Real Time Indoor Locating System based on Ultra-wideband and Machine Learning

Long Cheng
Research and Development Department
Kiwii Power Technology Corporation
Troy, NY, USA
dearlongcheng@gmail.com

Yani Guan
Strategy and Marketing Department
Kiwii Power Technology Corporation
Troy, NY, USA
yani_guan@kiwiipower.com

ABSTRACT
Accurately identifying and tracking the indoor location of people or objects in real time is of great importance in many fields. Although GPS is the predominant locating technology, it is unsuitable to use GPS indoors since GPS signals could not easily penetrate solid objects such as walls or ceilings. Other technologies, such as Bluetooth, WiFi, ultrasound, infrared and RFID, that can be applied indoors lack the accuracy, the range and the speed required in many indoor localization applications. Therefore, our paper focuses on a more promising technology meeting the challenges of indoor real-time localization, including potential accuracy, ease of installation and functional range, which is ultra-wideband. Ultra-wideband is suitable for indoor real-time localization because of its short radio frequency pulse duration and wide bandwidth, which can minimize the effects of multipath interference and allow for high-resolution ranging and easier material penetration. In this paper, a complete process of designing a real-time indoor locating system based on ultra-wideband, which is called Pexy, is presented. In addition, since accuracy is an important evaluation factor for a real-time indoor localization system, several signal processing and machine learning methods are also well designed to improve the accuracy of the ultra-wideband based system in this paper.

Keywords
Indoor localization, Ultra-wideband, Machine learning, RTLS.

1. INTRODUCTION
Indoor localization is attracting more and more attentions from both industry and academia. Obtaining accurate indoor localization information is useful in many applications, such as asset tracking, security monitoring, health-care system, logistics management, and automatic guided vehicle (AGV) control. Predominant localization technology, GPS, however, is unsuitable, inaccurate and unreliable to be used indoors since it is limited by its penetration ability against solid objects such as walls or ceilings. Several different technologies such as RFID, ultrasound, Bluetooth and infrared have been explored for real-time indoor localization, but they still could not achieve satisfactory performance in the accuracy, the range and the speed.

In the recent decade, the ultra-wideband (UWB) has drawn considerable attention and shown better performance compared to other technologies in the field of indoor localization. UWB signals are defined as signals with either a large relative bandwidth that is typically larger than 20%, or a large absolute bandwidth that is greater than 500MHz. The short duration of UWB pulses assures the resistance against multipath interference and allows a supreme time resolution [1]. Furthermore, compared with traditional narrowband radio frequency (RF) signals, UWB signals are more likely to pass through obstacles between the anchor and the tag with less delay and attenuation [2]. Our work is motivated by the fact that UWB is a more promising technology for indoor localization. Therefore, we make use of UWB to design a real-time indoor locating system and try to improve the accuracy of the real-time indoor localization.

The real-time indoor locating system designed by Kiwii Power Technology Corporation is called Pexy, a centimeter-accurate, scalable, reliable and easy-installable locating system based on UWB with fast transmission speed, large system capacity, high refresh rate and multi-object tracking ability. In an open environment, 99 percent of ranging error for Pexy is within 2 cm, so Pexy is able to achieve a 3 cm median position error on the two dimensional plane and a 10 cm median position error on the three dimensional space. Compared to traditional UWB based indoor locating system that can at most achieve decimeter level accuracy, Pexy secures a much higher accuracy by leveraging carefully designed signal processing and machine learning methods. To our knowledge, Pexy is the first UWB based real-time indoor locating system in the world that utilizes machine learning methods to improve the localization accuracy.

The ability to support multiple tags in the UWB based real-time indoor locating system while maintaining high update rate is another highlight of Pexy. In addition, Pexy can automatically and dynamically locate and track the current number of tags in the system.

In this paper, the design of a real-time indoor locating system based on UWB is presented, including the localization method, the deployment of anchors and tags, and the signal processing and machine learning methods used in the real-time indoor locating system.

2. SYSTEM DESCRIPTION
Pexy integrates the DecaWave DW1000 chip with IEEE802.15.4-2011 UWB compliant, the STM32F4 ARM microcontroller, the serial port, the omnidirectional antenna, the regulators, the crystals and some other electronic components in both the anchor and the tag. 5 volts rechargeable battery is used to supply power to anchors and tags. The Pexy modules are shown in Figure 1. One anchor node in Pexy is deemed to be the master, which schedules the function time of anchors and tags as well as setting the desirable system parameters such as the update rate and the maximum numbers of tags and anchors in a certain application scenario.

Figure 1. Pexy hardware.

Before using DW1000, each of the DW1000 chips needs a custom calibration for both the transmit delay and the receive delay.

Pexy employs Two-Way Time of Flight (TW-TOF) method to take the range measurement. To determine the real-time location of a tag, Pexy uses trilateration, which means computing the real-time location of a tag using its real-time ranges to a number of pre-known locations of anchors. With the real-time range as the radius, a spherical surface, which indicates possible locations of the tag, can be formed with the anchor as the center of the sphere. In two dimensions, the intersection of two circles narrows down the possible locations of a tag to two points. With one more range measurement, the correct two dimensional location of the tag can be finally determined. In three dimensions, at least four range measurements are needed to determine the location of a tag. If given more than four range measurements, probably there is no unique solution can derived from trilateration since the range measurements usually contain error and noise. In this case, the non-linear least squares solver [3] is added to trilateration to obtain the optimal location solution. And with more range measurements, the reliability of the locating system can also be improved.

In addition, several signal processing and machine learning methods, such as Kalman filter, particle filter and nonlinear regression, are used in Pexy to improve the location accuracy.

3. EVALUATION

Pexy can be used for both two dimensional location and three dimensional location. At least four anchors needs to be deployed at known locations. Tags should be placed at the test sites. No extra wires or computers are required for the system installation. A laptop can be used to report the location information of the tags. Pexy can be classified into the infrastructure-based modified COTS Technology Category.

4. ACKNOWLEDGMENTS

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5. REFERENCES

[1] Zwirello, L., Schipper, T., Harter, M. and Zwick, T. 2012. UWB localization system for indoor applications: Concept, realization and analysis. *Journal of Electrical and Computer Engineering*, (Jan. 2012), 4-15. DOI= http://dx.doi.org/10.1155/2012/849638.

[2] Lee, J.Y. and Choi, S. 2004. Through-material propagation characteristic and time resolution of uwb signal. In *Ultra Wideband Systems, 2004. Joint with Conference on Ultrawideband Systems and Technologies. Joint UWBST & IWUWBS. 2004 International Workshop* (May 18 - 21, 2004) IEEE, 71-75. DOI= http://doi.ieee.org/10.1109/UWBST.2004.1320938.

[3] Wright, S. and Nocedal, J., 1999. Numerical optimization. *Springer Science*, 35, 67-68.