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Design of Indoor Position System Based on DWM1000 Modules

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Abstract. The traditional indoor position system is realized with laser scanners and cameras. The methods need complex calculation and have poor real-time and high cost. In this paper the UWB position technology is used to realize the indoor position system with TDOA. The platform of position system is based on DWM1000 modules, and the software and hardware are developed independently. The test result shows that the system has good reliability and feasibility and the position accuracy is within $\pm 10\text{cm}$.

1. Introduction

The indoor position technology is often used in the scientific research. The GPS position system can't work well indoors, so the laser position technology and the visual position technology are often used in that environment. But the above position technology is of high cost and poor real-time performance, and they can't also work well in the complex environment. [1-2]

According to the above problem, the UWB position technology with DWM1000 modules is proposed to realize the indoor position.

2. Basic principle of UWB position

UWB (Ultra-Wide Band) position is a kind of position method developed in recent years. In this method, the information is transmitted with much narrowed signal pulse or very wide spectrum bandwidth signal, which has the advantages of strong penetrability and high position accuracy within centimeters. The common UWB position has four methods, including time of arrival (TOA), time difference of arrival (TDOA), angle of arrival (AOA) and received signal strength indication (RSSI). TDOA is adopted in this paper after carefully comparison. [3-5]

The principle of time difference of arrival (TDOA) is the calculation of the distance between the source node and the target node by measuring the time difference of different source nodes receiving the position signal from the target node. The source node stands for the base station, and the target node stands for the point whose position is measured. The position of the target node can be calculated with trilateration-centroid algorithm depending on the difference of the distance between the source node and the target node. [6]

2.1 Ranging Method

The UWB position system adopts the ultra-wide band Gaussian pulse signal, whose time domain pulse width is less than 0.5ns with extremely high position accuracy. The UWB position system usually has several source nodes, which can receive pulse signals from the target node and process the received



pulse sequence to get the receiving time, namely the distance between the target node and the source node. [7] The concrete principle is shown in figure 1.

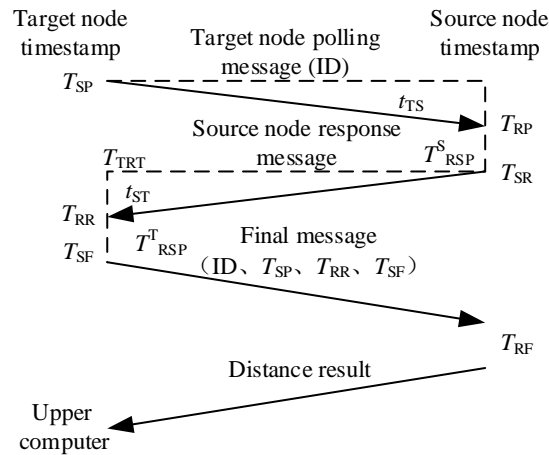


Figure 1. UWB ranging principle

When receiving the polling message (ID) from the target node, the source node records the current time T_{RP} , transmits the response message to the target node and records the transmitting time T_{SR} . The target node records the receiving time T_{RR} and transmits the time (T_{SP} , T_{RR} , T_{SF}) recorded by the target node to the source node at T_{SF} when receiving the response message from the source node. After receiving the final message from the target node, the source node acquires the data enough to calculate the distance. The calculation is as below.

(1) The round-trip delay time of the target node message $T_{TRT} = (T_{RR} - T_{SP})$ minus the response time of the source node in this period $T_{RSP}^T = (T_{SR} - T_{RP})$, and the single-trip time between the target node and the source node of twice, t_{TA} , t_{AT} , is obtained.

(2) The round-trip delay time of the source node message $T_{SRT} = (T_{RF} - T_{SR})$ minus the response time of the target node $T_{RSP}^S = (T_{SF} - T_{RR})$, and the single-trip time of between the target node and the source node is obtained.

Thus the source node sums and averages the flying time between the target node and the source node obtained above to get the single-trip time T_{OF} . In this way the source node can use its own clock to time, avoiding the problem of synchronizing clock.

Let T_{RSP}^T be equal to T_{RSP}^S , and the single-trip time is calculated as below.

$$T_{OF} = \frac{(T_{RR} - T_{SP}) - (T_{SR} - T_{RP}) + (T_{RF} - T_{SR}) - (T_{SF} - T_{RR})}{4}$$

The distance between the target node and the source node can be calculated by multiplying T_{OF} with the speed of light (the speed of UWB signal transmission).

