Ultra Wideband localization using two anchors

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Abstract. *This article describes an approach to using only two anchors to perform localization with Ultra-Wideband(UWB). Positioning of the anchors is key to achieve success in this work, and after a theoretical review, preliminar results will be shown as a step further to encourage future work;*

1. Introduction

Knowing the position of humans, objects, equipment or even animals has become necessary for a ton of applications and consumer electronics in the modern world. New technologies surge every year to track desired objects or living beings and are on constant development. Positioning can be divided into two scopes: Outdoor positioning and Indoor positioning. Outdoor positioning has a common and suitable technology named Global Positioning System (GPS) that works well on open spaces, however satellite radio signals have extreme difficulties in penetrating solid walls and even obstacles. Indoor positioning is a point of research that has grown significantly in the 21st century.

The search for a technology that combines precision with the capability to mitigate interference from other radio technologies gave birth to Ultra Wideband (UWB) a radio transmission technology made originally to be centimeters accurate in a short-range but also viable for outdoor applications. This is possible due to its specific characteristic: A very short time duration wave pulse combined with the capability to spread signal in a very wide bandwidth. Both of these characteristics make it easy to distinguish the pulse emitted by UWB from other radio emissions in a noisy environment. These features make UWB transmitters able to transfer a high amount of data in a short period, useful for Real-Time Localization Systems (RTLS) that needs a high frequency of updates for tracking moving objects or living beings.

Localization techniques are often based at least three fixed transmitters (Anchors) and moving devices (Tags) to perform the necessary positioning calculus based on each strategy. We wanted to go beyond the necessity of at least three anchors and decided to take a step into a new perspective, using only two anchors, to evaluate the performance.

In this paper, we show everything you need to know about localization with UWB to understand the work done and discuss future applications. First we discuss the most common localization techniques and then we show our proposal. Than we show results from an experiment made with UWB technology and discuss the preliminary results taken from it.

2. Theoretical Review

There were three essential correlated works that gave all the base for this work, the first one was UWB communication systems: a comprehensive overview[Maria-Gabriella and Di benedetto 2006], this book was the basic of how every single theoretical aspect of UWB was designed for work, which is essential for starting the research on UWB, we need to know how it work and perform before actually put our ideas into work.

The second correlated work was Location, localization and localizability[Yunaho Lio et al. 2010], made to understand the principles of localizability and its necessary and mandatory conditions, which was essential to understand how our model would behave in terms of localization.

And the third that will be more elucidated is: “A survey of indoor localization systems and technologies”[Zafari, Faheem, Athanasios Gkelias, and Kin K. Leung 2019]. In this work we have all the principles of the localization techniques and how they work. The first topic that needs to be talked about to understand our project is the most common localization technique, the Time of Arrival(ToA) that uses Trilateration to track an object:

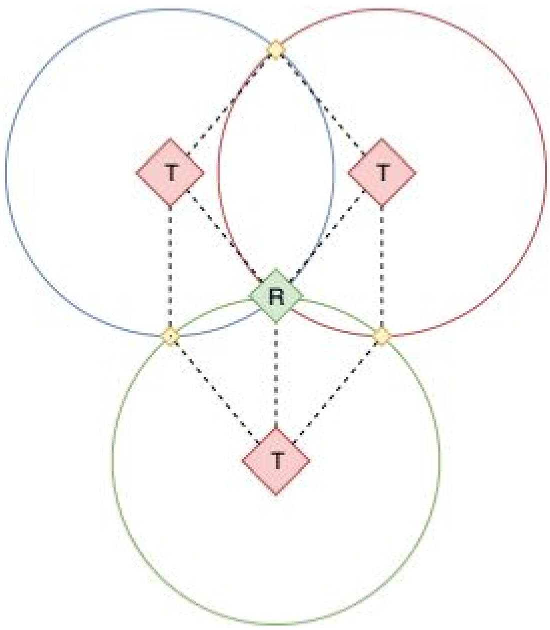

Figure 1. Time of Arrival Demonstration, T = Anchor, R = Tag

This technique is based on the time that the signal travel from a device to another and the speed of transmission that is the same as the speed of light. The time that the signal leaves the transmitter, usually called the time of departure, needs to be known for correct calculation. Since distance is equal to speed times time, a circle can be formed from the transmitter for all the possible positions the receiver could be placed, Figure 1 shows how ToA works. Combining three transmitters and one receiver, using a method called trilateration[Sakpere, Wilson, Michael Adeyeye-Oshin, and Nhlanhla BW Mlitwa. 2017], it is possible to know the receiver location, which is placed on the intersection of the three circumferences created by the transmitters. For this method, all the devices need to be synchronized for the correct time measurement, what might be a problem due to a common issue named clock drift[Heydariaan, Milad, Hessam Mohammadmoradi, and Omprakash Gnawali 2019] that is basically the clocks becoming out of sync and giving wrong data. Some key factors that affect ToA precision are the bandwidth and the sampling rate, the larger the bandwidth the higher the accuracy[Maria-Gabriella and Di Benedetto 2006].

