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Research Article

An Effective Positioning Algorithm Based on Deep Learning and Multi-Centroids

*Hao Yang

Joint Technology Transfer Center of Yancheng Polytechnic College, Yancheng Polytechnic College, Yancheng, China
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***Corresponding author:** Hao Yang
Joint Technology Transfer Center of Yancheng Polytechnic College, Yancheng Polytechnic College, Yancheng, China.

Abstract
Indoor environment plays an extremely important role in human production and life, so people's demand for indoor positioning is increasing day by day. However, the presence of non line of sight, multipath, and varying interference in indoor environments has prompted research and attention to indoor positioning algorithms.
This paper proposes an effective positioning algorithm using BP Neural Network and improved centroid. Firstly, we use deep learning method to train a novel distance loss model. Furthermore, a multi-points centroid positioning algorithm is proposed to improve the positioning precision. Experiments are verified in some buildings and the experimental results show that the proposed algorithm increases the positioning accuracy compared with traditional positioning algorithms.

Keywords: *Indoor Positioning; Deep Learning; Centroid Algorithm.*

I. INTRODUCTION
People's indoor activities are occupying an increasingly large proportion in general life and production activities, especially the demand for convenient indoor services[1-7]. Although GPS satellite positioning technology is mature, the conditions for positioning are based on a vast open area. Due to the relatively enclosed indoor environment, difficulty in signal penetration through walls, and indoor multipath interference, satellite navigation technology is unable to provide indoor navigation and positioning services[8]. When satellite positioning is not available in indoor environments, indoor positioning technology is used as an auxiliary positioning tool for satellite positioning. Indoor positioning refers to achieving location positioning in an indoor environment.

Currently, more and more experts and scholars are investing in the research of indoor positioning technology. With the popularity of smart terminal devices[9], indoor positioning has begun to use methods such as Bluetooth, WiFi, geomagnetic and inertial navigation, but there are still many shortcomings. For example[10], WiFi is the wireless technology that people come into contact with the most in their daily lives, and this wireless interconnection technology is used in various environments[11, 12]. At the same time, WiFi devices are low-cost, and various mobile devices such as smartphones, tablets, laptops, etc. all include modules for receiving wireless signals, which can effectively achieve WiFi data transmission. Wireless positioning is widely used in the field of indoor positioning. In general, indoor environment plays an extremely important role in human production and life, and there is an urgent need to develop and use corresponding indoor positioning technologies[13-15]. Users obtain their geographical location through the use of mobile device positioning technology, and provide various location related services to users based on their location information and query information, as well as through the network[16].

With the rapid development of artificial intelligence technology, researchers have begun to introduce neural network technology to improve the accuracy of indoor positioning. In this article, we propose an effective positioning algorithm based on Deep Learning and Multi-Centroids. Firstly, we using Convolutional Neural Networks(CNN) to improve the accuracy of attenuation model in predicting the distance from beacon to reference point. Moreover, we use multi-point centroids to minimize errors in positioning calculations as much as possible. Compared to traditional three-point positioning methods, it improves the accuracy of indoor positioning and makes the system more robust. We conducted experiments in multiple experimental scenarios for verification. After comparative analysis, the method proposed in this article has better stability and positioning performance.

II. DIFFERENT POSITION TECHNOLOGIES

WiFi and Bluetooth positioning technology use the principle of triangulation for positioning. When the terminal (mobile phone, pad, etc.) enters the signal coverage range of the beacon, the terminal can sense its broadcast signal and calculate the location coordinates of the device. This technology is widely used in the field of indoor positioning.

RFID is a technology that uses radio frequency signals to locate and track objects or devices. It determines the distance of an object by measuring the signal strength between the RFID tag and the reader/writer. Using multiple RFID readers can achieve more accurate positioning. However, its signal is affected by interference and the angle issue between the tag and the reader/writer.

Ultrasonic positioning technology consists of an ultrasonic transmitter and receiver, which measures the time interval between signal transmission and reception, and calculates the distance between the object and the transmitter. To achieve more accurate positioning, multiple transmitting and receiving devices can be used to determine the location of objects or equipment.

