High Precision Ranging UWB System for Automotive Applications

Ahmed Khaled Mustafa , Modather Ahmed Mustafa , Mohannad Fathy Youssef and Youssef Hassan Mohammed
Military Technical College, Egypt, shaltoot81@gmail.com

,modther.emira15@gmail.com,mohannad_fathy99@yahoo.com ,youssefhassan129@gmail.com

*Supervisor:*Lt. Col. Dr. Ahmed Fouad Youssef, Major. Dr. Ahmed Abdelraheem
Military Technical College, Egypt, afyousef@ieee.org , a.abdelraheem@ieee.org

Abstract*– ultra-wide band technology has become a standard in accurate ranging and localization as well. The technology can be used in indoor positioning systems to solve problems of GPS in indoor environment. In this paper we develop a system that can measure accurate ranges to be used in sensitive range applications. The system integrates the DWM3000 module with the nRF52840 developmental kit. The proposed system can be used in different applications. One of these applications is the smart gate system which is discussed below. Accuracy of 10 cm is achieved by the proposed system.

I. Introduction

Recently, people widely use GPS applications for positioning and localization of open areas and outside applications. However, it is difficult to use it for indoor applications. An alternative way for indoor positioning and ranging is the usage of ultra-wideband (UWB) technology[1]. It offers a promising solution for indoor localization problem with the help of its spectrum 3.1:10.6 GHZ [2]. the technology uses maximum mean power spectral density of -41.3 dBm which supports reduction of interference with other systems. UWB has many important features such that very high resolution, suitable for high-speed communication, signal is not affected by obstacles as it can occupy low carrier frequencies and signal strength against multi-path phenomenon [3]. UWB systems has several applications in both civilian and military fields. At military field, it is used for detection and tracking of an important equipment carried by one soldier to be capable of localizing it in case of any problem or a soldier carrying an important equipment till he achieves his mission or a drone carrying medical tools till it reaches the battle field. At civilian field, it is used in autonomous cars and smart home applications. A smart application is proposed in this paper which is a smart gate system [2].

In this paper, we concern about UWB Two-Way Ranging (TWR) using python package for data extraction and visualization. This paper is organized as follows: Section I is an introduction of UWB and its applications. Section II discusses the theory of TWR and its types. Our experimental work and application constructed is discussed in section III. Section IV summarizes our work and is a brief conclusion of the paper.

II. Theory

Two-Way Ranging (TWR) is a method to achieve accurate range between two nodes one acts as a source node

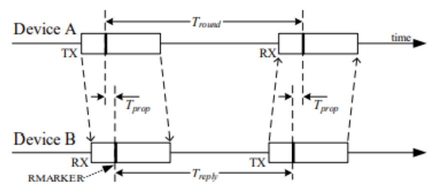


Figure (1) single-sided two-way ranging

(anchor) and the other acts as target node (tag) [4]. It has two types: Single-Sided Two-Way Ranging (SS-TWR), Double-Sided Two-Way Ranging (DS-TWR) which are described next.

A. Single-Sided Two-Way Ranging (SS-TWR)

It has a simple measurement of a single message round trip delay from source node to target node and response is sent back to the source node.

Figure(1) shows the operation of SS-TWR where device A is responsible for initiation of the exchange and device B responds to complete the exchange and both devices timestamps the transmission and reception times of packets precisely to be able to calculate times T_{round} and T_{reply} by subtraction. And time of flight, T_{prop} is estimated by

$$\hat{T}_{prop}= \frac{1}{2}(T_{round} - T_{replay}), \qquad (1)$$

each of device A and B measures T_{round} and T_{replay} independently using their local clocks, and both have clock offset error e_A and $e_B$from their nominal frequency, so the time-of-flight estimation resulted has considerable error increasing as T_{reply} increases. DW3000 can overcome this problem by using this modified equation.

