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A High Resolution Ultra Wideband Positioning System

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***Abstract* – This paper presents an algorithm for target localisation in an open space using ultra wideband (UWB) radar. It discusses why localisation is needed and justifies the use of UWB radar in the positioning system. It also discusses the method used to localize the target as well as the problems encountered using said method. Experimental results on a simple open space target localisation are also presented in this paper.**

***Index Terms* – Positioning system, time of arrival, trilateration, ultra wideband.**

I. INTRODUCTION

Positioning systems are rapidly gaining popularity in our society. The ability to locate assets and people is invaluable in many applications such as location based services, assets management as well as safety and security. Many smart phone users are already using the Global Positioning System (GPS) functions of their phone as a navigation tool. Asset management in warehouses, intruder detection as well as equipment and personnel localisation in hospitals are some of the applications of positioning systems that address vast markets.

No doubt the potential applications for positioning systems are huge. However, the requirements for each of the applications may differ to a great extent. GPS usually offers location accuracy of several meters and is mainly used for outdoor positioning applications as its performance indoor is poor due to attenuation and multipath. Wireless Local Area Network (WLAN) is a candidate for indoor positioning however it has low accuracy and high power consumption. Visual based tracking has many advantages but its performance is limited in poor visibility conditions. In order to address the problems mentioned above, UWB radar is chosen as the technology of choice in developing the positioning system.
Section II describes the UWB waveforms as well as the bandwidth properties of UWB signals. Section III discusses the two step method used to find the position of the target, the method used when there are multiple targets as well as the problems that arise from using those methods. The results obtained so far will be shown in Section IV. Section V will conclude the paper and discuss the future work.

II. UWB

According to the Federal Communications Commision (FCC), a UWB signal is defined as any signal that has an absolute bandwidth of at least 500MHz or fractional bandwidth greater than 0.2 [1]. The absolute bandwidth is the difference between the upper and lower frequency of the -10dB emission point while fractional frequency is the absolute bandwidth divided by the center frequency.

The most valuable trait of UWB is of course the ability to achieve large bandwidth at low center frequency. One of the advantages of having a large bandwidth is the very fine time resolution, making it easier to resolve multipath components (MPC) [2]. Having a low center frequency allows penetration through various materials, allowing it to operate in dense multipath environments [3]. Furthermore, with its low power transmission, UWB is able to coexist with other wireless devices without causing much interference to them [4].

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III. TWO STEP POSITIONING

A two step approach is adopted in order to calculate the position of the target. In this method, the first step is to extract certain parameters from the received signal in order to estimate the position of the target. The second step will be to calculate the position of the target based on the parameters from the first step.

A. First Step – Distance estimation.

Some of the common parameters used to estimate the position is time of arrival (TOA), angle of arrival (AOA) and received strength signal (RSS) [5]. TOA is chosen as the parameter of choice in order to take full advantage of the fine time resolution of UWB signals. TOA can easily be converted to distance by multiplying the TOA with the speed of light and dividing it by 2 since it’s a two way TOA. In the signal received, each sampling point is approximately 61.04ps apart. To make it simpler, it is converted to distance before processing.

Before extracting the distance, the received signal is modified so that all the amplitude is on the positive side by multiplying the amplitudes on negative side with -1. Through a series of experiments; it is observed that the amplitude is approximately linearly proportional to the distance. Hence the signal is normalised by multiplying the distance with the amplitude at that distance. After the signal is normalised, the average is taken as the threshold in order to determine the distance of a target to achieve a dynamic threshold. The idea is with the presence of a moving target, the average will be increased above the noise level thus enabling us to determine the distance of the target. However, we need to make sure that the threshold is always above the noise level so that in situations where there are no targets detected, the noise will not be considered as valid targets. Figure 1(a) shows the original received signal and Figure 1(b) shows the signal after the modification.

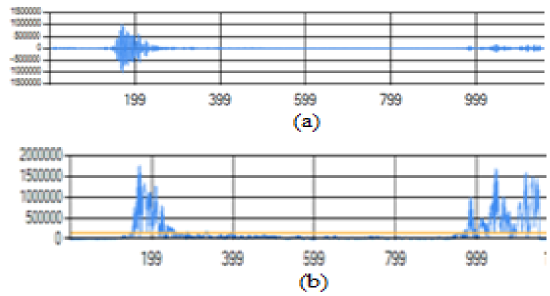

Fig.1. Original received signal (a) and modified received signal with the threshold (b).

