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Underwater Obstacle Detection System Design using Sonar Sensor

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Abstract: In underwater field, Unmanned Underwater Vehicles (UUV) are created to help human do marine research and doing task underwater. A fully sensors robotic vehicle that is using high technology to bring new capabilities to work in the subsea environment. One of the problems facing by underwater vehicle is it need to be completely waterproof with the aid of technical skills for underwater usage and need to detect any incoming obstacle to avoid collision which might lead to hazard. Thus, this project focused on the design an underwater obstacle detection system using sonar sensor. The system need to be in small size to ease the mobility of the UUV when it performs tasks. Different distance and depth will be used to test and evaluate the distance detection since the distance also influenced by its relative depth. This project uses sonar sensor MB7078 XL-MaxSonar-WRC1 as distance detection to determine the distance between sensor and obstacle. In this project, the scope of the study focused on the interface between mechanical structure and electrical circuit design which need to be waterproof and have a detection range between 20cm to 60cm. The underwater obstacle detection system is going to undergo a series of experimental test at the end to evaluate its ability and performance underwater.

Index Terms: Detection system, sonar sensor, underwater obstacle, unmanned underwater vehicle.

I. INTRODUCTION

Vehicle (ROV) robot is very well stable with million upon millions of ROV is created and used widely the new age of world. The request for autonomous robot in robotic sector is increasing being widespread issue in many situations and place around the world. The operator and the vehicle communicate well is a main factor affecting whether a vehicle is created and design as a Remotely Operated Vehicle (ROV) or Autonomous Underwater Vehicle (AUV). For instance, in environments where communication with a vehicle is inhibited or not possible, autonomous control is then required as opposed to remote control. Due to various limitation of sensor applied in robot, especially in deep sea or riverine, the robot faced the challenge at a high level [1]. UUVs played an important role in underwater exploring deep underground and allows in exploring great depths while mapping the whole underwater ground. The demand from worldwide and a higher level of request for more advanced underwater robot technologies is eventually grow and leading the fully autonomous, technology, high efficiency, stable underwater vehicles. In this new generation, many research efforts had been done to increase the autonomy of the underwater vehicle while minimizing the need of technical manpower from robot operators [2]. Therefore, a development of autonomous underwater vehicle (AUV) is totally needed especially for Malaysia to follow up world underwater technology.

In Malaysia, autonomous underwater vehicles (AUVs) are still not widely studied and used. In term of technology, Malaysia is still far behind as compared to world technology due to some limitations like earth coordination, robotics knowledge, lack of high and efficient underwater technology. One historical example of underwater vehicles is the utilization from the Australian Country Navy which performed missions for searching the black box's signals for MH370 missing incident around the Southern Indian Ocean on March 2014 [3]. With help of AUVs from others, mission manage to be carried out. However, AUVs are very expensive for the components, has heavy body and very large in size because all components are placed inside the sealed body. The AUV investigation and navigation is not sufficient because underwater has low transparency and hard to observe the whole underwater life in detail [4]. Old case stated, the underwater vehicle has a database as navigation system to indicate the positions of all the obstacles respect to its body and can sense the incoming obstacles. Recent case stated, the new generation of underwater vehicle included sensors to estimate the positions and velocity of the incoming obstacles which shows the modes traditionally suggested are machine vision or sonar [5].

AUVs might be in high risk of hazard is underwater environment as obstacles could happen to be at anywhere. For exploration in deep sea purpose, AUVs might be collide with any possible object or wall far away from the station. AUV is very expensive and this asset can be spoiled if collision between obstacle happens especially for those sensitive components. Therefore, development of underwater obstacle detection system would be a good new feature on AUV to improve the safety issues of the AUVs [6]-[7] while increasing the performance of AUV for more tasks. For AUV which following the planned path in a mission or task, navigation system will guide it with 2 main modules which is navigator and local path planner [8]. A mission for exploring deep sea underwater will have very high cost where the underwater vehicles is very expensive [9]-[11].

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II. METHODOLOGY

This methodology paper is divided into 3 main parts which is hardware development, software development, experiment and analysis. In hardware part, material used, circuit on Arduino and assembly of system on AUV will be conducted. In the end, a prototyping of underwater obstacle detection system using sonar sensor will be produced. When dealing with a changing environment which is sensed on the fly, it is advisable to use a reactive path planning technique which does not need a complete description of the workspace between the current position and the goal [12]-[13]. The AUV project methodology flow chart of this project is shown in Fig. 1. Overview content are shown in the flowchart which include all steps and procedure taken. This chapter discussed the method used to design a complete underwater obstacle detection system using sonar sensor in term of hardware and software.