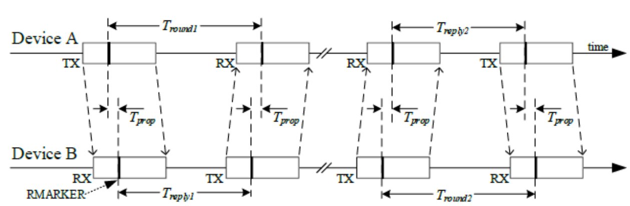


Figure (2) Double-sided two-way ranging with four messages [4].

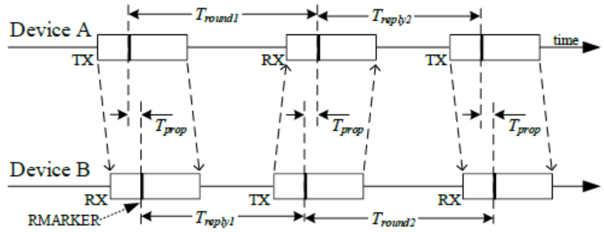


Figure (3) Double-sided two-way ranging with three messages [4].

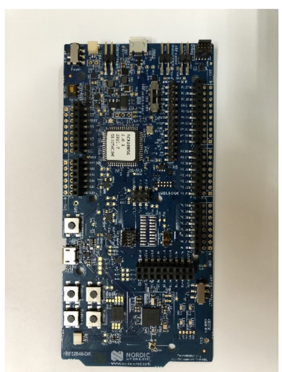
$$\hat{T}_{prop} = \tfrac{1}{2}\left(T_{round} - T_{replay}(1-C_{offset})\right). \qquad (2)$$

B. Double-Sided Two-Way Ranging (DS-TWR)

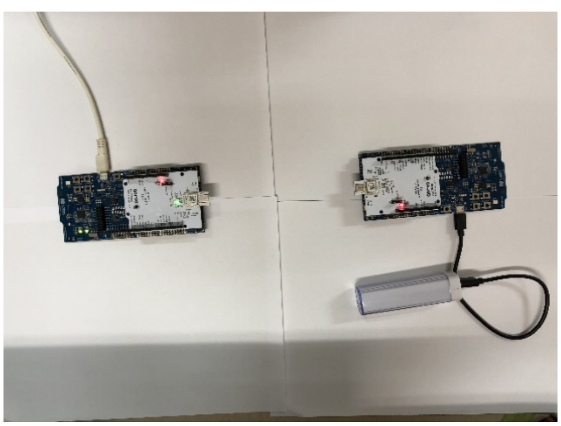
It is an extension for the basic (SS-TWR) in which there are two measurements for round trip delay used and combined to give a resultant time of flight in which error is reduced even for long response delays. It can be measured by four messages or three messages.

Using four messages: Figure (2) represents the operation of using four messages in DS-TWR. First, device A initiates the first-round trip measurement at which device B responds, then device B initiates the second-round trip measurement at which device A responds to complete the full DS-TWR exchange.

(a)



(b)



(c)

Figure 4 (a) DWM3000evb, (b) Nordic nRF52840-DK, (c) proposed system.

Figure (5). Gate is closed and red light is ON at distance > 50 cm

Timestamping of the transmission and reception times is precisely occurred by both devices.

Using three messages: The previous four messages can be reduced to three messages by considering the reply of the first-round trip to be the initiation of the second-round trip measurement as shown in **figure (3)**.

The time-of-flight estimate, T_{prop}, in both the three and four message cases may be calculated using

$$\hat{T}_{prop} = \frac{(Tround1*Tround2-Treply1*Treply2)}{(Tround1+Tround2+Treply1+Treply2)} \qquad (3)$$

III. EXPERIMENTAL WORK

A. setup:

We used two separate kits each consists of a DWM3000 evaluation board [5] connected to a Nordic nRF52840-DK board [6], which are compatible to each other, as a backbone to provide the J-link interface with PC for data transfer and programming.

nRF52840-DK board is used to receive the data from the DWM3000EVB and provide the ranging information either to the GUI software on the PC to be represented for user or to a processor to take an action in some applications.

