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Efficient Maneuvering and Control Designing of Unmanned Underwater Vehicle (UUV)

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Abstract: The autonomous underwater vehicles become progressively important with the advances in underwater robotics technology. Nowadays, AUV (Autonomous Underwater Vehicle) can be used in many fields including geographical research, search, rescue and defence system. This paper reports a successful project of path planning control system for Underwater mobile robot vehicles based on Arduino that modified the others navigational approaches for underwater robot vehicles. Efficient and optimal path planning control system is crucial for underwater mobile robot and autonomous underwater vehicle operations. In this paper, we develop and demonstrate an efficient underwater path planning control system with the android application and surveillance function for the Underwater Mobile Robot based on the Arduino Mega 2560 R3. For this research, the cost will be optimum and using an easy to obtain parts. Specifically, the goal of this study is to compute the paths of underwater robot vehicles by using an Arduino which can travel by itself without direct control from the operator.

Keywords: AUV, Path Planning, Maneuvering , Autonomous Underwater Vehicles

1. INTRODUCTION

The 71% of earth's surface is secured with water which makes it a critical site for logical research and examination (Schneider et al.,2011). Currently, due the way that the sea draws in awesome thoughtfulness regarding the issues of natural assurance and vitality creation, the request in the utilization of submerged robotic systems for solving various issues of investigating the sea basically increments (Evgeny . *et al.,* 2016) (Ali *et al.,* 2016). Submerged examination these days is normally done by either proficient jumpers or unmanned underwater vehicles (UUV). However, human diver's can't get to dangerous or profound submerged districts. Therefore, this is the reason UUV are utilized as a part of those cases.

Unmanned underwater vehicles (UUV) are isolated into two gatherings of vehicles, the remotely operated vehicles (ROV) and the self-ruling (autonomous) underwater vehicles (AUV) (El-Hawary *et al.,* 2001) (Ali *et al.,* 2018). ROV is furnished with power links and correspondence links while on the other hand, AUV doesn't utilize any links to associate with the vehicles and have no restriction of movement range, and consequently free to move. Some tasks are overly complex that the maneuverability becomes very complicated. However, be that as it may, these issues can be overcome by utilizing an AUV which is unpiloted and is self-sufficiently controlled. From this point of view, the examination on AUV will be promising (Watanabe *et al.,* 2015) (Rashidah *et al.,* 2016). Contrasted with ROV which is controlled through the contribution of an administrator ordinarily from a mother vessel over the water's surface, AUV that works autonomously with no client input. Nevertheless, harder to control (Ahmed *et al.,* 2018).

Controlling submerged vehicles and robots to empower them to perform valuable capacities in the profound sea represents a troublesome issue that has challenged specialists for a long time. Lead by the underlying work of (Yoerger *et al.,* 1985) (Ali *et al.,* 2017), the utilization of sliding-mode control techniques to submerged vehicles became an active area of interest (Frank *et al.,* 1988) (Jamie *et al.,* 1992) (Anthony *et al.,* 1993). The inspiration for utilizing the sliding-mode approach is to empower strong control of the questionable nonlinear vehicle framework. Other research concentrated on utilizing adaptive or neural-network control to manage instability in the plant model (Roberto *et al.,* 1990) (Kevin *et al.,* 1990) (Yuh *et al.,* 1990) (Dana *et al.,* 1991).

Profundity (depth) control of submerged vehicles is another critical issue in submerged robotic systems. Without profundity control, the full workspace of submerged vehicles can't be utilized. Until recently, specialists have seen profundity control as an issue

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related to substantially submerged vehicles, for example, submarines or Autonomous Underwater Vehicles (AUV) (Shawn *et al.,* 2012).

Unlike the references displayed here, the concentration of this report is not on expanding power or adjusting to existing vulnerability, but instead on enhancing framework execution by misusing point by point learning of the framework elements. The approach taken here includes expanding the current vehicle feedback control with data in light of a basic physical comprehension of the controller hydrodynamics, in a way that advantages the control of the whole framework. To accomplish great outcomes, this approach requires an exact model of the controller hydrodynamics. In this report, the coordinated-control approach is portrayed, and exploratory approval is given.

