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A Twice Centroid Localization Algorithm

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Abstract : Football is the world's largest sport, but also a test of speed, endurance of a sport, athletes' running ability can directly affect the results of the game. Nowadays, the development trend of football is that the competition is more and more fierce, the conversion of attack and defense is faster and faster, and the coach's tactics are more inclined to team cooperation, so the requirements of athletes' running ability and timing judgment are higher and higher. In this paper, the trilateral positioning method and RSSI distance measurement are combined to determine the accurate position of the mobile node (athlete) through the quadratic centroid positioning algorithm to reduce the error, and the ZigBee positioning system is used to achieve the positioning method. The hardware system records the real-time position of football players during training and competition. According to the location, the track map is drawn, and the temperature, humidity and air pressure of the field where the players are located are recorded at same time. The data is transmitted to the upper computer through the wireless transmission module. All the data are stored according to different ID, which is used to analyze the status of athletes' training and competition. The positioning accuracy of football players can reach 90% by strengthening the running training of athletes.

Key words : Athlete positioning system; Twice centroid algorithm; RSSI distance measurement; Zigbee.

I. Introduction

Football is the most popular sport in the world and it is also the kind of sport which test speed and endurance of players. The running ability of athletes can affect the outcome of the competition directly. Therefore, running ability is one of the important basic ability of football players, and it is also the significant indicator for coaches to evaluate athletes at same time. Nowadays, the development trend of football can be described as three phenomenon: more and more intense competition, faster transition between attack and defense, and coaches' strategy are more inclined to teamwork. In the competition, whether players can appear in the correct position in time has directly impact the result of the game, based on this point, the higher requirements for running ability and timing judgment of the players has been asked. Therefore, the real-time positioning system can be used in football competitions to locate, store, analyze the running trajectory and step number of athletes. According to the trajectory, some related parameters such as the amount of exercise and consumption of the athlete can be calculated.

The field of wireless positioning technology can be divided into wide-area positioning and short-distance wireless positioning, wide-area positioning can be divided into satellite positioning and mobile positioning. The positioning technology mainly includes ultra-wideband technology (UWB), Bluetooth technology, ultrasonic positioning technology, infrared positioning technology, radio frequency identification technology (RFID), WIFI technology and ZigBee technology. The frequently-used wireless ranging technologies currently include: positioning algorithm based on AOA (Angle of Arrival Positioning), positioning algorithm based on TOA (Time of Arrival Positioning), positioning algorithm based on TDOA (Time Difference of Arrival Positioning), and positioning algorithm based on RSSI (Received Signal Strength Positioning). ZigBee makes up the gaps in the field of low-power,low-cost and short-distance wireless communication. Hence, ZigBee positioning technology has been used at this time. In order to achieve the optimum impact of positioning, CC2530 is used as the core solution project, each part of the function in the entire positioning system is implemented based on the ZigBee protocol framework structure, in addition, the secondary centroid positioning algorithm is combined in order to reduce errors.

II. Positioning Technology Introduction

1.1 Trilateration

Use the ZigBee positioning system to determine the accurate position of the mobile node (athlete) by combining the trilateral positioning method and RSSI ranging. The RSSI technology is mainly based on the signal

strength value received by the node, and directly converts it into its distance value through the experience or theoretical model formula of the propagation signal. Theoretically, as the distance increases, due to the attenuation of the wireless signal, the received RSSI will decrease. Therefore, according to this relationship, the direct distance between two nodes can be obtained directly through the RSSI value.

$$RSSI = -(10n \times \log_{10} d + A) \quad (1)$$

In formula （1）, A is the radio frequency parameter, the RSSI value is known, n is the signal transmission constant, d is the distance between the mobile node and the reference node, where A and n can be calculated and used as known quantities before the measurement is officially started. The optimal range of A is 45-49, and the optimal range of n value is 3.25-4.5.