One kit is used as an anchor node connected to PC or a laptop and represents the fixed source node. The other one is used as free movable tag node powered by a power bank battery. **Figure(4)** represents the two-way ranging system components and configuration.

The smart gate and led system are controlled by an Arduino UNO kit programmed by python using **pyfirmata** library to control the servo motor and led system.

B. Calibration

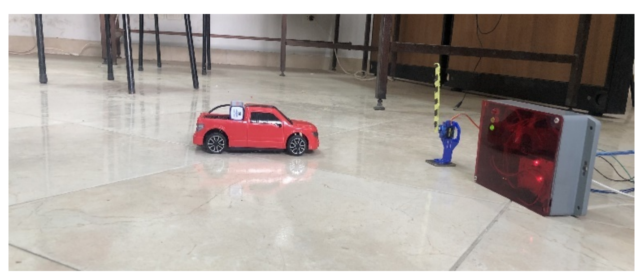


Figure (6). Gate is open and green light is ON at distance < 50 cm

System is calibrated at 2m distance and accuracy of 10cm has been achieved. The accuracy is acceptable with respect to measured distance.

C. Channel configuration

After some experiments on the field parameters of channel is chosen. According to IEEE standards we choose a 500 MHZ bandwidth channel at center frequency of 6.5 GHZ. And a 128 preamble length is used. The longer the preamble length the higher the accuracy of ranging. Optimum value of 128 is selected. Pulse repetition frequency of 64 MHZ and data rate of 6.81Mbits\s is selected.

D. Smart gate system

For, we made a prototype for the smart gate system station which has the anchor module of the system and the tag module is mounted inside a car shown in **figure(5)**. We used a python code to program a servo motor to open the gate at a distance limit of (50 cm) between anchor and tag nodes and after the car leaves the gate by distance of (50 cm) the gate is closed. **Figure (5)**,**(6)** represent the application system

IV. Conclusion

UWB TWR is achieved by integration between DW3000 module and nRF52840-DK which are compatible to each other and accuracy of 10cm is achieved after calibration process.

output range of the proposed system is extracted and driven into arduino board and used to control a servo motor and a led system to open and close a smart gate automatically according to the distance between the car and the gate. the threshold distance is selected to be 50cm.

V. future work

Ranging is accurately achieved by the proposed system. The next step is to do localization using array antenna on and calculate the time difference of arrival to both elemnts in the array. Or by using 3 modules of the proposed system and with the help analytical methods positioning can be achieved.

Acknowledgment

First, we would thank Allah for blessing us in every step in our project and for giving us the endurance and perseverance to complete this work. Second, we would like to express our deep thanks, gratitude and sincere appreciation to our supervisors: Lt.Col.Dr. Ahmad Fouad Youssef and Major. Dr. Ahmed Abdelraheem for the great efforts, continuous encouragement and piece of advice that was offered during working in this project that keep us in track to reach this level of knowledge. We could not have to complete this work without the continuous support of our Radar department members. Finally, we want to thank Egyptian academy of scientific research and technology for sponsoring us.

References

[1]M. Ghavami, Lachlan Michael, Ryuji Kohno - Ultra Wideband Signals and Systems in Communication Engineering-Wiley (2007).

[2]Kazimierz Siwiak, Debra McKeown - Ultra-wideband Radio Technology -Wiley (2004).

[3] Mohammadreza Yavari and Bradford G. Nickerson, “Ultra-Wideband Wireless Positioning Systems”, March 27, 2014, University of New Brunswick.

[4]Decawave Sensor, DW3000, Decawave, 2013. [Online]. Available:www.decawave.com.

[5]DWM3000evb, Datasheet, 2020. [Online].Available: qorvo.com

[6] DW3000_Arduino_Shield_QSG_Nordic, [Online]. Available: qorvo.com