Comparison and Analysis of Indoor Wireless Positioning Techniques

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***Abstract*—This paper conducts an investigation for a lot of indoor positioning techniques. Several kinds of indoor positioning techniques are briefly introduced. And the paper makes an illustration of their principles and advantages or disadvantages. Positioning methods can be divided into two categories, range-based and range-free. Range-based positioning techniques are classified. And do a concise discussion of their principles. Finally, difficulties and focus of further research of indoor positioning are presented.**

Keywords: Indoor positioning; Range-based;Range-free

I. INTRODUCTION

The Global Positioning System (GPS) is a space-based global navigation satellite system (GNSS) that provides reliable location and time information in all weather and at all times and anywhere on or near the Earth when and where there is an unobstructed line of sight to four or more GPS satellites. It is maintained by the United States government and is freely accessible by anyone with a GPS receiver. But in a complex environment near the ground, indoor or basement, GPS signal is severely attenuated. So GPS positioning can not work. For this situation, it makes a lot of methods and measures to achieve the purpose of accurate positioning in the room. Currently there are many indoor positioning techniques, such as infrared ray (IR) techniques, ZigBee techniques, wireless Bluetooth techniques, radio frequency identification (RFID) techniques, ultrasound techniques, ultra-wideband (UWB) techniques and optical tracking techniques. The following will be introduced one by one.

II. INDOOR WIRELESS POSITIONING TECHNIQUES STYLE

A. IR Positioning Techniques

The principle of infrared positioning is that infrared IR modulated infrared ray emission is identified by the optical sensor installed in the indoor positioning receiver. Although the infrared has a simple structure, low cost and relatively high accuracy indoor etc., because light can not pass through obstacles, it makes the only line of sight infrared ray communication. The two main disadvantages of the indoor positioning are Short sight lines and Transmission distance.

The Active Badge system [1] was a predecessor to the Bat system, and tracks objects in an environment to store in a centralized location database [Figure 1]. Objects are tracked by attaching a badge, which periodically transmits its unique ID using infrared transmitters. Fixed infrared receivers pick up this information and relay it over a wired network. The walls of the room act as a natural boundary to infrared signals, thus enabling a receiver to identify badges within its room. A particular badge is associated with the fixed location of the receiver that hears it.

Figure 1. Base station (left) and transmitter (right) of Active Badge system

B. Bluetooth Techniques

By measuring the signal strength of Bluetooth technology to locate, is a low-power short-range wireless transmission technology. Install the appropriate indoor Bluetooth LAN access points, configure the network based on multi-user network connection mode, and to ensure that the Bluetooth LAN access point is always the master of this piconet, the user can get location information, to achieve the use Bluetooth positioning purposes.

Bluetooth technology is mainly used in small-scale positioning, such as single-room or warehouse. Bluetooth indoor positioning technology of the biggest advantages is the device small and easy to integrate the PDA, PC and mobile phones, so it is easy to popularize.

In theory, the holder features integrated Bluetooth mobile device user, as long as the device's Bluetooth feature is turned on, Bluetooth indoor positioning system will be able to determine its position. The technology used for short-range indoor positioning device and easy to find the impact of signal transmission from sight. The lack of Bluetooth devices and equipment is expensive, but also for complex spatial

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environment, the stability of the Bluetooth system somewhat less, by the noise signal interference.

C. RFID Techniques

Radio frequency identification technology uses radio frequency non-contact way to exchange data bi-directional communication in order to achieve the purpose of identification and localization. A short distance of this technology is general up to tens of meters. It can get in a few milliseconds centimeter level accuracy of the information, and a large transmission range, low cost. And it has non-contact and non line of sight and so on. Currently, RFID is hot and difficult research dissemination model theory, user privacy and security issues such as international standardization. Advantage of it is relatively small size identified, and relatively low cost, but the drawback is the role of proximity, does not have the communications capabilities, and not easily integrated into other systems.