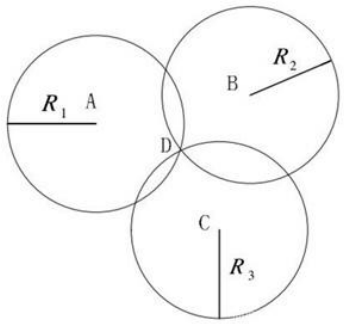


Figure 1 Trilateral positioning method

If A, B, and C are reference nodes (location base stations), D is a mobile node (carrying a location tag), as shown in Figure 1, the corresponding coordinates are （X_1，Y_1）、（X_2，Y_2）and（X_3，Y_3）. The position of the mobile node is the intersection D of the three circles, and its corresponding coordinates are (X，Y）. The distances between the location of the mobile node and the three reference nodes are d_1、d_2, and d_3, respectively.

According to the geometric relation expression:

$$\begin{cases} (X - X_1)^2 + (Y - Y_1)^2 = d_1^2 \\ (X - X_2)^2 + (Y - Y_2)^2 = d_2^2 \\ (X - X_3)^2 + (Y - Y_3)^2 = d_3^2 \end{cases} \quad (2)$$

By simplifying formula (2), the position coordinates of the mobile node can be obtained as the following formula (3):

$$\begin{bmatrix} X \\ Y \end{bmatrix} = 2 \begin{bmatrix} X_1 - X_3 & Y_1 - Y_3 \\ X_2 - X_3 & Y_2 - Y_3 \end{bmatrix}^{-1} \begin{bmatrix} X_1^2 - X_3^2 + Y_1^2 - Y_3^2 + d_3^2 - d_1^2 \\ X_2^2 - X_3^2 + Y_2^2 - Y_3^2 + d_3^2 - d_2^2 \end{bmatrix} \quad (3)$$

1.2 Twice Centroid Location Algorithm

Divide the football field into a grid, taking into account the running range of the football players in the game and the speed change interval, the football field is evenly divided into about 850 small squares of 3m×3m, and the center point of the football field is the coordinate origin. Establish a rectangular coordinate system, as shown in Figure 2, divide the football field into four quadrants, and each corner of the small squares that were evenly divided before corresponds to a coordinate value; The distance from multiple grid points to each reference node is measured on the spot, denoted as d. According to the formula: $RSSI = -(10n \times \log_{10} d + A)$, the values of d_1、d_2, and RSSI of the two points are brought in, and A (radio frequency parameter) and n (signal transmission constant) can be obtained.

If the mobile node is in the first quadrant area, according to the trilateral positioning method, the mobile node can receive three sets of positioning requests from the positioning base stations placed at the four corner flags, and determine the mobile node's position according to the RSSI and distance formula. However, usually the positions determined by the three sets of data will not overlap, that is, there is an error, as shown by the three vertices of the triangle ABC in Figure 2. In the figure, E, F, and D are the midpoints of each side, and the intersection of the three midlines of the triangle is the centroid of the triangle. The coordinates of the centroid O point are taken as the result of the first positioning.

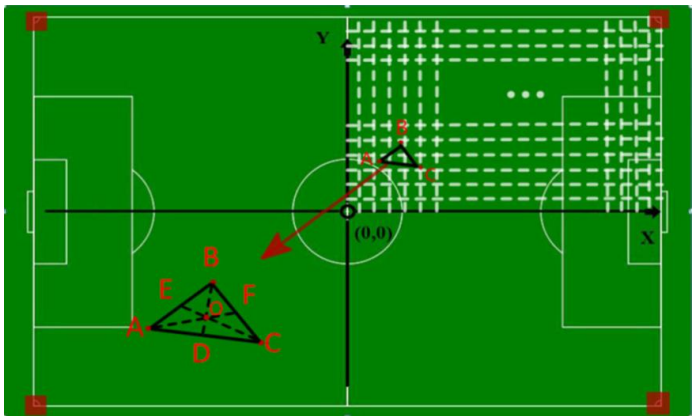


Figure 2 Triangular centroid positioning

In the small grid square where the triangle center of mass O is located, a rectangular coordinate system is established with the center of mass of the square as the origin. As shown in Figure 3.

