UWB RFID Technology Applications for Positioning Systems in Indoor Warehouses

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Abstract

This work experimentally addresses and discusses the feasibility and difficulty of UWB (Ultra Wideband) technology to track products in indoor warehouses. A warehouse environment is simulated by existing positioning system equipment and software systems, in which location-tracking products are tested using an IP Camera. The test results indicate that UWB in indoor warehouses can effective track products in real time, enabling warehouse operators to track products quickly.

Keywords: UWB, Positioning system, RFID

Introduction

GPS (Global Positioning System) is very widely used for location tracking outdoors, but is not suitable for indoor operation, because GPS signals are very weak and frequently bounce off surfaces, causing signal confusion. Current indoor positioning systems mostly use wireless transmission technologies, such as infrared, ultrasound, RF and Bluetooth. However, infrared technology has limitations in for precise positioning: it is suitable only for short-distance transmission, and is vulnerable to interference from neon lights and lamplights in rooms. Ultrasound RF (Radio Frequency) signal is popular in outdoor positioning systems, but has limited use in indoor positioning systems (IPS). Bluetooth technology, which suffers from unstable positioning and noise signal interference, is mainly used in small-scale positioning. In contrast, UWB technology has various benefits such as high performance in multipath channels, simple transceiver architecture and low transmission power [1]. UWB is a promising new technology with anti-jamming capability, high-precision positioning, low production costs, low power consumption and low emission power, making them highly advantageous for indoor positioning technology. This work describes the application of UWB technology to a complex indoor warehouse environment to achieve precise position. The target products are tracked using an IP camera.

Deploying Methods

UWB Technology

UWB is a radio frequency platform applied in personal area networks to communicate wirelessly over short distances at high speeds [2]. It operates within a frequency range of 3.1 to 10.6GHz, and has limited transmission powers. Military and law enforcement agencies have adopted UWB for decades for fine-resolution ranging, covert communications and ground-penetrating radar applications [3]. The FCC (Federal Communications Commission) of the US approved the First Report and Order (R&O) in February 2002 for commercial use of UWB technology under strict power emission limits for various devices [1]. Researchers are increasingly recognizing the significant potential for UWB technology in applications such as precise positioning and shortrange multimedia services [3]. This work performs tests using a two-way communication tag comprising UWB (frequency 6.0 GHz and 8.0 GHz) and 2.45GHz microwave signals. The UWB radio pulses are used to determine precise location, and the conventional radio signals are used for control and telemetry [4].

Algorithm

Methods of locating radio sources include time of arrival (TOA), time difference of arrival (TDOA), angle of arrival (AOA) and relative signal strength (RSS). UWB RFID technology calculates signal locations using the AOA and TDOA algorithms, which are described briefly in this work. AOA uses multiple antennae at a base station to determine the incident angle of an arriving signal. If a handset transmitting a signal is within the line of sight, then the antenna array can determine the signal direction. A second base station with the same technology then also locates the handset, and compares it with data from the first base station to locate the caller [5] (as shown presented in Fig. 1). However, this technique requires a line of sight between the handset and the base station, since reflected signals may provide a false bearing line. Because cellular communications do not (need OR require) line-of-sight transmission, AOA is often combined with another location technique, such as TDOA [6]. TDOA is best explained in terms of TOA. AOA and TOA differ mainly in that the latter uses the absolute time of arrival at a certain base station, rather than the difference between two stations. Since signals travel at a known velocity, the distance can be calculated directly from the time of arrival. The time of arrival data from two base stations narrows a position to two points, and data from a third base station is required to resolve the precise position [5]. TDOA is similar to TOA, except that pairs of base stations compare their measured distances by time of arrival of the same handset signal. The difference of arrival time defines a hyperbola with the loci at the two base stations. Three base stations produce three sets of difference times, creating three hyperbolic equations that define a single solution [6], shown as Fig. 2.

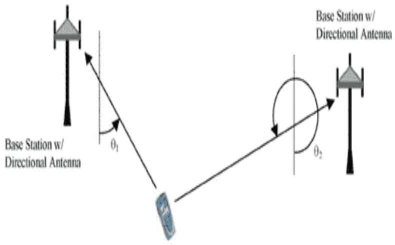


Figure1: Angle of Arrival [5]

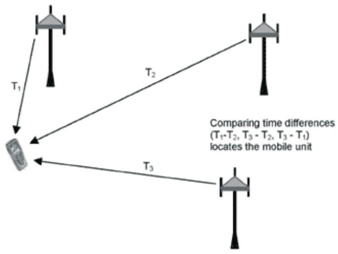


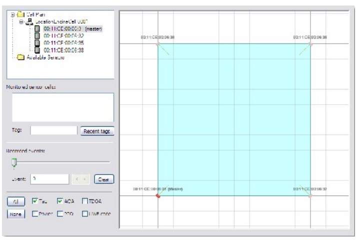
Figure 2: Time Difference of Arrival [5]

System setup

The indoor positioning systems were deployed in a room with approximate dimensions of 6m (L) × 3m (W) × 3m (H) space. Some metal cupboards were placed in this room to simulate a complex warehouse environment. Four sensors were then installed in the four corners of the ceiling, and each sensor was connected by wires, as shown in Table 1. The coordinates of each sensor were then identified to the back-end system software, which was set up to draw 2D and 3D images, as shown in Fig. 3. An IP Camera was placed in the ceiling of the room, so that it could film a scene across the whole room. The locations of tagged cases were stored in the 2D and 3D images, and in IP Cameras, as in Fig 4.

