An Overview of Ultra-Wideband Positioning Technology and Its Applications

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ABSTRACT: UWB is a kind of wireless communication technology used in plenty of high-tech factories but seldom seen in humans' daily life. Encouraged by the public, experts are urged to do futher reserch because of its accurate positioning. This paper introduces the background and features of UWB. Five methods of UWB localization are listed and the disadvantages and principals of each method are also listed, like RSSI (Received Signal Strength Indication). Existing applications of UWB are divided and shown in two types: which are categorized by function and scene. The conclusion and expectation about UWB are shown: creative methods need to be applied to drop the cost of such products so that they have access to potential customers.

1. INTRODUCTION

Along with the development of technology comes the demand for UWB(Ultra-Wideband) positioning technology. As the name implied, UWB is a wireless communication technology systems whose ratio of system bandwidth and central system bandwidth is more than 20% or whose system bandwidth is greater than 500 MHz. [1]

UWB is used for military and radar for plenty of decades. FCC (Federal Communications Commission) passed the final provision permitting UWB used in commercial way in 2002.[2] Since then, band 3.1~10.6 GHz are open for commercial use. A lot of companies began to do research and developed relevant products. For example, electronic equipment like iPhone 11 and fitting like Air Tag from Apple include this technology.

UWB has plenty of advantages. Compared with common communication systems, full digital structures can be implemented in UWB communication systems so that their circuit is easy to make and the cost is correspondingly low. A system can be completely put on one chip on account of depending on a simple digital circuit to digitally modulated pulse, instead of using a traditional method to modulate. On top of that, the transforming power of UWB is strictly less than 0.56 mW, power consumption is only 50~70 uW, which is only about one thousandth of the cellular handset. Therefore, UWB won't do too much harm to users' health. At the same time, battery life is greatly prolonged.[3] Shown by experimental data, in the environment whose multipath fading depth of normal warless signal is 10~30 dB, the multipath fading for UWB is less than 5 dB. [4] i.e. UWB has Excellent anti-multipath fading performance. Besides, UWB could carry lots of information so that the ability to transform information is strong.

With so many advantages, which benefit the customers, perhaps many companies in this area are willing to choose to use this technology. However, some factories or companies do not use this technology due to financial or other reasons. So what principles of positioning of UWB technology are used and what sences in different kinds of businesses in which fields are fit to use this technology? This paper summarized basic methods used in the positioning of UWB technology and listed common applications used in society till now. Nevertheless, there are more areas where this advanced technology is suppposed to be applied. The objective of this paper is to show the mass more information about this technology; and promote the creativity of applications in more factories in such areas. Therefore, some cheap electronic commodities also can contain this accurate positioning technology so that more customers are access to it, which means this technology is going to get better promotion.

2. METHOD

This paper focus on the positioning application of UWB. The way of different positioning methods and principles are similar. Using the positions information of the known node gets the tag position information by corresponding algorithms.[5] There are two types of positioning ways judging from whether the way is connected with the distance. The distance between the known node and the target node to be located is determined by the response eigenvalue of the receiving and receiving signals in one related to distance. Then, using corresponding positioning algorithms determine the exact position of tag node. The other one depends on the connectivity and other

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information to accomplish the positioning aim tag node. [6]

The steps to accomplish the positioning aim tag are as followed. First, obtain relevant information about the aim position. On top of that, create a corresponding mathematical model. Thirdly, calculate the aim position using the information from the former steps.[7] According to the measurement parameters, there are four methods to position an aim position. They are Received Signal Strength Indication, Angle of Arrival, Time of Arrival and Time Difference of Arrival.

2.1. Received Signal Strength Indication

Based on the method of receiving signal strength rule, according to the relationship between the received signal strength and the target node under test to capture the value of intensity of field. On the basis of the value of intensity of field of fading signal and emit signal to get the spacing of the received signal.[8] using the multiple measuring distance and the corresponding localization algorithm can obtain the location of the object under test. In an ideal state, the attenuation of signal strength during the propagation of wireless signals in two-dimensional space is shown in Figure 1.