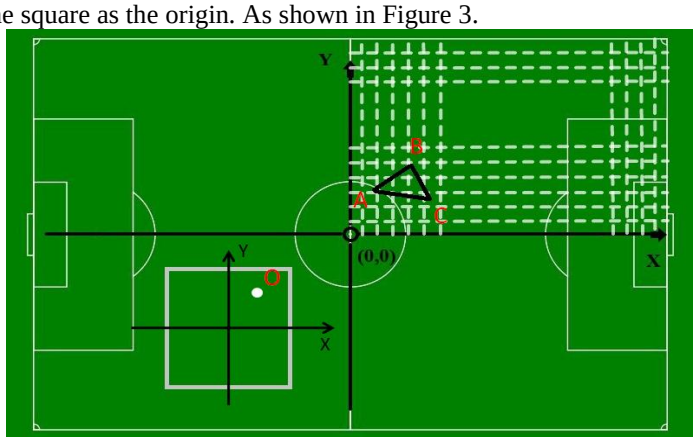


Fig. 3 Second centroid positioning

The RSSI values of the four vertices of each grid point in the football field are known. After the RSSI values at the O point are different from the RSSI values of the four vertices of the grid, the absolute values are taken. The RSSI values of the three points with the smallest value (the three vertices closest to point O) are selected as the final three According to formula (4), the RSSI value required for edge positioning is as follows:

$$d = 10^{\frac{[ABS\ (RSSI\ )-A]}{10\times n}} \qquad (4)$$

The distances d_1、 d_2 and d_3 between the mobile node and the nearest three vertices of the grid-shaped small square can be calculated, and the precise position coordinates of the mobile node can be obtained at this time.

III. Hardware Design

The wireless sensor network positioning based on ZigBee must first go through a training phase to collect information for different positioning points. The RSSI positioning algorithm is used to calculate the distance between the mobile node (coordinator) and the terminal, and then the precise coordinate position of the mobile node is calculated. The fixed terminals at the 4 corner flags on the sidelines use CC2530 to process the temperature, humidity and atmospheric pressure data and send them to the coordinator, and then display the data on the host computer.

The terminal nodes set up at the four corner flags mainly include: the sensor DHT11 for detecting ambient temperature and humidity and the sensor BMP085 for detecting atmospheric pressure data; the core chip CC2530 for processing and transmitting data; Printed inverted F PCB antenna for signal transmission and reception; when temperature, humidity and air pressure information is detected, the data is first preprocessed by CC2530, and then sent to the coordinator through the antenna for wireless communication. The structure of the terminal sensor node is shown in Figure 4. The wireless temperature, humidity and air pressure monitoring system consists of two parts: the PC monitoring terminal and the Hardware ZigBee network. The Hardware ZigBee network system consists of two

parts: the coordinator node, the temperature and humidity and the air pressure sensor terminal nodes. The coordinator node is responsible for establishing the network, and sending and receiving instructions; the temperature and humidity sensor terminal node is mainly responsible for collecting temperature and humidity information; the PC terminal is responsible for displaying the temperature, humidity and atmospheric pressure data sent by the Hardware system in an intuitive data or graphical manner , It is convenient for coaches to make corresponding training plans according to weather conditions.

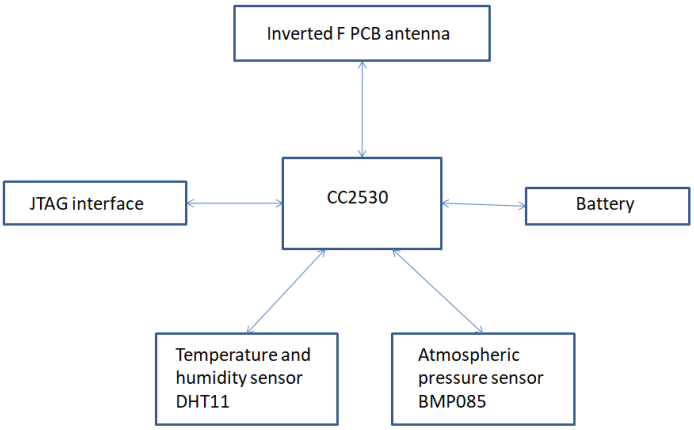


Figure 4 Terminal sensor structure

IV. Experimental Principle

LQI is the link quality indicator. The link quality indicator which specified in the ZigBee standard is used to indicate the quality of received data packets. It provides the strength and quality information of the wireless signal when receiving the data frame for the network layer or application layer. It needs to decode the signal and generate a signal-to-noise ratio indicator. The value range of LQI is 0x00~0xFF which respectively represents the worst quality (0x00) to the best quality (0xff) of the received signal. The relationship between RSSI and LQI is shown in formula (5):

$$RSSI = -\frac{81-(LQI*91)}{255} \qquad (5)$$

After the RSSI value is obtained, the RSSI value must be converted into the corresponding distance. ShadowiIlg model which based on the statistical model is used and it has been verified in various real environments, and its general model is shown in formula (6):

$$RS(d) = RS(d_0 + 10\lambda \lg\left(\frac{d}{d_0}\right) + \zeta_\sigma) \qquad (6)$$