3. Our Contribution

Our method is also based on ToA, but using only two anchors does not give us a way to perform trilateration, Figure 2 shows the possible locations that are given by using only two transmitters:

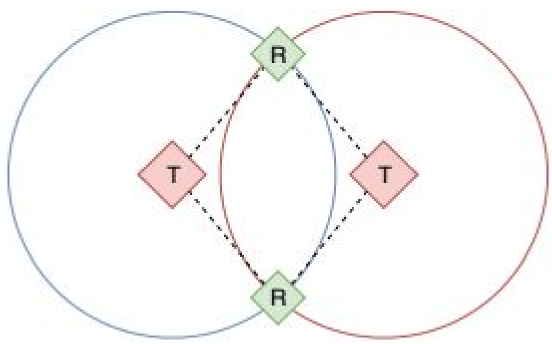

Figure 2. Two Anchors Reflections

As we can see in Figure 2, there are two possible locations a tracked object could be placed based on the distances from each transmitters. So, our method needs a way to eliminate the reflection and only track the real object, which can be done with a smart positioning of the transmitters, as shown in Figure 3:

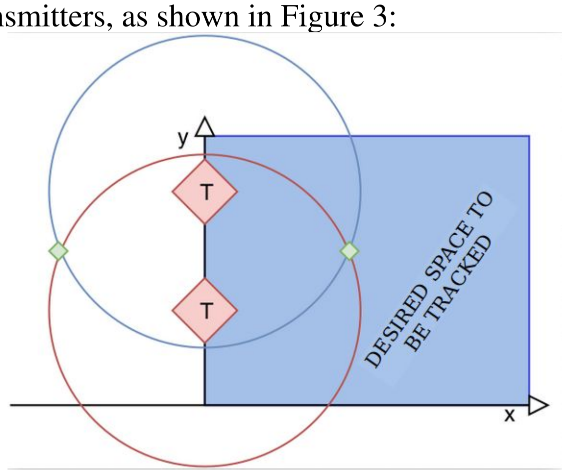

Figure 3. Positioning the two anchors

By positioning the two anchors like that it is possible to eliminate the reflection based on the "x" value, if it is positive, it correspond to the real object, if it is negative it corresponds to the reflection. Of course it could be placed as well on the x axis, the important part is the knowledge of the desired space to be tracked and positioning the anchors on a way that the desired space can only be fully tracked by one of the possible locations of the tag.

To test our model, we came up with a simple experiment to track a moving object going on a straight line, as shown in Figure 4:

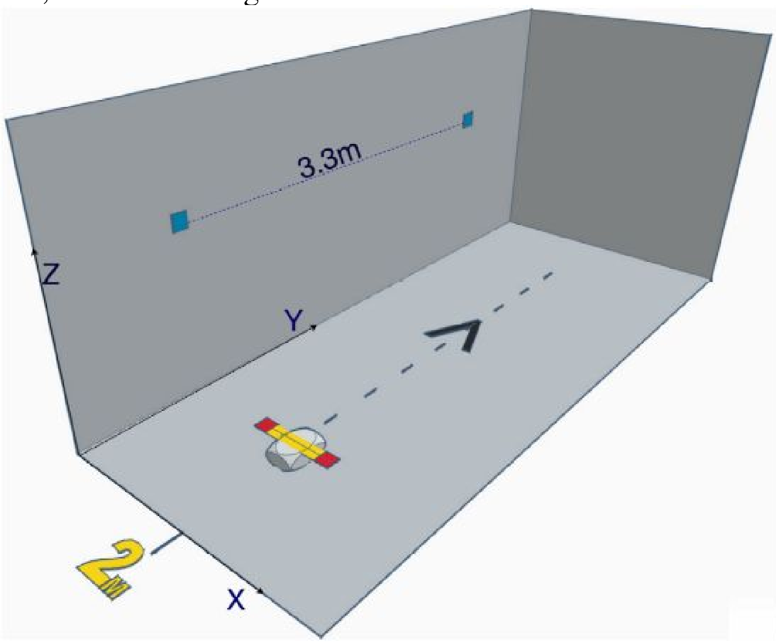

Figure 4. Representation of the Experiment

The idea was to use the wall as the Y axis based on the Figure 3 model, and to move a remote controlled vehicle in a straight line (keeping x=2 at the whole time), with two tags attached on it separated by 15cm from the center on different directions. The conversion from a 3D distance to a 2D distance was made using the Pythagorean theorem, where:

(1)3D Distance^2 = 2D distance^2 + Anchor Height^2

The purpose of using two tags is to measure accuracy in both of them, and try to get the center of the object accuracy even better by calculating the x's average from each tag.

