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Real-Time Indoor Tracking

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Abstract – In this paper, a development of an autonomously navigating robot car, where the robot car would autonomously navigate towards a user-defined destination location, using a UWB based indoor localization system is described. For accurate 3-axis indoor localization, Pozyx indoor localization system was used, which uses Decawave DWM1000 chips for UWB communication. Time of Arrival distance calculation method, and Least Linear Square Algorithm were used for calculation of location co-ordinates of the Pozyx mobile tag, which was integrated with the robot car. A GUI was developed on Unreal Engine, to provide real-time visual representation of location of the robot car. The user was allowed to set destination co-ordinates using pick and place in the developed Unreal Engine GUI. The autonomous navigation robot was programmed, using an Arduino Uno microcontroller. Minimum accuracy for indoor static indoor localization achieved for the system for all the 3-axis was 90% in the 3D environment. Furthermore, a minimum accuracy for autonomous navigation towards destination co-ordinates achieved for the system in the x-axis and y-axis was 87%. A minimum navigation speed of 35cm/s was achieved by the robot car. For future works, autonomous navigation in 3-axis could be performed. Communication between the robot car and controlling PC could be performed using wireless methods, to improve range of operation of the robot.

Index Terms - Indoor tracking, Autonomous navigation, Indoor localization

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1. Introduction

Location awareness is becoming highly important in daily lives of humans (Rainer, 2012). From exact location of one's children, to the exact co-ordinates of an Unmanned Aerial Vehicle, these have become integral for smooth and efficient performance of highly important daily tasks. GPS has revolutionized outdoor localization, and has ensured the possibility of self-navigating outdoor vehicles. Indoor localization is much more complex due to the highly variable indoor environment layouts (Faird, Nordin & Ismail, 2013). Overcoming this complexity can lead to increased accuracy and efficiency in indoor localization.

2. Materials and Methods

Real-time indoor localization co-ordinates in the 3D axes of the Pozyx tag, was achieved at first. Once the localization co-ordinates had been acquired, these co-ordinates were then communicated to Unreal Engine, for visual representation of the Pozyx tag a virtual environment, as shown in Figure 1. This communication was achieved via COM Port 3.

Figure 1: Virtual environment (GUI) developed to display real-time location of robot car using Unreal Engine

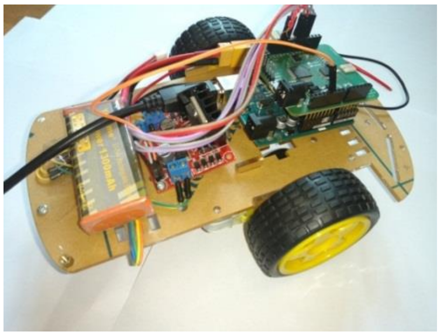

Figure 2: Robot car developed for autonomous navigation, with the help of indoor localization

Alongside achieving indoor localization co-ordinates, a 2-wheel drive robot car was developed, as shown in Figure 2, equipped with necessary components to allow it to turn, move in different directions, and adjust its speed etc., and to self-navigate to a desired destination, once integrated with the localization system. The indoor localization system and the 2-wheel robot car were then integrated using Arduino Uno as shown in Figure 3. Since the Pozyx localization system and the robot car both used Arduino Uno for their operations, integration with each other was achieved with minimal difficulty. The flowchart of Figure 4 highlights the overall operation for the whole project