Infrared positioning technology uses Time of Flight (ToF) measurement to measure the distance between an object and the transmitter/receiver. The accuracy of this technology is high, but it may be obstructed or interfered by obstacles, which can affect the positioning accuracy.

Geomagnetic positioning is a method of using the Earth's magnetic field for positioning. However, the strength and direction of the geomagnetic field vary at different locations and are highly susceptible to indoor environmental influences, resulting in relatively low accuracy. But it can be combined with other positioning technologies to improve positioning accuracy.

III. DEEP LEANING FOR IMPROVING THE DISTANCE FROM THE BEACON TO THE COORDINATES

In general, if the coordinates and distances to the coordinates of three beacons are obtained in advance, three-point positioning can be used to calculate the coordinates to be located. However, due to the inability of the signal attenuation model to accurately estimate the distance from the beacon to the coordinates, there is a significant positioning error. In actual positioning, the propagation conditions of wireless signals are complex and varied, influenced by indoor layout, beacon hardware equipment, location and size of obstructions, and even weather conditions, indoor environment temperature and humidity, which can affect the received wireless signal emphasis and thus affect the calculation of the distance from the beacon to the coordinates.

The main components of CNN include Convolutional Layer, Pooling Layer, Fully Connected Layer, and Activation Function. Among them, the function of Convolutional Layer is to analyze the basic characteristics of the relationship between wireless signal strength and distance; The function of Pooling Layer is to reduce the amount of data while preserving important features; The function of Fully Connected Layer is to analyze and judge the extracted features; The function of Activation Function is to increase the nonlinearity of the model. In this way, CNN network models can handle complex correlation data between strength and distance.

IV. MULTI-POINT CENTROID POSITION ALGORITHM

For traditional three-point centroid algorithms, multiple base station devices are required to provide signals. Its basic principle is to take the estimated position coordinates as the center of the point set, which is the mean of the coordinates of each point. If there are m position points, which are (x_1, y_1), (x_2, y_2), (x_3, y_3), the formula for calculating the centroid (C_x, C_y) is

$$C_x = \frac{x_1+x_2+x_3}{3} \quad (1)$$

$$C_y = \frac{y_1+y_2+y_3}{3} \quad (2)$$

As shown in Figure 1, for the traditional three-point centroid algorithm, the centers of the three circles are the three position points. Based on the actual positioning situation, this article considers using multiple center points, intersection points, and intersection point centers together as position reference points. Taking three base stations as an example, the position reference point set Reference_Set includes

1) There are three base station coordinates, namely o_1, o_1, o_2 and o_3.

2) There are 6 intersection coordinates between base stations, which are *a*, *b*, *c*, *d*, *e*, *f*.

3) There are 120 intermediate points between the two intersection coordinates. For example,

If *p* and q are two coordinates, which are belong to intersection coordinates, their center point is the centroid point:

$$Med(p,q) = \frac{coordinate(p)+coordinate(q)}{2} \quad (3)$$

Where $p, q \in [a, b, c, d, e, f]$.

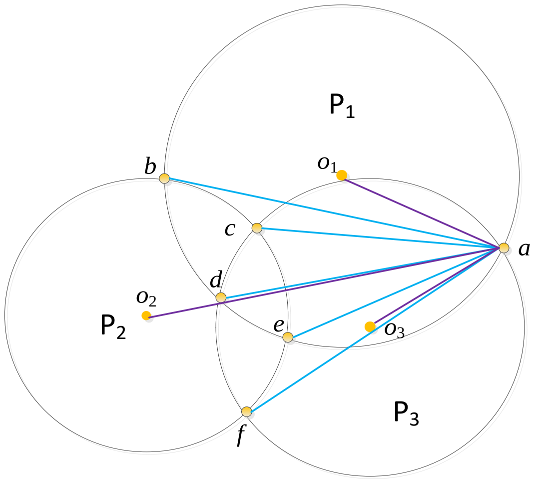

Fig.1 Multi-Point Centroid Points

According to our multi-point centroid algorithm, there are a total of 129 centroids used for error correction calculation, which can greatly improve the positioning accuracy. The following experiments also provide verification.

