**Development of the Network Communication System for Object Localization**

1. Abstract

The aim of the project is to use UWB positioning technology to design a wireless system for robot localization. Our research proposed a new improved method using unified modules without the differentiation as base stations and tags. In this phase of the project, we thoroughly explored and modified the program embedded in the UWB modules, so that not only can we acquire the distance between any pair of modules, but also, we can change the output from the serial port to get any kind of information we want. We also did multiple experiments to get a large amount of data to estimate the performance of the modules in different conditions.

1. Principle of the Amended Program Embedded in the UWB Modules

To get a better knowledge of the program, let us recall the communication protocol of UWB localization first.

Assume we have two modules named Device A and Device B. Device A initiates the first ranging message and Device B responds, generating 2 time stamps and ; then after some time, Device B initiates the ranging and Device A responds, generating two more time stamps and (see figure 1).

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Figure 1. UWB Communication Protocol

The calculation method of flight time can be calculated by the following formula:

Noted that the ability of Device A and Device B are the same. So, there is no need to differentiate base stations and tags. The names “Anchor” and “Tags” are used to specify which device is the transmitter and call the other device first. In terms of habits, we call the transmitter in the first round “Anchor”. The other we call it “Tag”.

Here we show some applications based on the modified UWB Embedded Program.

1. Define a coordinate system using 3 modules

Use 3 modules, named , , and , Through transmission between UWB modules, we know the distances between every two points, which means the length of , , are our initial constraints.

To simplify the problem, we assume that is on the original point and the line is on the X axis. So, the coordinate of is (0,0), and the coordinate of is (,0) (see Figure 2).

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Figure 2. Schematic Diagram of Coordinate System

First, we know that

After elimination, one obtains

Hence , Consequently, the remain coordinates are given by

Thus, we can get the coordinates system using the position of as the original point, the line where the line segment is located as x-axis, the line passing through point and perpendicular to . When dealing with multiple modules, the system is suitable for the modules to be added and we can calculate their positions.

1. Application on customized output data: Wireless Synchronization

By customizing the output of various intermediate quantities of the module communication and distance calculation process, we can implement a wide variety of functions. Here we propose a new kind of UWB communication protocol that does the wireless synchronization using the intermediate value: time of flight.

The new process of communication and wireless synchronization of a pair of UWB modules are as follows:

Initially, we have a pair of UWB modules, called Module A and Module B. Firstly, Module A plays the role of the transmitter, transmitting a signal to Module B. The signal includes the local timestamp of Module A transmitting the signal, called . At the same time, Module A memorizes locally. Module B receives the signal, and after an artificially set delay time, Module B plays the role of the transmitter, and transmits the signal to Module A. The signal includes the local timestamp of Module B receiving the signal from Module A and transmitting back, called and . Then, Module A receives the signal from Module B and memorizes the local time (see Figure 3).

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Figure 3. Communication Protocol for UWB Wireless Synchronization

Then we can do the synchronization. In other word, we need to know the time offset between Module A and Module B. Denote , . Thus, we have

The meaning of wireless synchronization is that, after a time of the process above, once we know the offset time between a pair of modules, we can easily know the distance within only one time of signal transmission. In this scenario, we have

1. Experiments on UWB modules performance on different conditions

To further test the performance of the UWB modules, we designed multiple tests in different conditions. Below is the form of the number of tests on combinations of different heights and distances. The sampling distances are four points that are evenly distributed from the module’s closest measuring range to the farthest. Heights from the module to the ground are set accurately. The lowest height is 10 cm because, in the application phase, the module will be mounted on the robot, the robot moves on the ground, and the height of the robot is low. For each test, we select 100 points and write scatter plots and histograms.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Height Distance | Close | Medium-Close | Medium-Far | Far |
| 10cm | (1) | (2) | (3) | (4) |
| 60cm | (5) | (6) | (7) | (8) |
| 110cm | (9) | (10) | (11) | (12) |
| 160cm | (13) | (14) | (15) | (16) |

For each of the tests, we made a scatter plot and analyze the data. The statistics that we are mostly concerned with are Range and Standard Deviation because we need to figure out how close the data is distributed. Considering the space limitation, here we show one scatter plot and corresponding data analysis (see Figure 4).

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Figure 4. Test No.10 (110 cm Above the Ground, Medium-close in Distance)

Statistics (in mm):

Max: 6866

Min: 6782

Mean: 6820.4

Range: 84

Standard Deviation: 15.0962

Variance: 227.8945

For all the 16 test results, we also made a histogram to directly show the distribution of each test. So that we can easily compare any tests (see Figure 5).

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Figure 5. Histogram of Test Results

Through the experiment, we conclude that, for the distance of placement, the modules still work fine in the close range (about 1m), but when the distance goes too far, the accuracy may not be so good. In the middle range, the modules perform best. For the height of placement, placing the module too low may have a bad influence on the accuracy, but not so severe.

After that, we did a further experiment on 3 modules to build a coordinate system and see how it distributed (see Figure 6).

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Figure 6. Coordinate System Diagram

Statistics (in mm):

Standard deviation of x-coordinate of A1:16.2394

Standard deviation of x-coordinate of A2:19.1461

Standard deviation of y-coordinate of A2:16.6332

1. Discussion

Overall, in this phase of the project, we enhanced the functionality of the embedded program of UWB modules and did multiple experiments based on the application scenario.

For the next step, we should consider adding the modules to the robots, and adapt the corresponding hardware schemes and programs so that the UWB module can be a functionality of the robot. The problem includes input-output interface conversion, wire/wireless connection, running place of the computation program, etc.

For the convenience of the group work, we have also written sufficient documents as notes and built a code repository to share the code online.

Appendix: Shared code repository on GitHub

https://github.com/wanghaoyi518/UROP\_UWB