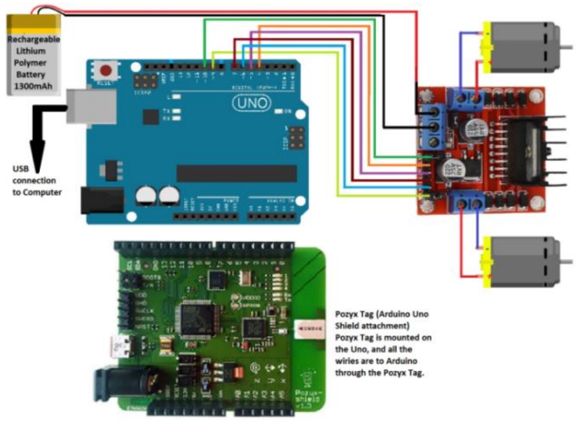

Figure 3: Wiring diagram for the developed robot car and localization system

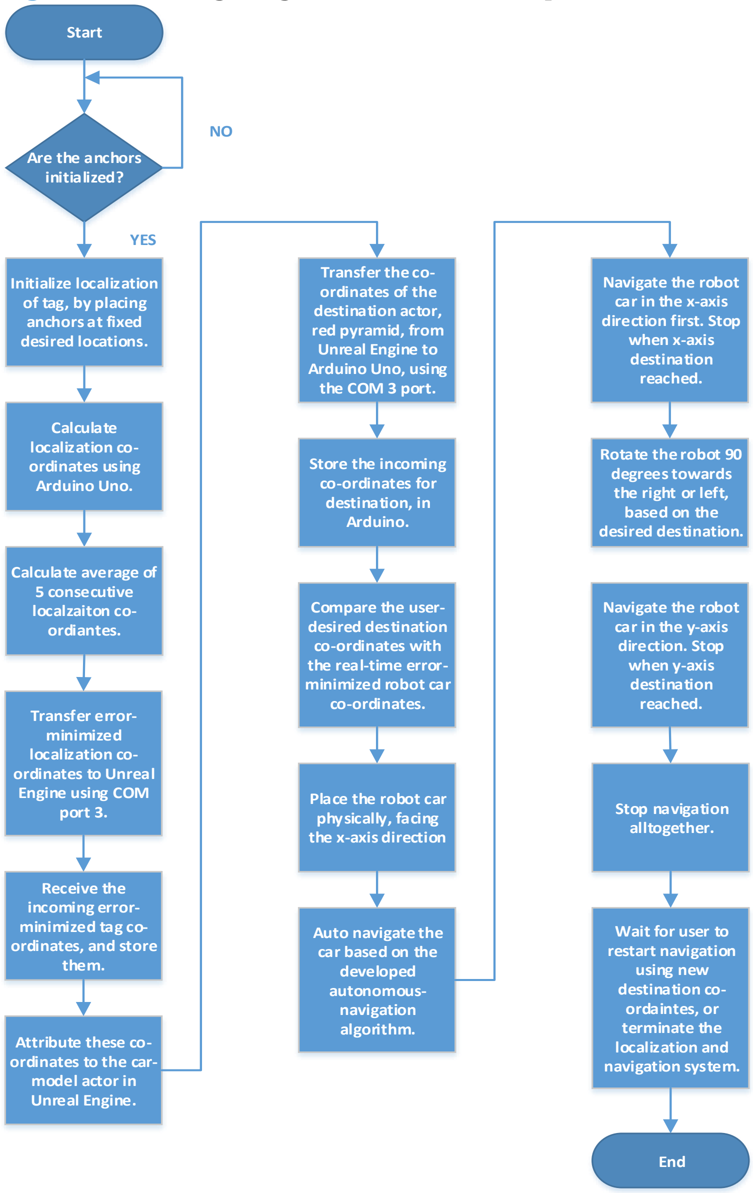

Figure 4: Overall operational sequence for the developed system

3. Results and Discussion

3.1 Accuracy Test for Pozyx Tag Using Arduino IDE

The indoor localization system was tested for several important parameters involved in localization using Arduino IDE and Unreal Engine; which includes visual representation of these localization co-ordinates using Unreal Engine, and autonomous navigation of the robot car using these localization co-ordinates in an indoor environment. For the initialization of the localization system, 4 Pozyx anchors were placed at fixed locations co-ordinates as shown in Figure 5.