2.2 Position Method

After the distances between the target node and the three source nodes at least are obtained as above, the position coordination of the target node can be obtained with trilateration-centriod algorithm at the upper computer as shown in figure 2.

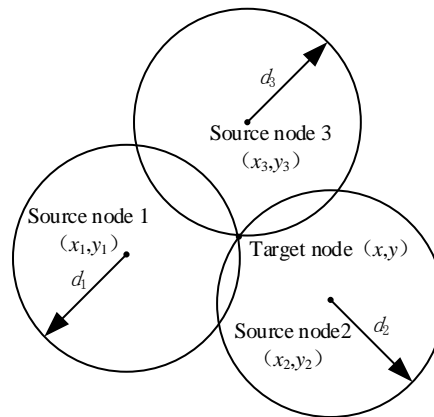


Figure 2. Principle of trilateration-centroid algorithm

The unique point of intersection can be used as the position of the target node by calculating with the distances between the three source nodes and the target node. The coordination of the target node (x,y) can be calculated with the formula as below.

$$x = \frac{(y_2 - y_1)\gamma_1 + (y_2 - y_3)\gamma_2}{2((x_2 - x_3)(y_2 - y_1) + (x_1 - x_2)(y_2 - y_3))}$$

$$y = \frac{(x_2 - x_1)\gamma_1 + (x_2 - x_3)\gamma_2}{2((x_2 - x_1)(y_2 - y_3) + (x_2 - x_3)(y_1 - y_2))}$$

$$\gamma_1 = x_2^2 - x_3^2 + y_2^2 - y_3^2 + d_3^2 - d_2^2$$

$$\gamma_2 = x_1^2 - x_2^2 + y_1^2 - y_2^2 + d_2^2 - d_1^2$$

$d_i(i=1,2,3)$ stands for the distance between the target node and the three different source nodes.

3. Hardware Design

The target node and the source node use the same PCB board. The working mode (the target node or the source node) and the address can be set by dial switch. After receiving and treating the data from the target node, the source node sends the result by USB interface to the computer to calculate and display. The hardware diagram of the system is shown in figure 3.

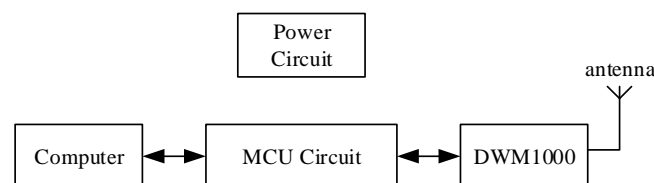


Figure 3. Hardware diagram

3.1 Power Circuit

The target node and the source node are all powered by lithium battery bank with the capacity of 400mAh. The power circuit converts +5V of the battery bank to 3.3V to supply the system. The power circuit is shown in figure 4.

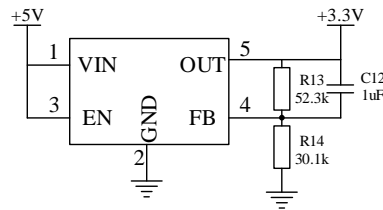


Figure 4. Power circuit

The maximum current requirement of DWM1000 is about 160mA. Considering the current requirement of DWM1000 and other chips, TPS73601 is chosen as the power chip, which is a kind of enhanced step-down voltage regulator with reverse current protection and maximum output current of 400mA.

The output voltage of TPS73601 can be regulated between 1.2V and 5.5V. The feedback voltage, the voltage of pin4, can be regulated by changing the resistance of R13, R14 at the outgoing end to change the output voltage. In this circuit, R13, R14 are set as 52.3k and 30.1k separately to regulate the output voltage to 3.3V to supply the system.

3.2 MCU Circuit

The system uses the mcu of STM32F105RT6. The core of the mcu is Cortex-M3, equipped with 256kB flash and 64kB RAM, the package of LQFP64.

Since the source node and the target node communicate (send/receive data to/from each other) at least twenty times a second and there are more than one target code, a great amount of data volume is involved. If the communication between the source node and the upper computer chooses RS232 interface, the calculation of the distance and position will be affected because of the slow transmission speed of RS232. Therefore, the USB interface is chosen to realize the communication between the source and the upper computer. STM32F105 has the perfect USB communication ability, so it is chosen as the MCU of the system.