SpotON [3] is a well-known point to point positioning system using RFID. SpotON analysis is based on wireless signal strength, and takes aggregation to achieve three-dimensional positioning. Designers take point to point network communications combined with the ideological orientation. Each user or an RFID tag attached to an object, by estimating the distance between each RFID tag is given the relative position between users. Therefore, SpotON can provide the absolute position of the user, and also provide relative position. This allows the system can also be joined by more and more participants to improve the positioning accuracy. Although there is some of the hardware design, a complete system is to the not yet completed.

D. Ultrasonic Positioning Techniques

Ultrasonic positioning technology has one-way law and reflective distance ranging method, which ultrasonic transmitter and receiver echoes generated by the measured object, according to echo the time difference with the launch wave under test to calculate the distance. Ultrasonic ranging mainly takes reflective distance method by triangulation positioning algorithm to determine the location of objects. The higher the overall accuracy of ultrasonic positioning, simple structure, but the ultrasound by the multi-path effects and non-line-sowing great influence, and needs a lot of the underlying hardware infrastructure investment, the cost is too high.

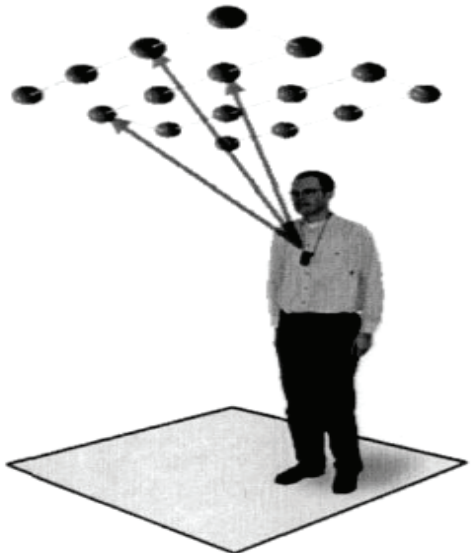

Figure 2. Active Bat system

A typical system is composed of the current AT & T Laboratories Cambridge, the development of Active Bat system [2]. The system consists of a collection of mobile or fixed wireless transmitters, a matrix of receiver elements, and a central RF base station. The wireless transmitter consists of an RF transceiver, several ultrasonic transmitters, an FPGA, and a microprocessor, and has a unique ID associated with it. The receiver elements consist of an RF receiver, and an interface for a serial data network. The receiver elements are placed on the ceiling of the building, and are connected together by a serial wire network to form a matrix. This network is also connected to a computer, which does all the data analysis for tracking the transmitters. The positioning error range is controlled in 9 cm. Although it has the positioning accuracy, the expansion of the system is not strong, not easy to deploy, the cost is higher. Diagram shown in Figure 3:

E. UWB techniques

UWB is a new communication technology and has great differences with traditional communication technologies. It does not require the use of traditional communication system in the carrier, but by sending and receiving a nanosecond or less of the extremely narrow nanosecond pulses to transmit data, which has the magnitude of the bandwidth. UWB can be used for precise indoor positioning, for example, found the location of the battlefield soldiers, robot motion tracking.

UWB systems compared with traditional narrowband systems has many advantages, such as the penetrating power, low power consumption, resistance to multi-path effects, high security, low complexity, and highly accurate positioning and so on. Therefore, UWB technology can be applied to indoor stationary or moving objects and people location tracking and navigation, and can provide very accurate positioning accuracy.

F. Optical tracking techniques

Optical tracking technology, the requirements of the linearity between the tracking target and the detector can be seen in the video surveillance system, often used in the monitored environment to install multiple cameras, a video

monitor, to observe the object in real-time dynamic monitoring. Optical positioning technology achieves the targeted goal by infrared cameras and reflective fixed ball (attached to the test target), or the coordination of infrared light-emitting diodes. This method can achieve high accuracy positioning, but with the expansion of the scope positioning, with the increase in the number of cameras, that require substantial investment in the underlying hardware, the cost is relatively high.

