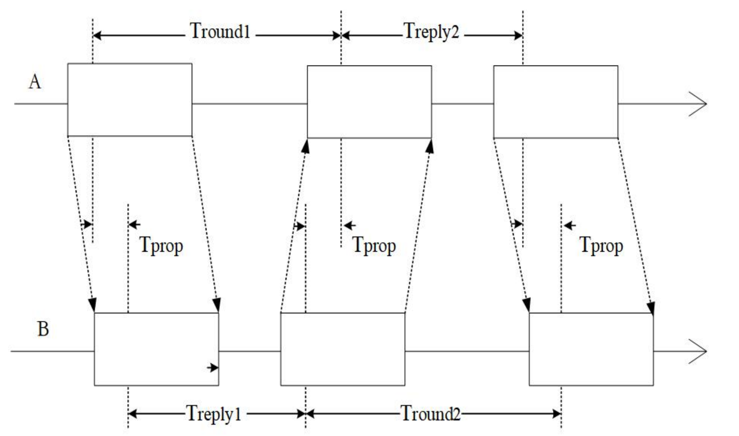
Introduction

As to expanding the application scenario, human demand for positioning is more and more popular. UWB positioning technology compatible with IEEE 802.15.4-2011 standard has been widely used in indoor positioning due to its strong anti-interference ability, good penetration, high positioning accuracy, fast real-time positioning speed and other advantages. A TOF and TDOA joint positioning algorithm, which not only takes advantage of the fact that TDOA does not require complete clock synchronization between the two nodes to be tested, but also introduces TOF measurement to suppress the problem of excessive error caused by the hyperbolic nature of TDOA algorithm. It can meet the characteristics of good positioning accuracy and strong stability.

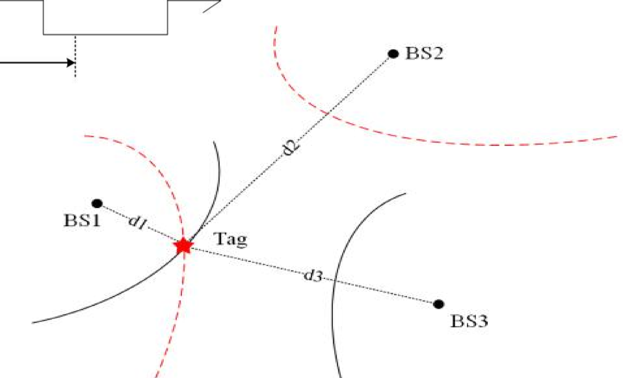
Method

The positioning system is a UWB wireless sensor network based on IEEE802.15.4 standard protocol. It drives four wireless connected devices using DW1000 chip to complete positioning, three of which are used as base stations and one as mobile tag.

- The two-side bidirectional ranging (DS-TWR) algorithm in TOF technology is successively adopted between each base station and the tag for ranging.
- The TDOA positioning algorithm is selected to locate the system module.
- An outlier function was introduced to filter outliers caused by noise interference in the transmission process.
- Kalman filtering was introduced to reduce the discreteness of positioning and improve the positioning stability of the system.



DS-TWR algorithm eliminates the influence of time drift by recording the time stamp of ranging communication



TDOA does not require complete clock synchronization between the two nodes to be tested

$$\begin{cases} T_{prop} = \dfrac{T_{round\,1} \times T_{round\,2} - T_{reply\,1} \times T_{reply\,2}}{T_{round\,1} + T_{round\,2} + T_{reply\,1} + T_{reply\,2}} \\ d_{i,j} = c * T_{prop} \end{cases}$$