2. BACKGROUND

The project components are appropriate for an entire coordination in a UMR that insignificant change would not influence any of the outcomes. Furthermore, this project has made the UMR a user-friendly project. This project will have the characteristics such as simple to deal with, simple to keep up, low cost, safe and can be utilized whenever. For instance, this project has an integrated program which will enable the user to just change the path of the underwater mobile robot by using the application from android. For this project, the development of thrusters which will react to the direction and path of the UMR can be overseen in the source code from the Arduino. Certain input which is the target location will be set and burned into the microcontroller (Arduino). In spite of the fact that the target location initially set in the source code, the target location still can be changed by the user by utilizing cell phone or other gadgets since this UMR project is built with the Bluetooth technology and compatible with all Android gadgets. This input is then converted into the development of thrusters. Thus, the path of the UMR is accomplished. As the possibility of other significant parts or components will be incorporated together with this UMR project, this project is constructed with the components were as little as possible to make the UMR have a lightweight and fit for handling large loads.

From the **(Fig. 1),** this project starts when the power supply is turned on. In this project, 12VDC supply source is used to power up the thruster, transmitter and also the camera while the 9VDC is used as a supply source for the microcontroller (Arduino). After that, the camera will turn on before let the underwater mobile robot moves underwater. As the camera on, the video can be monitored through an LCD HD monitor on the ground station. Then, the point target location will be set inside the Arduino by using any device that has the Android and Bluetooth technology by using the Underwater_Mobile_Robot App. However, the Underwater_Mobile_Robot App not available in Google Store since it is designed only for this project. After setting the point target location, the Arduino will read the data and send the signal to the motor driver in order to control the speed and direction of the thrusters. The IMU sensor then will send the current point location to the microcontroller to compare the current location with the target point location. If no, the process will repeat until the underwater mobile robot reaches the target location. If yes, the process of this project was complete, and the flow is ending as shown below in **(Fig. 1** and **Fig. 2)**.

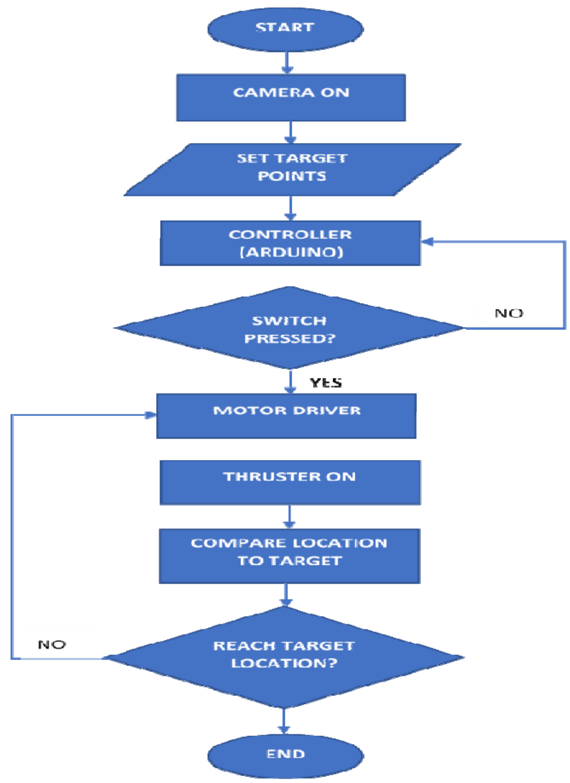

Fig. 1. Flowchart of the project

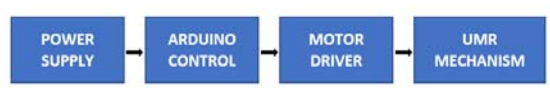

Fig. 2. Block diagram of the project

3. MATERIALS AND METHODS

3.1 Angle and Distance Measurement

To measure the initial heading, θ_0, it is important to know the initial position or starting point, P_{START} and also the end position or next point, P_{END} of the underwater mobile robot. Assume the initial position or starting point and the ending position or next point are given as equation 1:

$$P_{START} = (X_0, Y_0) \quad (1)$$
$$P_{END} = (X_1, Y_1)$$

Then, the relative distance can be measured by using equation 2.