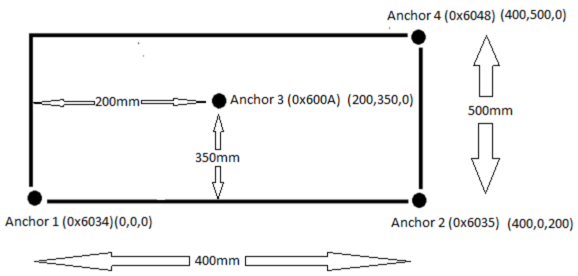

Figure 5: Experimental Setup 1

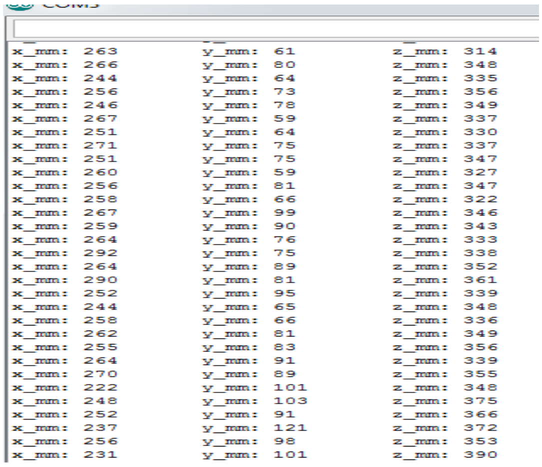

Figure 6: Trial 1 results using Arduino IDE

The test was performed with the Pozyx tag placed at 5 different locations, separately. The locations at which the tag was placed during the testing were (265, 80,350), (315,260,445), (160,280,500), (300,380,470), and (280,135,870). For each location, 25 values for the calculated localization co-ordinates, in millimetres, for the three different axes, namely x-axis, y-axis and z-axis, were collected by noting the values printed in the Serial Monitor, as shown in Figure 6.

The average percentage accuracy for each of the axis, indicate that the results obtained from localization system were satisfactorily accurate. Despite sporadic fluctuations in the obtained localization values, the average localization values were at least 94% accurate for the axis, at least 91.79% for the y-axis, and at least 97.42% for the z-axis, as shown in Table 1 and Figure 7.

Table 1: Results for accuracy test of localization system using Arduino IDE

	Average Percentage Accuracy (%)		
	X-axis	**Y-axis**	**Z-axis**
Trial No. 1	98.57	95.75	97.65
Trial No. 2	98.37	98.51	98.69
Trial No. 3	96.18	96.24	97.97
Trial No. 4	94	95.71	97.42
Trial No. 5	95	91.79	98.69

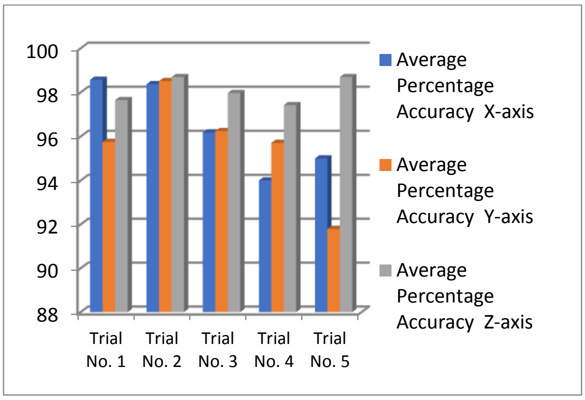

Figure 7: Accuracy results of localization system using Arduino IDE for 3-axis

3.2 Test for Accuracy of 3-axis Indoor Localization and Visual Representation of Localization Using Unreal Engine.

The test was performed with the Pozyx tag placed at 5 different locations, separately, with the Pozyx anchors placed at locations shown in Figure 8. The locations at which the tag was placed during the testing were (16,24,35), (10,16,53), (27,27,34), (23,38,54), and (23,27,39). For each location, 15 values for the calculated localization co-ordinates, in centimetres, for the three different axes, namely x-axis, y-axis and z-axis, were collected and tabulated. These calculated localization co-ordinate values were printed on the simulations screen of the Unreal Engine simulation program, as shown in Figure 9.