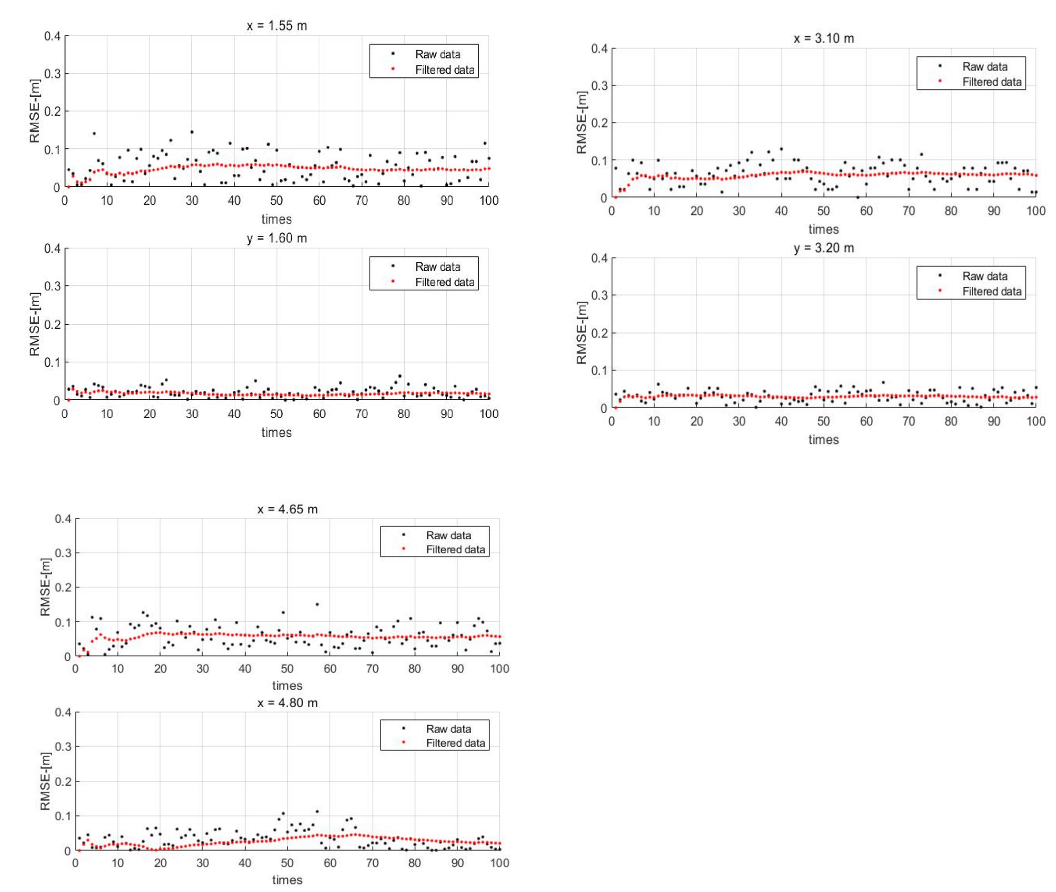
$$\begin{bmatrix} x \\ y \end{bmatrix} = d_1 \begin{bmatrix} x_{2,1} & y_{2,1} \\ x_{3,1} & y_{3,1} \end{bmatrix}^{-1} \begin{bmatrix} -d_{2,1} \\ -d_{3,1} \end{bmatrix} + \frac{1}{2} \begin{bmatrix} x_{2,1} & y_{2,1} \\ x_{3,1} & y_{3,1} \end{bmatrix}^{-1} \begin{bmatrix} K_2^2 - K_1^2 - d_{2,1}^2 \\ K_3^2 - K_1^2 - d_{3,1}^2 \end{bmatrix}$$

The specific position of the label is calculated based on the above formula.

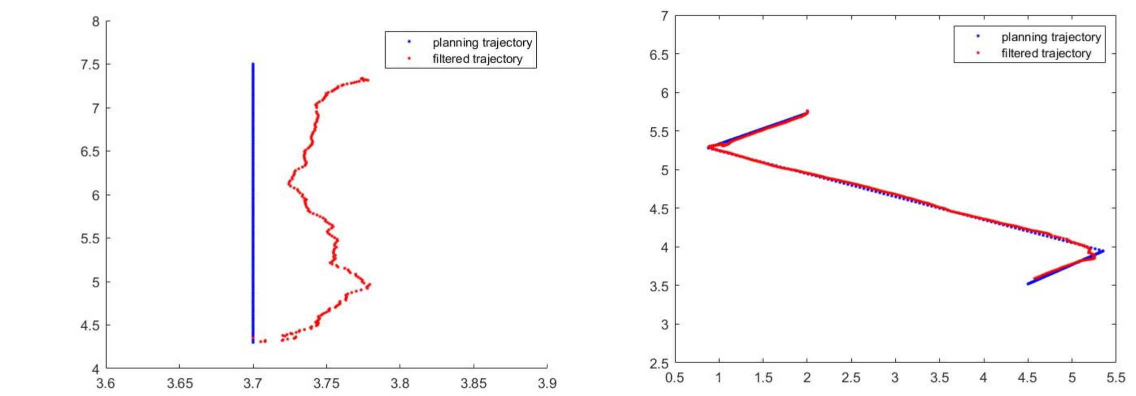
Results

In this experiment, the static and uniform moving tags were positioned in complex office environment and open environment respectively. Matlab was used to analyze and process the positioning effect of the system.

In the static experiment, the root-mean-square error was controlled within 5cm after adding Kalman filtering, which was 5cm less than before adding Kalman filtering, and centimeter-level positioning was basically realized.



In the static experiment, the tag with uniform motion of straight track, and cure track are positioned respectively. Due to the positioning error in the measurement process, the track after Kalman filtering was not straight. In the process of drawing the trajectory diagram, the interval of X axis was reduced to make it more clear that the error of the robot's filtered trajectory compared with the planning trajectory was roughly controlled to be about 10 cm. The filtered trajectory tends to the planned trajectory.



Conclusion

This localization system used DS-TWR combined with TDOA algorithm to effectively solve the problem of time desynchronization between positioning base station and tag. An outlier function was introduced to filter outliers caused by noise interference in the transmission process. The Kalman filtering was introduced for predictive estimation of localization data. The analysis of the experimental results showed that the root-mean-square error of the localization system with Kalman filtering was controlled within 5 cm in static experiments, which was about 5 cm less than that without Kalman filtering. In the dynamic experiments, the Kalman filtering line trajectory was shifted to the right compared to the planning trajectory and within 10 cm of the error. The Zigzag trajectory of the error after Kalman filtering was also within 10cm of the planning trajectory, except for the corners where the error was higher.

Acknowledgements

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