$$dX = X_1 - X_0 \quad (2)$$
$$dY = Y_1 - Y_0$$

By using that equation above, the absolute heading $\theta_{0\rightarrow 1}$ can be found with the arctangent of dX and dY. However, the basic $atan$ function doesn't handle negative signs correctly because it can't tell if which or both of dX and dY were negative. So, $atan2$ the function will be used.

3.2 Depth Measurement

A pressure sensor may be used to calculate the level of a fluid. This technique is commonly employed to measure the depth of a submerged body (such as a diver or submarine), or level of contents in a tank (such as in a water tower). In order to make the underwater mobile robot maintain at a specific depth, pressure sensor also will be used. Pressure is an expression of the force required to stop a fluid from expanding and is usually stated in terms of force per unit area. For most practical purposes, fluid level is directly proportional to pressure. In the case of fresh water where the contents are under atmospheric pressure, 1psi = 27.7 inH20, 1Pa = 9.81 mmH20, 1bar = 10197.16 mmH20. Equation 3 is the basic equation for such a measurement.

$$P = \rho g h \quad (3)$$

Where:

P = pressure
ρ = density of fluid
g = standard gravity
h = height of fluid above pressure sensor

4. RESULTS

(Fig. 3 and **Fig. 4)** are the sample result of Underwater_Mobile_Robot App which was created in App Inventor software. The function of all button in the app as described in **(Table-1)**.

Fig. 3. Underwater_Mobile_Robot App Icon

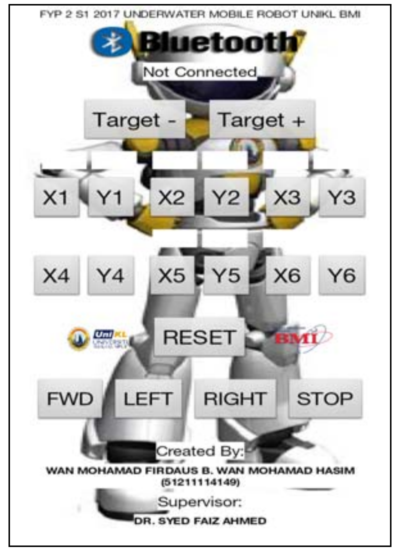

Fig 4. Underwater_Mobile_Robot App Screen

Table- 1: Underwater_Mobile_Robot App Function

Button	Function
Bluetoot h	To select the Bluetooth devices which are the HC-05 Bluetooth module and make the connection. "Connected" word will appear on the app screen if the connection between the Android device and UMR is successful.
Target +	To increase the point (eg: -1, 0, 1, 2, etc.).
Target -	To decrease the point (eg: 1, 0, -1, -2, etc.).
X1 – X6	To set the required target point into the x-axis which can be set in six(6) x-axis points from X1 up to X6. After touching the button, the target point will be shown above the button so that operator knows the point that had been set and this point can be replaced by retouch the button with new target point.
Y1 – Y6	To set the required target point into the y-axis which can be set in six(6) y-axis points from Y1 up to Y6. After touching the button, the target point will be shown above the button so that operator knows the point that had been set and this point can be replaced by retouch the button with new target point.
RESET	To reset all the target value and start a new operation.
FWD	To test the UMR to run forward.
LEFT	To test the UMR to turn left.
RIGHT	To test the UMR to turn right.
STOP	To stop the UMR after running the test.

