Research on WiFi Indoor Location Technology based on Kalman Filter and K-nearest Neighbor Algorithm

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Abstract

At present, there are many indoor positioning methods, mainly based on bluetooth, infrared, ultrasonic and other methods, but these have many limitations, so they cannot be widely used in real life. With the popularization of WiFi technology, WiFi indoor positioning technology based on received signal strength indication (RSSI) has the characteristics of high positioning accuracy, strong anti-interference ability, low cost and has received widespread attention from the society. This paper designs a joint positioning algorithm using Kalman filter and K-nearest neighbor algorithm (KNN) combined with WiFi information. Through testing, this technology has higher positioning accuracy and better stability.

Keywords

Kalman filter; K-nearest neighbor algorithm(KNN); Indoor positioning; Received signal strength indication(RSSI).

1. INTRODUCTION

Because the Global Positioning System (GPS) does not meet the user's requirements for accurate positioning of the indoor environment, researchers have began to explore other technologies to achieve accurate indoor positioning [1]. In recent years, with the widespread deployment of Wi-Fi in indoor environments, and the popularity of terminal devices with Wi-Fi communication capabilities, especially smart phones, coupled with the superior performance of Wi-Fi fingerprint location technology based on RSSI in indoor environments, making fingerprint positioning has become an important solution to today's indoor positioning problems. This article will introduce WiFi indoor positioning technology based on Kalman filter and K-nearest neighbor algorithm. This technology makes the positioning effect with strong stability and reliability through supervised machine learning and noise filtering, and has certain application value. On the one hand, it helps to reduce the time cost of the positioning system layout and save the storage space of the fingerprint library. On the other hand, it shortens the online phase in real time. Therefore, this is a more efficient fingerprint localization algorithm.

2. KALMAN FILTER

Kalman filter is a kind of linear system state equation, through the system input and output observation data, to optimize the system state Kalman filter is a kind of linear system state equation, through the system input and output observation data to optimize the system state Estimated algorithm [2]. Since the observation data includes the influence of noise and interference in the system, the optimal estimation can also be regarded as a filtering process. Because it is convenient for computer programming and can update and process the data collected in the field in real time, Kalman filter is one of the most widely used filtering methods

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at present, and it has been well applied in many fields such as communication, navigation and control.

When performing target tracking, prior knowledge tells us that the positioning trajectory is smooth. The current state of the target is related to the state at the previous moment. The filtering method can take these prior knowledge into consideration to obtain a more accurate positioning trajectory. Kalman filtering is that filtering is divided into two steps: prediction and correction. The prediction is to estimate the current state based on the state at the previous moment, and the correction is to integrate the estimated state and the observed state at the current moment to estimate the optimal state, as shown in the following formula (1).

Forecasting process:

$$x_k = Ax_{k-1} + Bu_{k-1}$$
$$P_k = AP_{k-1}A^T + Q$$

Calibration process:

$$\begin{aligned} K_k &= P_k H^T (HP_k H^T + R)^{-1} \\ x_k &= x_k + K_k (Z_k - Hx_k) \\ P_k &= (1 - K_k H) P_k \end{aligned} \tag{1}$$

The definition of each variable in formula (1) is shown in the following table 1.

Table 1. The definition of each variable in formula (1)

Variable Name	Definition
x_k	State at time k
A	State transition matrix
u_k	The effect of the outside world on the system at time k
B	Input control matrix
P	Error matrix
Q	Predictive noise covariance matrix
R	Measurement noise covariance matrix
H	Observation matrix
K_k	Kalman gain at time k
Z_k	Observed value at time k

3. K-NEAREST NEIGHBOR ALGORITHM

The core idea of the KNN algorithm is that if most of the K nearest samples in the feature space of a sample belong to a certain category, the sample also belongs to this category and has the characteristics of the samples in this category [3]. Here we use Euclidean distance as the criterion for judging, and predict the position coordinates at this time by selecting the smallest distance. The schematic diagram of the algorithm is shown in Figure 1 below.