Vicon MX system [4] is a typical use of optical tracking system. It is a set of network connections Vicon MX motion capture cameras and other equipment to provide real-time optical data, the data can be used online or offline, real-time motion capture and analysis. Vicon MX architecture major elements include: ① MX cameras (Vicon T40, T20 two cameras for real-time proprietary image processing); ② MX Components (MX UltranetHD, and modulus acquisition card module Vicon MX systems to adapt to the distributed architecture system contains different number of MX cameras and hardware from third parties); ③ MX software (Vicon MX system support Nexus, Polygon, and BodyBuilder software used in life sciences, engineering, and entertainment media production industry); ④ PC host (Vicon MX system requires a PC with Ethernet port, the host system data has been achieved exchange (this port must be a network port of the PC other than the host port), all used the Vicon MX system software will be installed on the PC host); ⑤ MX external package (Vicon MX system consists of a set of precise calibration system calibration kit and a set of criteria for systems initialization accessories. and attached to the reflective surface of the measured object ball). The system framework shown in Figure 4:

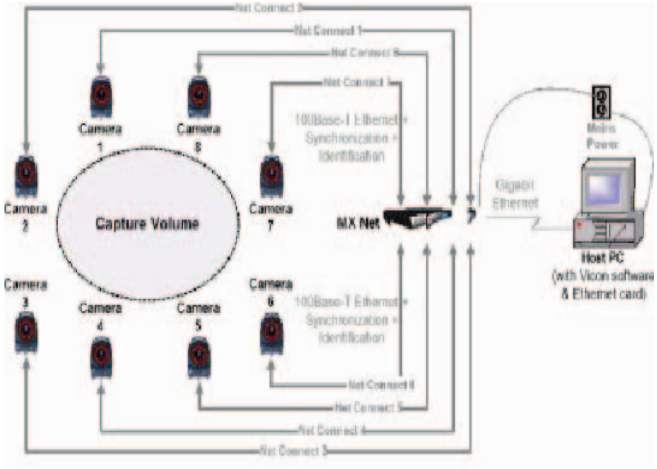

Figure 3. Vicon MX system block diagram

III. RANGE-BASED POSITIONING TECHNIQUES

A. *Received Signal Strength Indication (RSSI)*

The algorithm is based on the known signal transmit power and Received Signal Strength Indicator (RSSI) measured received signal strength values, calculated the effective signal propagation loss, and then used to estimate the value of the loss of distance, according to three or more value can be determined from the position of the target point.. But the biggest drawback of the way is sensitive to environmental change, and the positioning accuracy is poor, mainly due to signal transmission in the multi-path effects and shadows created by obstacles effects lead, so not suitable for indoor high-precision positioning.

B. *Time of Arrival (TOA)*

According to the known signal propagation speed and measuring the signal propagation time can also be achieved positioning. These methods are divided into Time of Arrival (TOA) positioning and Time Difference of Arrival (TDOA) positioning. TOA positioning is to measure two or more reference points and target points of the signal propagation time, which reached the target point, respectively, with the estimated distance between the reference points. To the reference point as the center, the corresponding distance between the target point for the radius of the circle, you can get two or more circles, the intersection of these circles should in theory be the target point position in two-dimensional plane. Geometrical principle shown in Figure 5, figure B1, B2, B3 representing the reference node 1,2,3, r1, r2, r3, respectively, the reference point to estimate the distance between the target point, the intersection X represents the estimated target node position. If there are multiple intersections of the situation, auxiliary methods can be used to blur.

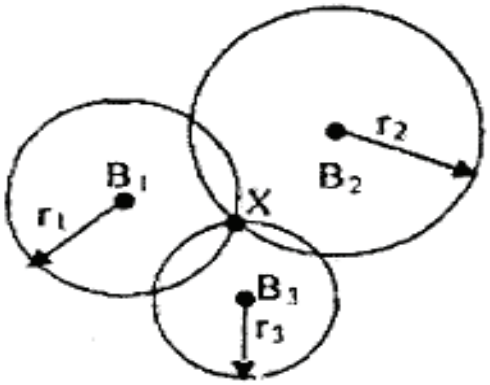

Figure 4. Time of Arrival (TOA)