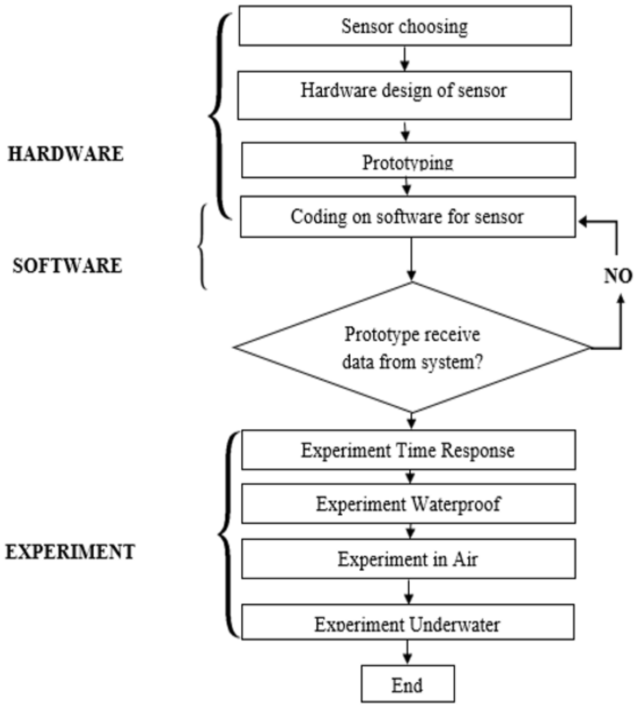

Fig. 1: Methodology flow chart

Fig. 2 shows the underwater obstacle detection system is equipped with power supply circuit include Arduino Uno, Waterproof ultrasonic sensor, 5V Energizer battery and LCD. Power supply provides 5V direct from battery to Arduino while sensor get power supply from Arduino. Ultrasonic sensor I to detect distance between AUV and obstacles under water. Then output from Arduino will direct to AUV thruster for further detection.

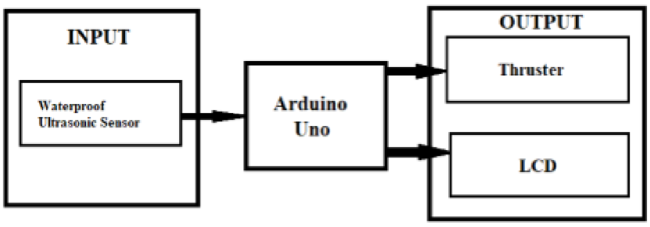

Fig. 2: Block diagram of the embedded system

A basic prototype of underwater obstacle detection system using sonar sensor had been developed as shown as Fig. 3 as a benchmark model in this project. The system model will be close tight and sealed waterproofing which has the parameters of height, H = 30cm; diameter, D = 10cm. All hardware including Arduino, electrical circuit, power supply will be placed inside the box while the sensor will go thru a hole of the box with a height of 15cm from the box's base.

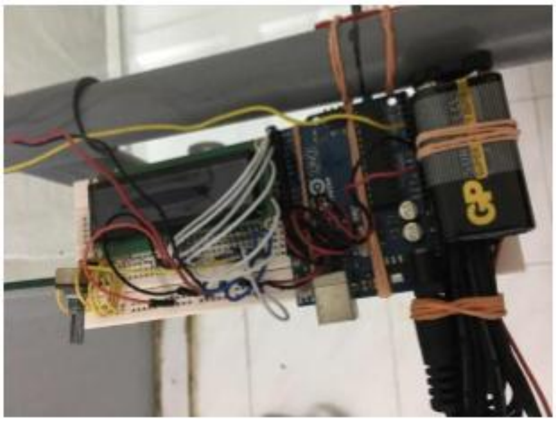

Fig. 3: Prototype of underwater obstacle detection system using sonar sensor

III. RESULTS AND DISCUSSION

Reaction time or response time states to the period for when we perceive something to when we respond to it. It is the capability to detect, process, and respond to an input and produce an output as result. Reaction time depends on various factors such as perception, processing, response. MB7078 XL-MaxSonar-WRC1 sensor is used to measure the distance to obstacles and transmit the data to controller for processing the signal data and do analysis. Command of "if… else if…" condition code into controller for sensor to response in a various of act. The measured distance output of sensor is observed so that is equal to desired distance input. Time taken for sensor to get desired distance measurement is recorded and tabulated in Table 1. Three times of test is conducted to get average result for more accurate. Based on the table, we can spot that response time for 28cm and 46cm measurement is shortest which is 1.33 seconds and 1.67 seconds while response time for 20 cm measurement has the longest time taken which is 3.67 seconds. The total average response time is 2.698 seconds. We can conclude that the response time for this sensor has reach the satisfaction of requirement.