V. EXPERIMENTS

In experiments, we validated the effectiveness of our method in different buildings. When placing beacon reference points, this experiment strives to evenly distribute them in the environment to be located, in order to cover the entire area as much as possible. The experimental results demonstrate the effectiveness and robustness of our method.

(1) Different number of APs

We first compared the positioning errors of different APs using the classic three-point centroid algorithm. The number of APs selected for the experiment is 5, 10, 15, and 20, respectively, which is show in Figure 2. According to the experimental results, the positioning accuracy of the algorithm proposed in this paper is superior to that of the three-point centroid algorithm. As the number of APs increases, the positioning error will decrease. Meanwhile, the advantages of our algorithm become more apparent. When the number of APs reached 20, the positioning accuracy improved by nearly 32%.

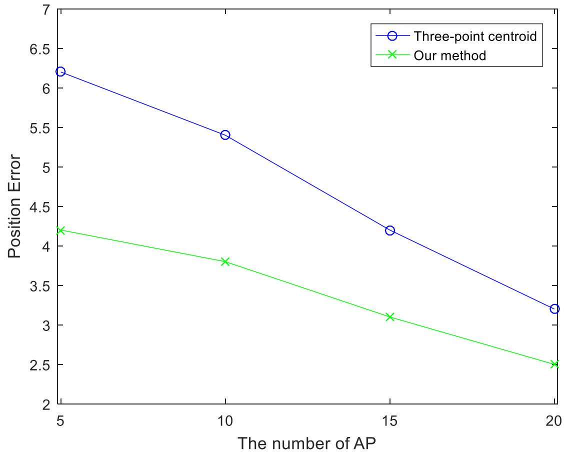

Figure 2 Different number of Aps

(2) Different sizes of Position Areas.

We then compared the positioning errors of different positioning spaces, and the comparative positioning method is still the classic three-point centroid algorithm. The number of APs selected for the experiment is 20, with four different positioning spaces: 20 square meters, 50 square meters, 100 square meters, and 120 square meters. According to the experimental results, the positioning accuracy of the algorithm proposed in this paper is superior to that of the three-point centroid algorithm. As the area of the positioning space increases, the positioning error will increase, but the advantages of the algorithm in this paper are more obvious. When the area of the positioning space reaches 120 square meters, the positioning accuracy improves by nearly 23%.

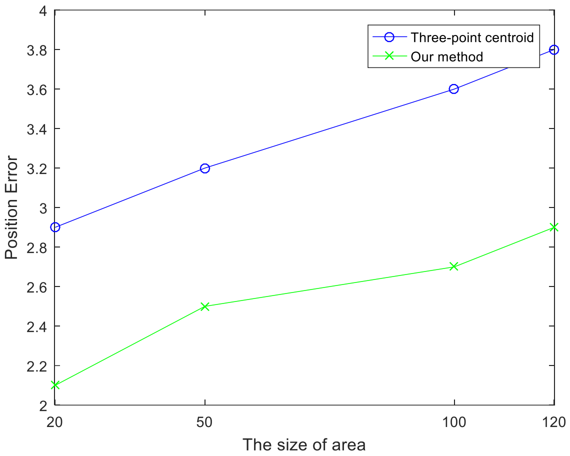

Figure 3 Different sizes of area

According to the experiment, our positioning algorithm based on Deep Learning and Multi Centroids proposed in this paper has good performance in different APs and positioning spaces.

VI. CONCLUSION

With the rapid development of IoT technology, people's demand for positioning performance is increasing day by day. Indoor positioning technology has become a hot research topic in recent years, but the overall positioning performance is still unsatisfactory. This article analyzes indoor positioning based on multi-point, designs a BP neural network and an improved centroid algorithm, and conducts experiments in indoor environments to improve positioning accuracy.

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