In the formula, RS(d) represents the RSSI value which received from the range transmitting point d (unit: m), The measured value is generally a negative value, and the absolute value can be used in the calculation. $RS(d_0)$ represents the RSSI value which received from the range transmitting pointd_0, it also named reference RSSI value reduction degree, $d_0$is called reference distance and it is generally taken as lm. λ is the path dynamic attenuation index which represents the attenuation speed of the signal's power as the transmission distance increases. This value has the huge relationship with the transmission environment and it depends on the type of environment. ζ_σ is used to represent a Gaussian distributed random noise with a mean value of 0 and a standard deviation of σ,the value is depend on the environment which means different environment have different values. According to formula (6), the calculation method of d can be obtained as shown in formula (7):

$$d = d_0 \times 10^{\frac{RS(d)-RS(d_0)-\zeta_\sigma}{10\lambda}} \qquad (7)$$

The distance d is determined by three factors: RS (d0), λ. The conventional method is to use the parameter experience values of different environments to evaluate the model parameter values in advance. In the calculation of distance, the first step is measure the distance between two nodes d_0 = 1 meter, its corresponding signal value is -40 (the absolute value is 40), then takes λ=2, ζ_σ=0. After simplification, formula (6) becomes the formula (8) :

$$d = 10^{\frac{RS(d)-40}{20}} \qquad (8)$$

V. Experimental result

The After a short period of serial data debugging, the terminal temperature and humidity, atmospheric pressure value, link quality, RSSI value and distance display results are shown in Fig. 5. It can be seen from Figure 5 that the current ambient temperature is 19 ℃, the humidity is 67%, the air pressure value is 1012kpa, the link quality LQI is 36, and the RSSI value is - 73. Therefore, the distance value can be calculated as 44.7m.

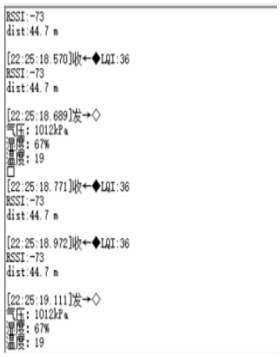
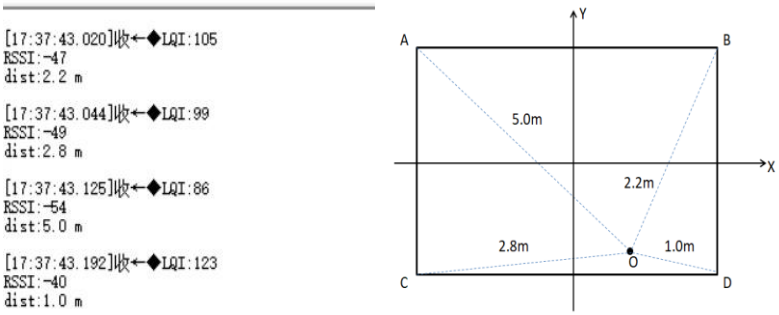


Figure 5 Single terminal display result

Due to the limitation of the field, the experiment adopts the same scale to reduce the length and width of the standard football field (110m * 60m) by 10 times. When the four terminals are turned on, the distance information received by the mobile node is as shown in Figure 6(a). If the mobile node is the football player in the game or training, and is set as point O, then the distance between O point and the four corner flags of the football field is 2.2m, 2.8m, 5.0m and 1.0m respectively, and the distance information is used to judge whether the player is in football The basis for which quadrant of the field is shown in Figure 6(b).