Table 1: Installation of four sensors in the four corners of the ceiling

Direction	Sensor	Direction	Sensor
Left rear side		Right rear side	
Left front side		Right front side	



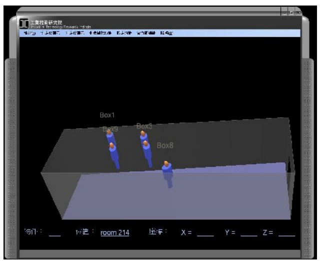


Figure 3: Drawing 2D and 3D images in back-end system

Figure 4: 3D image

Experimental results and performance evaluation

Experiments were performed to simulate a complex warehouse environment. A static test was first performed in which tagged cases were placed throughout a room, and the ceiling sensors induced tagged cases to launch microwave. Sensors transmitted information to the back-end system, which stored the locations of tagged cases in 2D or 3D images. The IP Camera could also display the locations of tagged cases. A dynamic test was also performed to track tagged cases from the 2D and 3D image systems and the IP Camera.

Experimental results, shown in Table 2, demonstrate that the system found the tagged case position quickly, and the measured distance position error was about 0.6m in the environment containing metal cabinets.

Table 2: Tagged case A position coordinates

Coordinate / Times	X	Y	Z
1	1.67	1.07	0.87
2	1.63	1.10	0.88
3	1.66	1.05	0.88
4	1.65	1.05	0.90
5	1.67	1.02	0.81
6	1.64	1.06	0.89
7	1.66	1.04	0.88
8	1.65	1.08	0.84
9	1.62	1.05	0.88
10	1.63	1.05	0.88
Average	1.648	1.057	0.871

The actual coordinates of tagged case A were (1.29, 0.64, 0.74), and the measured distance *d* between position *point*1 (X_A, Y_A, Z_A): (1.648, 1.057, 0.871) and position *point*2 (X_B, Y_B, Z_B): (1.29, 0.64, 0.74) can be written as the formula:

$$|P_1P_2| = \sqrt{(x_B - x_A)^2 + (y_B - y_A)^2 + (z_B - z_A)^2}$$

The distance *d* between two points was approximately 0.6 m.

The test contained two sources of inaccuracy. First, the panning range of the IP Camera was too small, causing the IP Camera to lose focus occasionally. Second, the recalculation of the sensor coordinate data by the IP Camera resulted in inaccurate estimates of location, as shown in Fig. 5.

Fig. 5 Out of focus

To verify the accuracy of the IP camera, the coordinates of the same tagged case were captured five times. The results list of Table 3 clearly indicate that the IP Camera could not capture the Dog case accurately.

Table 3: Capture coordinate of the same products case B

Times	Capture	Times	Capture
1		2	
3		4	
5			

Discussion

This work utilized UWB RFID for positioning, leading to the following obstacles:

1. Although the TDOA and AOA algorithms were utilized for positioning, an inaccuracy of 0.6m occurred.
2. The camera was out of focus. The positioning objects will send information to IP camera controller, will be calculated before the shooting objects out of focus.
3. UWB is currently illegal in Taiwan, and thus cannot yet be used commercially.

Conclusion

This work establishes a test environment for a positioning system based on UWB RFID technology. Static test results demonstrate that the inaccuracy of tagged case was around 0.6 meters. High-quality IP Camera equipment with an adjustable 360° pan is used to track objects, but has the disadvantage of poor focus. This research nonetheless provides a preliminary model for using UWB RFID for positioning technology in warehouse. Future work will be to continue to perform moving sample tests, and establish accurate monitoring systems.

References

[1] Faranak Nekoogar, "Introduction to Ultra-Wideband Communications," Prentice Hall, Nov 30, 2005

[2] Available: http://www.wisegeek.com/what-is-uwb.htm

[3] Dickey Arndt, Edward Dickerson, and Jianjun Ni, "Ultra-Wideband Two-Cluster Angle-Of-Arrival Tracking System Design for Space Exploration," ISSO Annual Report, 2006

[4] Ubisense Compact Tag, Ubisense Ltd.,2007

[5] Available:http://www.unstrung.com/document.asp?doc_id=15069&page_number=2

[6] Carl W. Kain, "Location-Based Wireless Services: Finding People Everywhere," CTAT Wireless Communications and Mobile Computing Group