In order to determine the distance of a target from the modified signal, the amplitude is checked from nearest to furthest points for amplitudes that are above the threshold. Once the amplitude is above the threshold, the amount of points with amplitude higher than the threshold is calculated. If the amplitude falls below the threshold for 40 continuous points, it is considered the end of one target and if there are at least 30 points before this that are higher than the threshold then it is considered a valid target. The values 40 and 30 are chosen after careful observation of a series of experiment done in order to keep false detection to a minimum. Figure 2 shows two valid targets are detected using the method mentioned. However, there are times when the two targets are too near each other that they are thought to be a single target as shown in Figure 3.

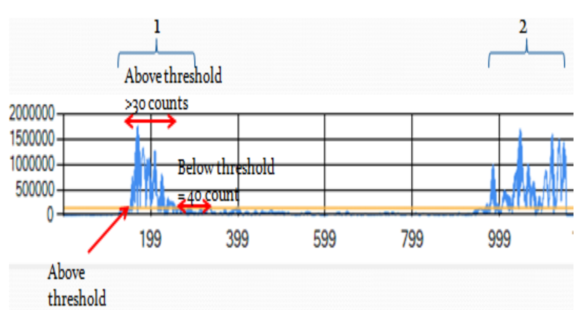

Fig.2. Conditions for valid targets.

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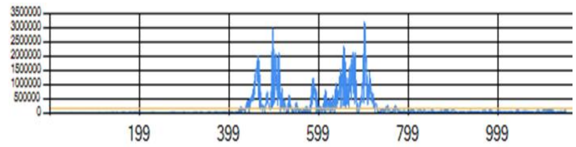

Fig.3. Two targets near each other and mistakenly identified as one target.

B. Second Step – Position calculation.

The second step is where the position of the target is determined based on the parameters obtained in the first step. There are a few methods to determine the position of the target such as geometric, statistical and location fingerprinting. Geometric approach calculates the position of the target based on estimated angles (triangulation) or distances (trilateration) using simple algebraic relationships [6]. Trilateration is chosen as the method of choice due to the simplicity in executing it.

The distance obtained from the first step is considered as a circle around the radar. Hence, with the intersection of at least three circles, it is possible to determine the position of the target. Let d1, d2 and d3 be the distances of each radar to the target which is obtained after the first step:

$$di = \sqrt{(xi - x)^2 + (yi - y)^2}, \quad i = 1, 2, 3 \quad (1)$$

where (xi,yi) is the known coordinate of the radars while (x,y) is the coordinate of the target. Solving equation (1) will yield:

$$x = \frac{(y2 - y1)\gamma 1 + (y2 - y3)\gamma 2}{2[(x2 - x3)(y2 - y1) + (x1 - x2)(y2 - y3)]} \quad (2)$$

$$y = \frac{(x2 - x1)\gamma 1 + (x2 - x3)\gamma 2}{2[(x2 - x1)(y2 - y3) + (x2 - x3)(y1 - y2)]} \quad (3)$$

where

$$\gamma 1 = x2^2 - x3^2 + y2^2 - y3^2 + d3^2 - d2^2 \quad (4)$$

$$\gamma 2 = x1^2 - x2^2 + y1^2 - y2^2 + d2^2 - d1^2 \quad (5)$$

However, this solution is only perfect if the distance obtained from the first step is without any error as shown in Figure 4(a). In the real world, there will always be error so the three circles will usually not intersect at one point. Instead there will be an area where the target is possibly in as shown in Figure 4(b).