C. *Time Difference of Arrival (TDOA)*

TDOA positioning is that different reference points are measured to the same target point to receive the positioning signal of the time difference, which calculate the target point to a different reference point distance difference. Target point to the distance between any two reference points difference d is constant. And the target point to two reference points must be located in the focus of the hyperbolic equation, determine the target point coordinates need to create two-dimensional hyperbolic equation of two or more. Hyperbola is the intersection of two two-dimensional position coordinates of the target point, as shown in Figure 6. When the three-dimensional positioning of the user needs to have N as a reference point both in the time of distance, a number of double-curved surface area is the intersection between the estimated location of the user. Of course, this method may exist to the ambiguity problem. Propagation time measurement based on the positioning method, is the positioning of the main research method used.

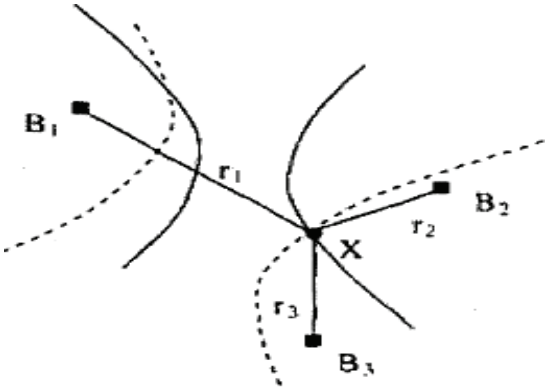

Figure 5. Time Difference of Arrival (TDOA)

D. Angle of Arrival (AOA)

Angles of Arrival (AOA) estimation problem is positioning issues in the areas targeted by the receiver antenna array reference point target point measured emission AOA, the formation of a reference point to the target point from the radial connection, that the direction of line. Obtained by the two reference points of intersection of two lines is the direction of target position, shown in Figure 7. Thus, AOA algorithm only requires a reference point in order to determine the location, and two straight lines is only one intersection, the intersection does not appear the phenomenon of multiple tracks.

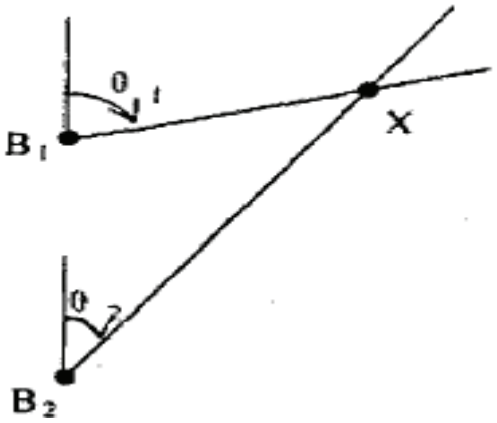

Figure 6. Angles of Arrival (AOA)

IV. INDOOR WIRELESS POSITIONING DEVELOPMENT

Positioning method described above has its own characteristics. TDOA and TOA positioning method is relatively easy to achieve, but also to achieve high accuracy, so these two methods has been more attention. Although AOA positioning methods require the antenna array to achieve, there is a lot of smart antenna research in recent. Therefore, the positioning method will become an inevitable trend, and its accuracy is higher. The hybrid positioning method can absorb the advantages of different positioning methods, but the need to provide measurements of different characteristics. So these are a hot and difficult in future. Comparison of specific performance is shown in Table I.

TABLE I. COMPARISON OF INDOOR WIRELESS POSITIONING TECHNIQUES

Wireless positioning techniques	***Positioning algorithms***	***Positioning precisions***
RFID	RSSI	Centimeters to tens of meters
Bluetooth	RSSI	Tens of centimeters to tens of meters
UWB	TDOA/TOA	A few centimeters to tens of centimeters
Ultrasonic	TDOA	tens of Centimeters
IR	AOA	A few meters
Optical tracking	Image processing	A few millimeters

V. CONCLUSION

With the development of wireless communication technology, sensor technology, computer technology and network technology, it makes the indoor precise positioning and business possible. For indoor positioning technology research mainly does do how to improve the positioning accuracy and reduce equipment costs, reduce power consumption and ease of the device itself and other issues of expansion and improvement, which requires further effort to do more research.

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