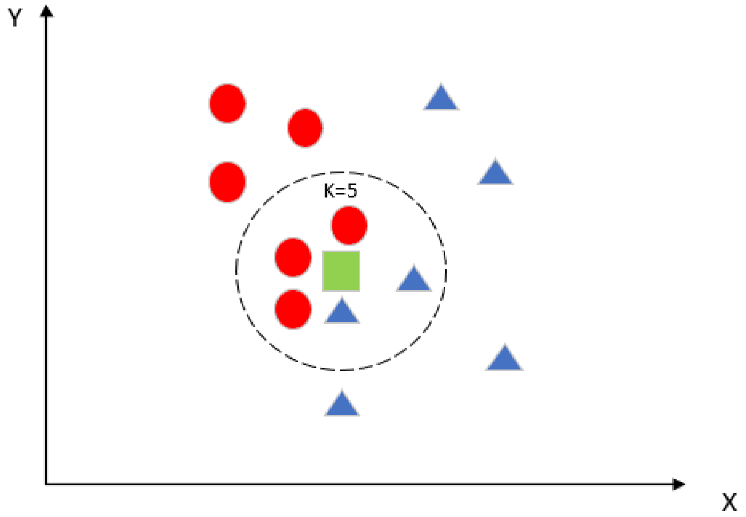

Figure 1. Schematic diagram of the KNN algorithm

It can be seen from the figure that when K=5, the number of red circles is greater than the number of green triangles, and the new green square is classified as red circles. The specific steps of the algorithm are shown below.

1)Calculate the distance between the test data RSSI and each training data.

2)Sort according to the increasing relationship of distance.

3) Select K points with the smallest distance.

4) Determine the frequency of occurrence of the category of the first K points.

5) Return the category with the highest frequency among the previous K points as the position coordinates of the point to be measured.

4. TECHNICAL IMPLEMENTATION PLAN

In radiology, ray tracing technology is a technique often used to predict the propagation of analog radio signals [4]. The introduction of ray tracing into wireless positioning technology is a new field developed by ray tracing technology in recent years, mainly to improve the positioning accuracy and response speed of wireless positioning technology. Therefore, in this paper, ray tracing technology is used to construct an RSSI fingerprint database in a certain space. The detailed program steps are as follows.

1) Extract part of the data set and use KNN algorithm for training.

2) In space, simulate a motion trajectory, and then add Gaussian observation noise as the observation position trajectory.

3) Collect the RSSI value at each grid point of the motion track.

4) Use KNN algorithm to identify the coordinates of the motion track.

5) Use Kalman filter to filter the motion trajectory and compare the changes in positioning accuracy before and after filtering.

5. SYSTEM TEST RESULTS AND ANALYSIS

5.1 Experimental Environment and Methods

In many cases, we use the actual measured data for the performance analysis and verification of the positioning algorithm, but the actual measurement workload is too large, data is not comprehensive, less flexibility, so using the simulation method to obtain RSSI data is another

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alternative way. Through ray tracing technology, the simulation assumes that an empty room is 20 meters long, 15 meters wide, 5 meters high, and has a grid size of 0.01 meters. There are 6 fixed emission sources evenly distributed in the room, as shown in Figure 2 below, one movable The signal received by the receiver of each emission source includes signals from 1 direct path and 6 reflection paths (the effect of multiple reflections is very small and can be ignored), calculate the RSSI of each position, and the data after 150 ray tracings are formed into an offline data set.