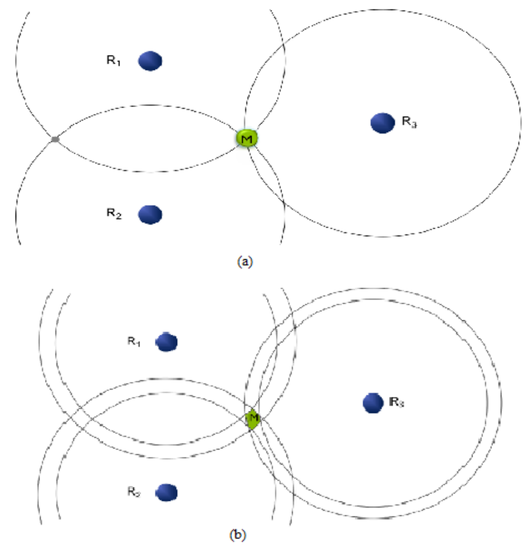

Fig.4. Intersection without error shown in (a) and intersection with error shown in (b).

C. Multiple targets.

When there are multiple targets detected within the area of interest, all possible target position is calculated using equation (2) and (3). For example, with two targets, there are eight possible positions for the targets. The distance from each position to the radar is then calculated.

$$ri = \sqrt{(x - xi)^2 + (y - yi)^2}, \quad i=1, 2, 3 \quad (6)$$

The difference between the distance, r_i, obtained from equation (6) and the distance used to calculate the position of the target, d_i, is the error of the possible position [7]. If the position calculated is the actual position of the target, then the error will be small as shown in Figure 5 where the two real targets have three intersections close to it. However, there are times

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when the targets are near each other and the other targets, known as ghost targets, end up having lower error than the real targets.

$$error = \Sigma(ri - di)^2, \quad i=1, 2, 3 \qquad (7)$$

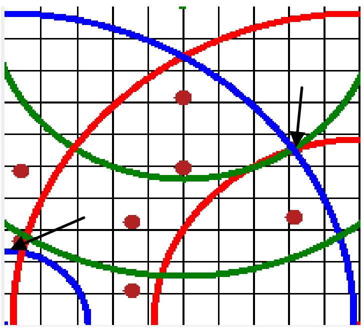

Fig.5. Possible targets when there are two actual targets.

IV. RESULTS

Table 1 shows the error from the distance estimated in the first step, tested up to 6m. The experiment is done by standing at 1-6m, with 1m increment, measured by using a measuring tape and taking the average at each distance detected by the radar over 10 readings. As can be seen the error is consistently below 10cm.

Table 1: Error from distance estimated in first step

Distance (m)	Error (m)
1.0	0.05
2.0	0.04
3.0	0.07
4.0	0.05
5.0	0.06
6.0	0.08

Table 2 shows the success rate of the second step, including the scenario where there are two targets. In the single target scenario, a human target walks around in an open space as shown in Figure 6(a) and the position is calculated for each frame, with the frame rate being 1 frame per second. The total number of frames to complete the path is 36 in both single and two target scenario. The target is considered successfully tracked if the calculated position is close to the actual position of the target. Losing the target or choosing the ghost targets instead of real target is considered a failure. The same is done for two targets and the walking path is shown in Figure 6(b). It can be seen that there is a 100% success rate for single target tracking but drops to 75% when there are two targets.

Table 2: Success rate of second step.

	1 target	2 target
Success	36	27
Fail	0	9
Success rate (%)	100	75

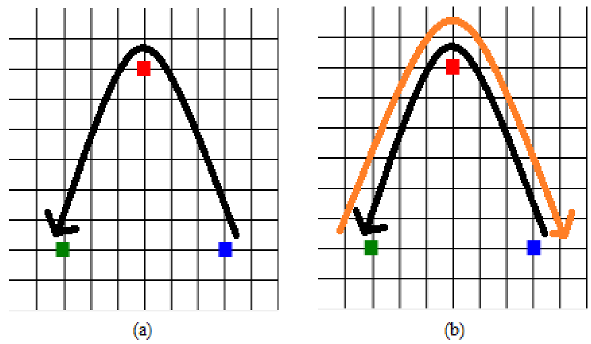

Fig.6. Path taken by single target (a) and 2 target (b)

V. CONCLUSION

Although the algorithm presented in this paper is able to do positioning with rather high success rate, there is still much work to be done. There is no problem tracking single target, however the success rate quickly drops when there are multiple targets. Furthermore, the current algorithm is tested in open space where interference is kept to the minimum. Future work includes improving the success rate when tracking multiple targets as well as tracking in a multipath environment.

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