The anchors and tags used are Decawave's DWM1001 Development Boards[Decawave], which, by fabric, comes with a full system ready to use if there are three anchors. So for our utilization, we needed the distances from each tag to each anchor, and this system was not able to deliver the results. So a Raspberry Pie was needed to retrieve the necessary distance data directly on each tag.

After collecting this data, we've made a script to solve the quadratic equations needed to get the x's and y's from the tags:

(2) (AnchorOneX – TagX)^2 + (AnchorOneY – TagY)^2 = 2D Distance(To Anc.1)

(3) (AnchorTwoX – TagX)^2 + (AnchorTwoY – TagY)^2 = 2D Distance(To Anc.2)

The solution of these equations are two values for TagX and two values for TagY, and here is the part that the positioning of the anchors are able to eliminate one of the (TagX,TagY) pair and leave the correct one.

Real results of the vehicle movement are shown below in Figure 5:

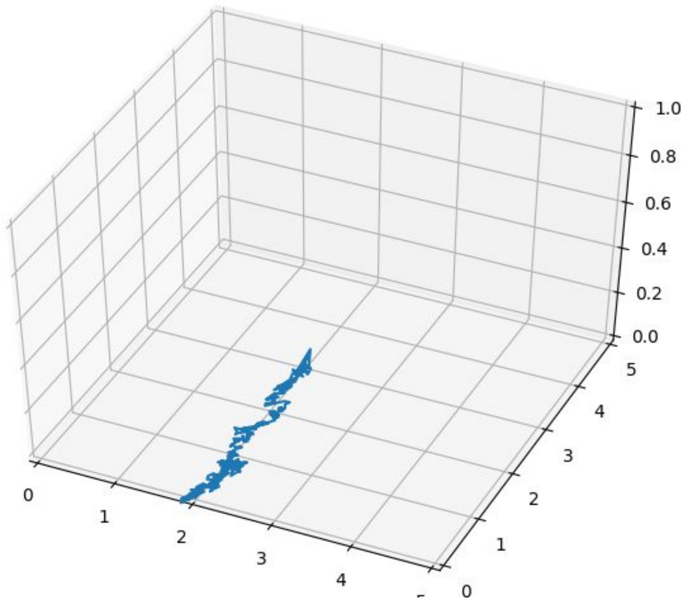

Figure 5. Real Experiment Results

The blue line in Figure 5, is the average X position for the two tags attached to the remote controlled vehicle. The disturbance in its form are justified from measurement errors, piloting mistakes and 3D conversions to 2D. Basically, we had no time to set up a precisely measured ambient because of devices availability.

Due to all difficulties we had an error margin fixed as 15cm, and measured accuracy as follows:

(4) Accuracy = Measurements inside Error margin / Total Measurements

In total, 550 measurements were made in a period of 55 seconds, which results in one update every 100ms. We came up with these results:

Tag One accuracy: 75,81% (between 1.70m and 2.05m)

Average Tag One X position: 1.94m

Tag Two accuracy: 86,90% (between 2m and 2.3m)

Average Tag Two X position: 2.14m

Average of Tag One and Two accuracy: 90,36% (between 1.85m and 2.15m)

Average of Tag One X and Tag Two X position: 2.04m

As mentioned before, the usage of two tags instead of one gave a better accuracy result for our remote vehicle, and the centimeter accuracy of UWB using only two anchors given these preliminary results is probably possible.

4. Conclusion and Future Work

We've designed a model that can perform localization using only two anchors, and preliminary results shows that it can be centimeter accurate, which is great for localizing objects inside building, where the GPS act quite poorly.

For future work, we want to simulate real world situations, such as: Tracking people walking inside Shopping Malls, cars changing lanes and even to enhance drone's space awareness. A future experiment with better controlled environment is also desired to prove accuracy and usability.

5. References

Bibliographic references must be unambiguous and uniform. We recommend giving the author names references in brackets, e.g. [Knuth 1984], [Boulic and Renault 1991]; or dates in parentheses, e.g. Knuth (1984), Smith and Jones (1999).

The references must be listed using 12 point font size, with 6 points of space before each reference. The first line of each reference should not be indented, while the subsequent should be indented by 0.5 cm.

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