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Table 1: Time taken for sensor to get desired distance measurement

Distance Input (cm)	Respond Time Test 1 (s)	Respond Time Test 2 (s)	Respond Time Test 3 (s)	Average Respond Time (s)
20	3	3	5	3. 67
22	2	4	4	3
24	4	2	2	2.67
26	1	4	3	2. 67
28	3	1	1	1. 67
30	2	2	2	2
32	3	3	4	3.33
34	4	4	2	3.33
36	1	2	3	2
38	3	3	2	2.67
40	2	1	4	2.33
42	4	3	3	3.33
44	3	4	1	2. 67
46	1	2	1	1.33
48	2	1	4	2.33
50	5	3	1	3
52	4	1	3	2. 67
54	3	3	4	3.33
56	2	2	2	2
58	4	4	4	4
60	3	2	3	2. 67
			Total Average:	2.698

Based on data in Table 1, it shows the response time for each measurement is consistent. The best response time is 2.698 seconds for AUV to measure distance of incoming obstacles. As a result, the sensor is stable to use for application in real life usage. Based on the observation recorded, the system is totally waterproof under testing inside 1meter depth tank. The PVC structure of sensor enable easy waterproofing process by sealing the white tape around it and connect to another PVC component. Even though, there is no leakage of water into the system, a layer of silicon at wiring circuit still needed for enhancing waterproofing and extra protection. This is to protect the electronic components spoil at water leakage. For depth manipulated variable also shows that the sensor can works well under water of different level from 0.1m to 1.0m. Fig. 4 shows interior of sensor circuit connected.

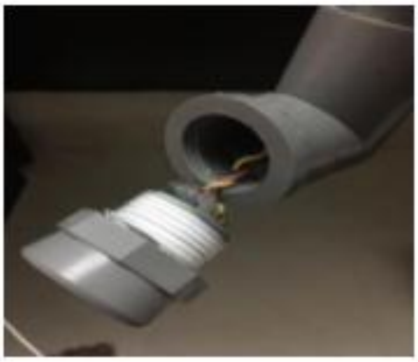

Fig. 4: The interior of sensor

The ultrasonic sensor of the underwater obstacle detection system is tested in air of 0.6 m height x 0.3 m width aquarium. The sensor is placed at a distance away from end of aquarium which act as front obstacle. Then the actual distance between sensor and obstacles is measured using a ruler and recorded. The initial distance input is 20 cm and increasing 2cm respectively until maximum which is 60 cm. The reading of sensor is taken 3 times and average if calculated to get more accurate result. The percentage of error for each distance is calculated to analyses the accuracy of ultrasonic sensor. Fig. 5 shows the desired distance input and average measured distance output from sensor output signal

From Fig. 5, there will be errors for every measured distance output respect to desired distance input due to systemic error such as environmental factor and interruption. The reading of measured distance output is taken 3 times to calculate average measured distance output. The accuracy of sensor is high because the percentage errors calculated are all below 10%. Such errors are hard to avoid since the sensor are sensitive to surrounding which might affect the output by producing noise in term of density, others sound wave and occupancy. Water contains are hard to control where chemical substances will easily dissolve into water such as chlorine. The performance of the MB7078 XLMaxSonar-WRC1 sensor is sufficiently good in terms of accuracy and consistency. This analysis shows that it can measure the distance value precisely in air for a range of 20 cm till 60 cm. This range theoretical suit a small scale moving AUV to detect and avoid obstacles. Since the measured distance output value from the experiment is roughly near to the actual desired distance input value, this underwater obstacle detection system can be applied to determine the distance between AUV and incoming obstacles. Fig. 5 shows a graph of signal voltage against distance between sensor and obstacle.

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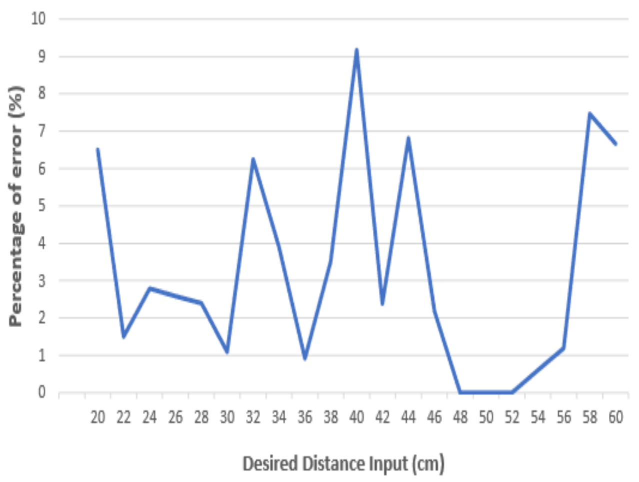

Fig. 5: Graph of signal voltage against distance between sensor and obstacle

In Fig. 5, the measured distance output value voltage of the ultrasonic sensor is increasing as the sensor is moving away from the end of aquarium (obstacles). The accuracy calculated from data recorded shows that the sensor has perform a good performance for distance measuring. The highest accuracy recorded is at distance from 48cm to 52cm for sensor to sense obstacle. 50cm is the ideal distance for an AUV to change or turn it direction to avoid crashing. The lowest accuracy of distance measured is 20 cm distance. As a conclusion MB7078 XL-MaxSonar-WRC1 sensor shows a good presentation to measure the distance value in air with a little percentage error. In addition, it also can be used as an underwater obstacle detection system for underwater vehicle in distance control submission since it has a widespread range of dimensions.