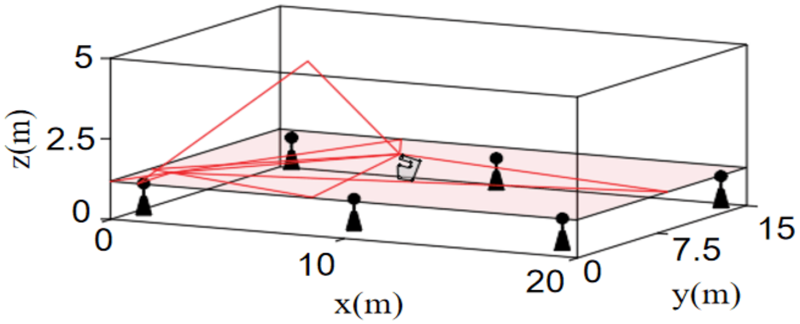

Figure 2. Schematic diagram of simulation environment

5.2 Comparison of Positioning Accuracy before and after Using Kalman Filter

In order to make the results more convincing, we have carried out many simulation experiments, which can better demonstrate the superiority of Kalman filtering for the positioning effect. The experimental results are shown in Figure 3 below.

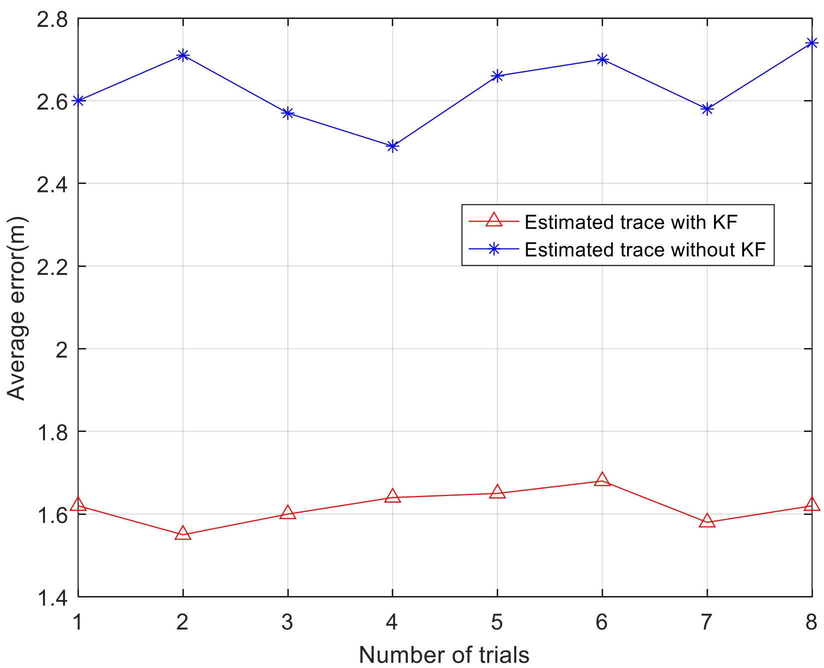

Figure 3. Comparison of positioning accuracy before and after using KF

5.3 Result Analysis and Conclusion

It can be seen from Figure 3 that in 8 experiments, the average error without Kalman filter is about 2.6 meters, meanwhile the average error with Kalman filter is about 1.6 meters. In addition, we can also see that When Kalman filter is used for positioning, the average error is smaller and the stability is stronger. The reason why such a good result can be achieved is that

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the prior knowledge is fully used: the movement of the target is continuous and basically uniform.

Although the RSSI is analyzed and processed in the experimental positioning process, and the positioning methods before and after Kalman filtering are compared, there are still shortcomings. The basis of this research can be further optimized and expanded.

1) The positioning accuracy of the method using RSSI is limited. If CSI (Channel State Information) information is used, the positioning result will be more accurate because it is based on state information [5].

2) The test is only carried out in a simple indoor environment, but the actual environment is very complicated. Irregular walls, numerous obstacles, movement of people, etc. will have a great impact on the positioning effect. These are all technologies that cannot be achieved with the solutions we currently use, but I believe that as our knowledge level improves, it will gradually improve to achieve a positioning technology with stronger anti-interference and higher accuracy.

3) In the simulation test, it is found that the error, especially at the large corner of the trajectory, can reach about 2m, which may be due to the defect of the algorithm. Therefore, we need more advanced machine learning algorithms to improve it (such as neural network algorithm, genetic algorithm), which is what we will focus on improving in the future.

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