3.3 DWM1000 Module Circuit

The position system uses DWM1000 position module, whose different working state can be switched by controlling relative registers. The module can communicate with MCU by SPI bus at the speed of 20MHz, and the module is suitable for the position application in the complex indoor circumstance due to its ability to combat multipath interference. The DWM1000 module is composed of transceiver, mode converter, state controller and SPI interface. The circuit between STM32F105 and DWM1000 is shown in figure 5.

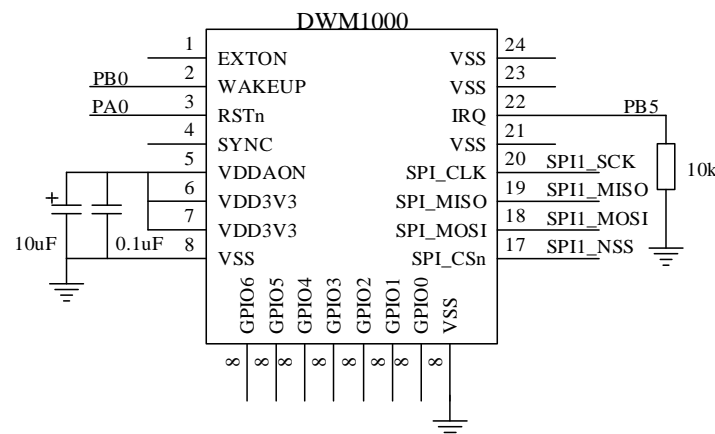


Figure 5. DWM1000 interface circuit

The SPI interface of DWM1000 is connected to SPI1 interface of MCU. The wakeup pin of DWM1000 is connected to PB0, RSTn pin is connected to PA0, and IRQ pin is connected to PB5.

The MCU communicates with DWM1000 to read data and sends data to upper computer to calculate the position of the target node.

4. Test

4.1 Ranging Test

Test points are set at intervals of 1m ranging from 1m to 11m. The source node is set at the origin point and the target node is set at every test point. The ranging test data is sent to the computer and displayed on the screen. The test data is shown in table 1.

Table 1. Ranging test data

Distance/m	Test data/m	Error/m	Distance/m	Test data/m	Error/m
2	1.98	-0.02	7	6.99	-0.01
3	2.96	-0.04	8	8.03	0.03
4	4.01	0.01	9	9.02	0.02
5	5.03	0.03	10	10.02	0.02
6	5.97	-0.03	11	10.96	-0.04

4.2 Position Test

The position test is done in doors. Four source nodes are set at the four corner of the room. The upper computer reads data, calculates the position coordination and displays it on the screen. The test data is shown in table 2, which shows that the error is less than 10 cm.

Table 2. Position test data

Measuring Position/cm		Setting Position/cm		Error/cm
X	Y	X	Y	
3	296	0	300	5.0
192	303	200	300	8.5
204	207	200	200	8.06
307	196	300	200	8.06
295	308	300	300	9.4
295	3	300	0	5.8

The position coordination effect picture is shown in figure 6. “o” stands for the set position, and “*” stands for the measured position.

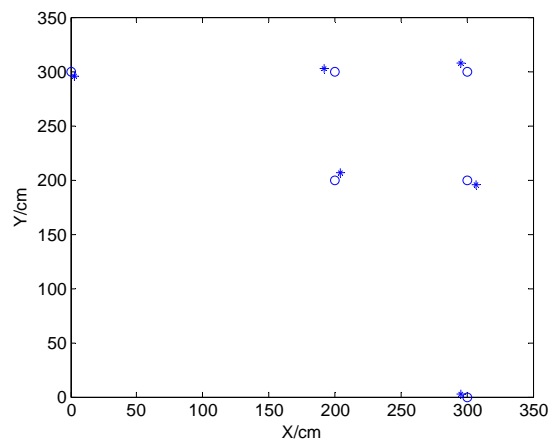


Figure 6. Position coordination effect picture

5. Conclusion

Aiming at the disadvantages of the position method used at present, a new position method with DWM1000 module is proposed in this paper. The principle and the hardware circuit are analyzed, and the test result is presented. The test proves that the position system has the advantages of high stability and high accuracy and meets the requirement of the indoor position.

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7. Reference

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