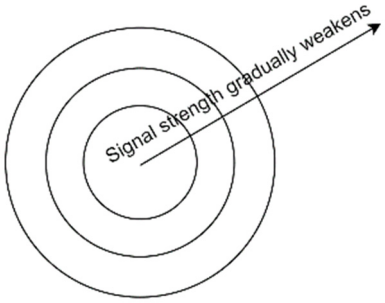

Figure 1 The Schematic diagram of signal weakness During wireless signal propagation

When using RSSI to locate aim place, output power is known. In this way, loss value can be calculated when the received power is known. The relationship is as followed.

$$P_r = \frac{G_t G_r P_t k \lambda^2}{(4\pi d)^2}$$

In this formula, Pr on behalf of the exam received power. Pt output power value. G and G correspondingly represent output and received antenna gain. K stands for loss factor. λ is wavelength. D is signal propagation distance. As the distance between the base station and the aim place is known, it is easy to calculate the exact location by this formula. Of course, in real world, there are some errors, compared with the ideal situation.[9] The positioning coverage distance of this method is relatively close. And the dependence on the channel transmission model is very large. The multipath and the change of environmental conditions will seriously deteriorate its accuracy. Especially, the accuracy of distance estimation is independent of the signal bandwidth so the advantages of the large bandwidth of UWB won't carry out. As a consequence, RSSI is generally not used alone for UWB localization.

2.2. Angle of Arrival

Based on two base stations, this research uses the angle of station and aim location to measure the exact aim place. Like Figure 2, we set two base stations as BS1 and BS2, and set a rectangular coordinate system and consider BS1 as original point. Then their coordinates are (0,0) and (x, y). And if the angle θ1 and θ2 are known, the coordinate of aim location (x0, y0) can be calculated. The formula is

$$\tan\theta_i = \frac{x_0 - x_i}{y_0 - y_i}, i = 1,2$$

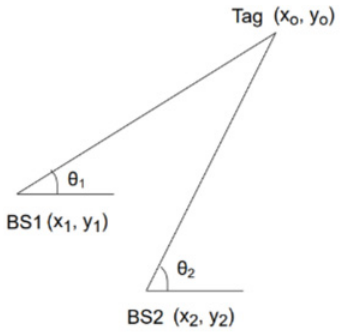

Figure 2 The positioning model of AOA

However, obtaining the arrival Angle of the signals from the measured point to the two receivers for positioning requires a complex configured antenna system. And the impact of the Angle error on the positioning accuracy is great.

2.3. Time of Arrival

Using the time spreading in the air to calculate between aim node and base stations.[10] Since the speed of an electromagnetic wave is known, the distance between base station and tag could be calculated by the cost time. Like Figure 3, the central point is the exact position if the circle is drawn the place UWB could send. Finally, solving a three-variable linear equation could work out this problem.

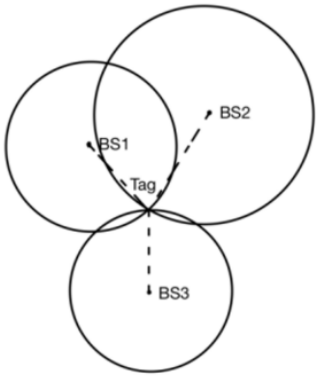

Figure 3 The ideal positioning model of TOA in two-dimensional space

However, TOA requires strict time synchronization between the reference node and the measured point, which cannot be met in most applications. During the

implementation of this method, the distance information between the UWB positioning tag and each base station needs to be measured so that the positioning tag needs to communicate with each base station back and forth. Therefore, the power consumption of the positioning tag is high.

2.4. Time of Arrival and Time Difference of Arrival

Compared with TOA, TDOA takes the difference of distance of aim place getting to base stations.[11] In this way, the accuracy of the positioning won't be influenced by the incorrection of Sy chronometer. Because the spread time of the warless signal is the difference of received and output time between aim place and base stations, which is difficult to carry out the synchronism between aim node and different base stations. In TDOA, only the synchronism of base stations is required.