The ultrasonic sensor of the underwater obstacle detection system is tested underwater of 0.6 m height x 0.3 m width aquarium. The sensor is placed at a distance away from end of aquarium which act as front obstacle. Sound wave in water and sound wave in air, they hit differently because of the physical properties differences between air and water. The intensity of the wave does not only depend on the pressure of the sound wave but it also effected by density and sound speed of the medium which thru the sound travel. The actual distance between sensor and obstacles is measured using a ruler and recorded. The initial distance input is 20 cm and increasing 2 cm respectively until maximum which is 60 cm. The reading of sensor is taken 3 times and average if calculated to get more accurate result. Fig. 6 shows the desired distance input and average measured distance output from sensor output signal.

From Fig. 6, there will be errors for every measured distance output respect to desired distance input due to systemic error such as environmental factor and interruption. The reading of measured distance output is taken 3 times to calculate average measured distance output. The accuracy of sensor is high because the percentage errors calculated are all below 10%. Such errors are hard to avoid since the sensor are sensitive to surrounding which might affect the output by producing noise in term of density, others sound wave and occupancy. Water contains are hard to control where different water source dissolved different composition of chemical substances. The performance of the MB7078 XL-MaxSonar-WRC1 sensor is sufficiently good in terms of accuracy and consistency. This analysis shows that it can measure the distance value precisely in air for a range of 20 cm till 60 cm. This range theoretical suit a small scale moving AUV to detect and avoid obstacles. Since the measured distance output value from the experiment is roughly near to the actual desired distance input value, this underwater obstacle detection system can be applied to determine the distance between AUV and incoming obstacles. Graph of signal voltage against distance between sensor and obstacle is shown in Fig. 6.

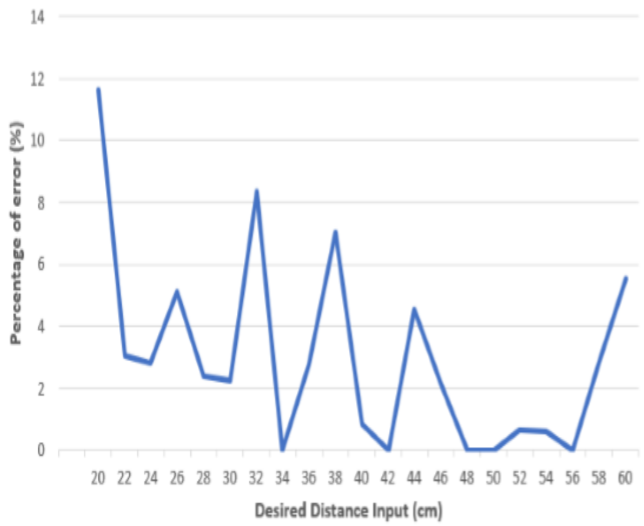

Fig. 6: Graph of signal voltage against distance between sensor and obstacle

In Fig. 6, the measured distance output value voltage of the ultrasonic sensor is increasing as the sensor is moving away from the end of aquarium (obstacles). The accuracy calculated from data recorded shows that the sensor has perform a good performance for distance measuring. The highest accuracy recorded is at distance of 30cm from sensor to obstacle. 30cm is the ideal distance for an AUV to change or turn it direction to avoid crashing. The lowest accuracy of distance measured is 20 cm distance. In conclusion MB7078 XL-MaxSonar-WRC1 sensor shows a good presentation to measure the distance value in air with a little percentage error. In addition, it also can be used as an underwater obstacle detection sensor for underwater vehicle in distance control submission since it has a widespread range of dimensions.

IV. CONCLUSION

In conclusion, the underwater obstacle detection system using sonar sensor can work well underwater with a minimum range of 20 cm and maximum range of 60 cm. The condition of medium must be a clean pool water without any water flow rate. The accuracy of the system is 1cm distance measurement with a depth rating of 1 meter under water surface. The maximum duration for the AUV activity in underwater is 1 hour per cycle. This underwater obstacle detection system using sonar sensor can maneuver around unanticipated obstacles that may be proud of the ocean floor. This ability can prevent serious damage to the vehicle or the environment.

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