(a) (b)

Figure 6 Judge the player's position for the first time

It can be seen from Figure 6 that at this time, the football player is in the fourth quadrant of the football field, so the RSSI values of points B, C and D are selected for the first positioning result. As mentioned above, under normal circumstances, the positions determined by the three groups of data will not overlap, that is, there is an error. As shown in Figure 7, the three vertices of the triangle EFG are the position information determined by the three groups of data, and the coordinate of the centroid O' of the triangle EFG is selected as the result of the first centroid positioning. Since the football field ABCD has been divided into several small meshes before the experiment, the vertex coordinates of each small mesh are known; the coordinate system is established in the small mesh where O' is located, as shown in Figure 7 (b), in which A ' B ' C ' D ' is shown The RSSI value of the point is known. The absolute value is taken after the difference between the RSSI value of O' point and the four vertices of the mesh. The three points with the least RSSI value are selected as the result of the second centroid positioning, and the final positioning result is selected.

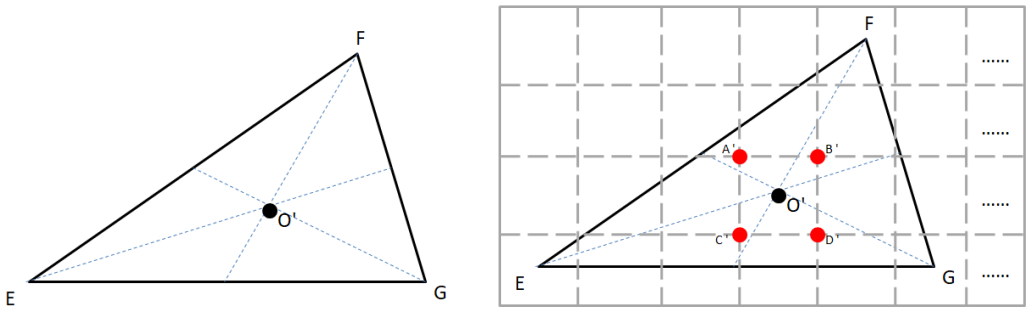


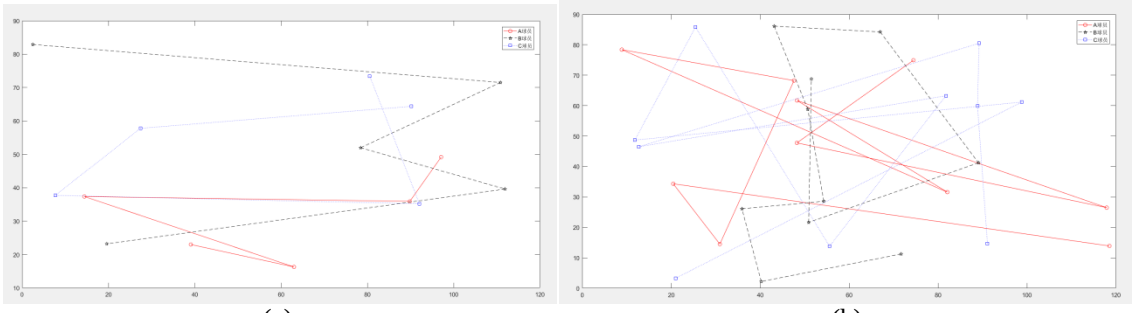
Figure 7 Second centroid positioning results

A football player's data is sampled every 8 seconds, and a rectangular coordinate system is established with the C point of ABCD as the origin. The experimental data are recorded as shown in Table 1. The experimental results show that the accuracy of the two centroid algorithms proposed in this paper can reach more than 90%, and can effectively reduce errors.

Table 1 Data comparison

Data sampling time point	Experimental data	Actual player position coordinates
The first second	(38 , 23)	(38 , 24)
The 9th second	(62 , 18)	(61 , 17)
The 17th second	(15 , 37)	(17 , 37)
The 25th second	(90 , 37)	(85 , 36)
The 33rd second	(96 , 50)	(96 , 49)

Record a number of experimental data, using Matlab can draw the running track map of football players, as shown in Figure 8 (a), 8 (b), for three football players in a period of time running track map.



(a) (b)

Figure 8 Running track of three football players

VI. Conclusion

This essay uses zigbee positioning system and RSSI distance measurement which combined with secondary centroid positioning at same time to realize real-time positioning of football players when they are running in the training or competition. The data which collected by the system is used to plot the player's running trajectory through Matlab and it can achieve a good training effect and improve the player's running awareness and ability.

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