Like Figure 4, there are three base stations named BS1(x1, y1), BS2(x2, y2) and BS3(x3, y3) and the distances between three base stations respectively are d1, d2 and d3. Set a rectangular coordinate system and consider aim place is original point. The distance difference of aim place with BS1(x1, y1), BS2(x2, y2) is d4= d2 -d1. Then, the aim place should be on the hyperbola considering d4 as focal distance and BS1(x1, y1), BS2(x2, y2) as focal point. After that, record the distance difference of aim place with BS1(x1, y1), BS3(x2, y2) is d5= d2 - d1. And draw the hyperbola whose focal distance is d5 and focal point is BS1(x1, y1), BS3(x2, y2). The meet point of two hyperbolas is the aim place.

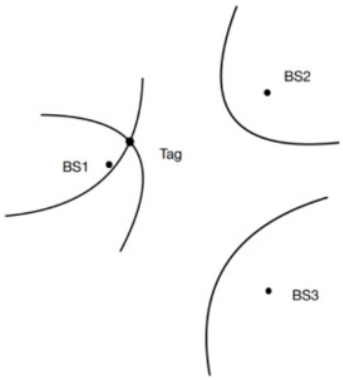

Figure 4 The positioning model of TDOA

2.5. Synthetic approach

At present, hybrid positioning has become the mainstream of new wireless positioning. The core idea of hybrid positioning relies on the use of reliable short-range measurements to improve the accuracy of position estimation in wireless systems. Different combinations of wireless positioning measurement methods (RSSI TOA TDOA AOA, etc.) have been implemented to enhance the accuracy of position estimation.

3. APPLICATION

3.1. Categorize by function

3.1.1. Real-time high accuracy management

This is for real-time location management of people, divides and cars. In this way, the objects would be checked at any time. For example, the elder in nursing homes are located and monitored to prevent them from getting lost and vehicle positioning management, etc.

3.1.2. Electronic fence

Some situations like crossing the board or keeping static for too long would be monitored and show up through control systems in order to avoid accidents and keep safe.

3.1.3. Data statistical analysis

Data statistical analysis can realize efficient data statistics, it is convenient for workers to check personnel distribution data, heat map data, real-time electronic fence warning data and other information.

3.1.4. Historical track query

Based on UWB, the historical track of the tag could be checked in a piece of time by showing the live playback in the background. For instances, check the time work enter and left the company or a moving track of a vehicle in a underground parking.

3.1.5. One click for emergency help

When there is a explosion or a fire happened in a factory. Workers who are in danger could be located through the positioning card, which is helpful for Rescuers' help.

3.2. Categorize by scene

3.2.1. Intelligence factory

In the manufacturing process, UWB could precisely locate every part of the process and check out the working condition of machines. As a consequence, power efficiency and safety of management could be improved.

3.2.2. Intelligence power plant

Putting UWB into staff system, video system and access control system so that manager could monitor the number and track of the workers.

3.2.3. Intelligence justice

Combine UWB positioning system and traditional supervision to meet the standard of supervision of visitors

and workers. As a consequence, it reduces the risk of safety problems.

3.2.4. Intelligence storge

UWB technology would help positioning of commodity to control dynamic management. It could check inventory, shipment, and search the system to raise the level of storage management.

3.2.5. Interlligence security

Nowadays, Some private houses like villas or cottages could place some base stations to keep residents safe. The distribution of base station still requires consideration.

4. CONCLUSION

As the demand for high-speed warless communication increases, UWB technology has developed a lot. The advantages of UWB technology outweight its disadvantages. There are numerous indoor positioning technologies. Each technology has its own limitations. Hence, the best way is to choose a suitable method in a different situation. To each other and to a certain extent, competing with each other high accuracy indoor positioning technology is more expensive and requires additional auxiliary equipment or a lot of artificial processing, which greatly restricts the low-cost technology popularization of positioning technology to improve positioning accuracy. Reducing the cost on the basis of providing high precision positioning is also a direction of indoor positioning.

The future trend must be the integration and use of various technologies to achieve complementary advantages. The lower the cost, the higher the accuracy of the technology and the easier the popularization. UWB has already been used in many fields. However, there are still plenty of fields that require such thechnology. More companies need to try to add this to their products in order to make a big fortune.

Therefore, more ways and methods need to be figured out that drop the cost of this technology such as finding the best way to arange these sensors indoors. In this way, with low cost, more companies are more likely to apply this technology. Also, the lices of the mass are going to be more colourful and convenient.

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