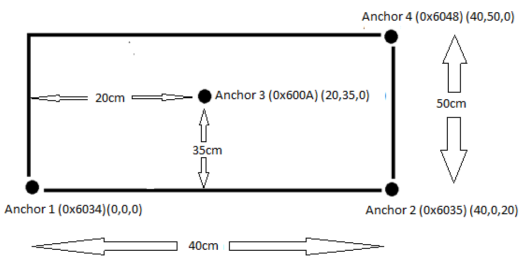

Figure 8: Experimental Setup 2

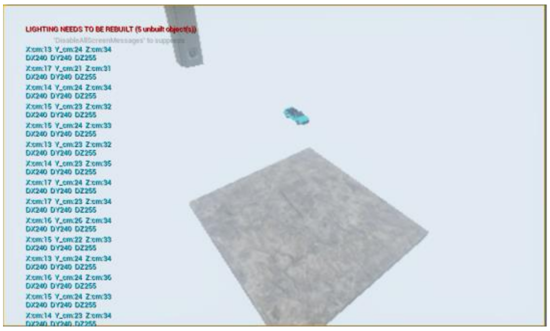

Figure 9: Trial 1 results using Unreal Engine

The percentage accuracy in each of the 5 trials, for each axis, is tabulated in Table 2. These values were graphed on a bar graph, to indicate the average localization accuracy obtained for each axis, for each of the 5 trials as shown in Figure 10. The average percentage accuracy for each of the axis, indicate that the results obtained from localization system were satisfactorily accurate. Despite sporadic fluctuations in the obtained localization values, the average localization values were at least 90.33% accurate for the axis, at least 91.85% for the y-axis, and at least 93.16% for the z-axis.

Table 2: Results for accuracy test of localization system using Unreal Engine

	Average Percentage Accuracy (%)		
	X-axis	**Y-axis**	**Z-axis**
Trial No. 1	93.33	97.78	95.81
Trial No. 2	90.67	92.08	94.84
Trial No. 3	93.58	94.32	97.97
Trial No. 4	95.36	95.96	96.79
Trial No. 5	97.68	91.85	93.16

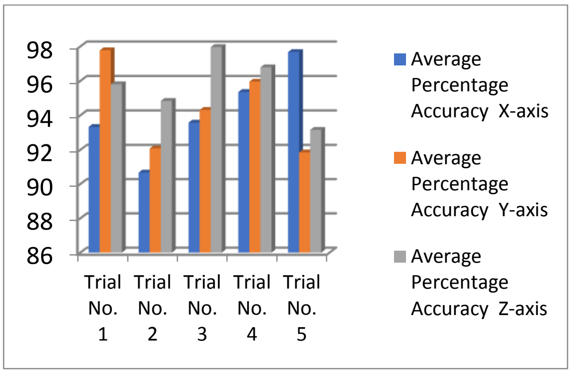

Figure 10: Accuracy results of localization system using Unreal Engine for 3-axis

3.3 Accuracy and Response Time of Robot Navigation Test

The test was performed with the robot car tasked with navigating to 5 different destination co-ordinates, separately, with the Pozyx anchors placed at locations shown in Figure 11. Since the robot car was only able to navigate on the x-axis and the y-axis, the test was only performed for the x-axis and the y-axis values, while neglecting the z-axis values. The desired destination co-ordinates during the testing were (150,150,0), (180,180,0), (200,200,0), (200,250,0), and (230,250,0). For each destination location, 10 trials were conducted, and the final destination coordinates reached, in the x-axis and the y-axis, were collected and tabulated. These final reached-destination co-ordinates were printed on the simulations screen of the Unreal Engine simulation program. Using the tabulated results for each axis, the average value for reached destination co-ordinates was calculated. The percentage accuracy for each of the 5 trials, for each axis is shown in Table 3. These values were graphed on a bar graph, shown in Figure 12 to indicate the average localization accuracy obtained for each axis, for each of the 5 trials.

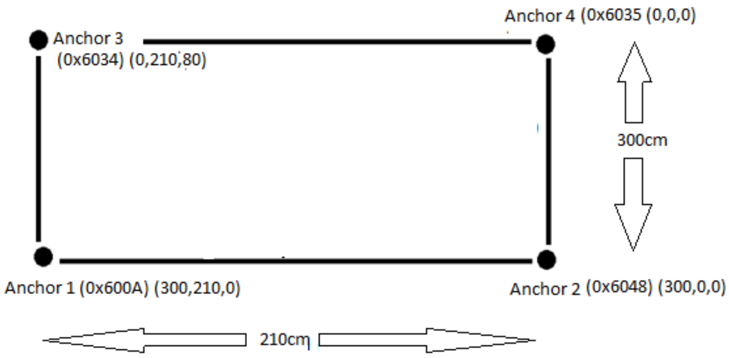

Figure 11: Experimental Setup 3

Table 3: Results for accuracy test of autonomous robot navigation in x-axis and y-axis

	Average Percentage Accuracy (%)		
	X-axis	**Y-axis**	**Z-axis**
Trial No. 1	98.07	96.20	0
Trial No. 2	94.56	92.28	0
Trial No. 3	95.80	87.10	0
Trial No. 4	87.20	97.24	0
Trial No. 5	95.48	97.64	0

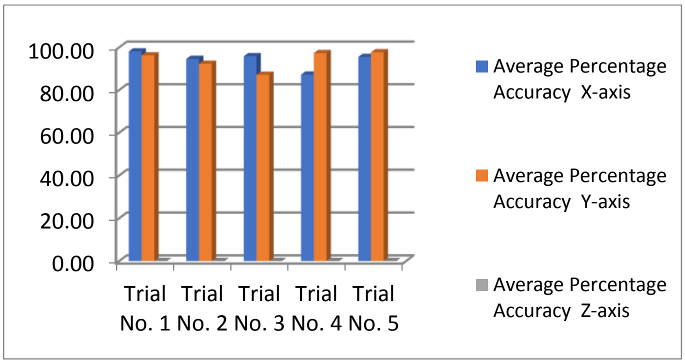

Figure 12: Accuracy results for autonomous robot navigation in x-axis and y-axis

The average time taken, in seconds, for the robot car to travel to the desired destination location, was obtained by calculating the average of time taken for all the 10 trials for each experiment. The average time taken was used to calculate the maximum and the minimum error in the values for the time taken. The average response time for the robot car was also calculated, and displayed in Figure 13, by dividing the total user-defined distance travelled by the time taken to reach the destination, as shown in Table 4, where the answer signified the average rate of travel, or the average speed of the robot in centimetres per second.

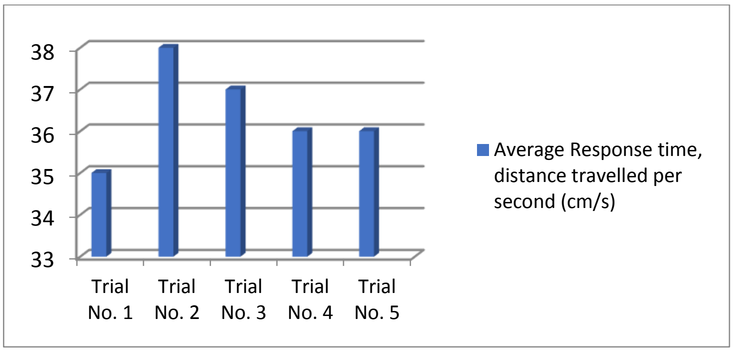

Figure 13: Average Response time results for autonomous robot navigation

Table 4: Results for response time of autonomous robot navigation

	Average Response time, distance travelled per second (cm/s)
Trial No. 1	35
Trial No. 2	38
Trial No. 3	37
Trial No. 4	36
Trial No. 5	36

The average percentage accuracy, shown in Figure 12, for each of the 2 axis indicates that the results obtained from robot navigation using the indoor localization system were satisfactorily accurate. Despite a deviation of the achieved destination from the desired destination location, the average achieved destination values were at least 87.20% accurate for the axis, at least 87.10% for the y-axis, as compared to the user-desired destination location co-ordinates

4. Conclusions

The effectiveness of the Decawave DWM1000 chip, for performing indoor localization in 3-axis, has been thoroughly tested, using the Pozyx tag. The results indicated an average static indoor localization accuracy of above 90%, in all the 3-axis of localization. Therefore, the use of Decawave DWM1000, which communicates using Ultra-wideband signals, in order to perform indoor localization has been proven to be highly effective and highly accurate.

The integration of a self-navigating robot, with the indoor localization system, in order to enable the robot to self-navigate in the indoor environment using the indoor localization system, was also successfully achieved. The robot car was developed and programmed for autonomous navigation. Thorough tests for the autonomous navigation of the robot car yielded a minimum of 87% accurate autonomous navigation results by the robot car with respect to its desired destination location. Thus, the autonomous robot car and the indoor localization system were effectively integrated.

The virtual room-like environment, created in Unreal Engine, allowed the user to select the desired destination co-ordinates by picking and placing a red-pyramid object, created in Unreal Engine. The location co-ordinates of the red-pyramid were then transferred to the Arduino Uno, through COM 3 port, and the robot car then auto-navigated to the user-desired destination. Throughout the autonomous navigation, the real-time location of the robot car was visually displayed in the Unreal Engine software.

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