4.1 Surveillance Function

(Fig. 5) shows the surveillance function of the Underwater Mobile Robot while the Underwater Mobile Robot in open air area and the **(Fig. 6)** show the surveillance function of the Underwater Mobile Robot while the Underwater Mobile Robot submerged in water. The result for the surveillance function in open air condition was very good and perfect since there was very minimum noise and disturbance to the signal of transmitter and receiver. However, the result for the surveillance function underwater condition was not so perfect as in the open air condition but it was still successfully done and acceptable results. This happens by the caused of some noise or disturbance occurs when the Underwater Mobile Robot dives deeper underwater due to the limitation of the transmitter and receiver signal. The surveillance function was done by using CMOS Camera Module HD, 5.8GHz Transmitter and Receiver and TFT LCD HD Monitor as shown in hardware description.

4.2 Underwater Mobile Robot Structure

(Fig.7) showing the final structure of the Underwater Mobile Robot. The structure was constructed by referring to the design that has been design earlier by using the Solidworks software. Total weight of the Underwater Mobile Robot structure is about 5kg and about 11kg with all the component and accessories. The structure very stable on water as can be seen in (**Fig.8)** due to wide and low structure design.

Fig. 5. Surveillance in open air

Fig. 6. Surveillance underwater

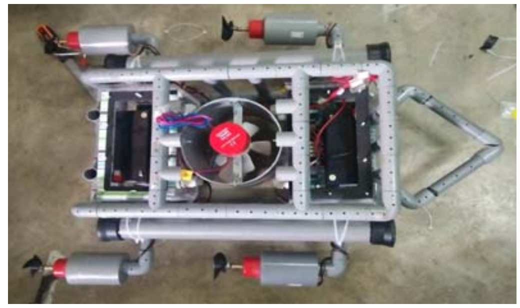

Fig. 7. Structure of UMR

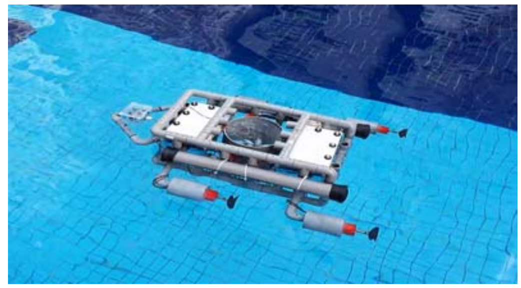

Fig. 8. Structure of UMR on the water surface

4.3 Path Planning Control System of UMR

(Fig.9) shows the target locations were set by the operator in the Underwater_Mobile_Robot App by using a smartphone as described in Table II which the initial position is (0, 0) and the next position is (1, 0), (1, 2) and (2, 3).

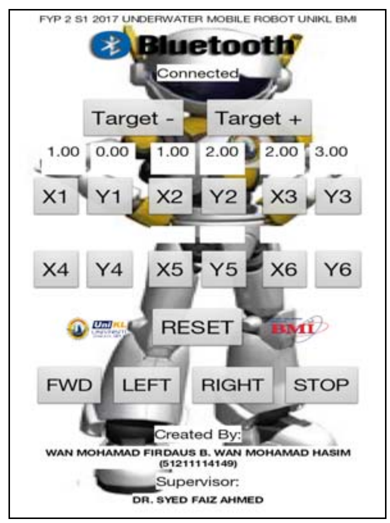

Fig. 9. Set the target location in Underwater_Mobile_Robot App

Fig. 10. The initial position of UMR

As shown in **(Fig.10)**, UMR will stay still with the position (0, 0) until the switch button on the UMR is press.

Fig. 11. UMR begin to operate

When the switch is press by the operator, the UMR will start to operate as shown in **(Fig.11)** to reach the first target location which is (1, 0).

Fig. 12. UMR reach the first target location

When the UMR reach the first target location set by the user which is (1, 0), it will read the next point location (1, 2) as shown in **(Fig.12)**.

Fig. 13. 90-degree turn

After the UMR reach the first target location, it continues to read next point location (1, 2) which make the UMR turn 90 degrees to the left and move straight for distance 2 meters as shown in **(Fig.13)**.

Fig. 14. UMR reach the second target location

As the operator set three (3) target location, UMR will read the third and final location after reach the second location. For the final location (2, 3), UMR turns to the right 45 degrees and go straight as shown in **(Fig.14)** until reaching the destination as shown in **(Fig.15)**.

Fig. 15. UMR reach destination

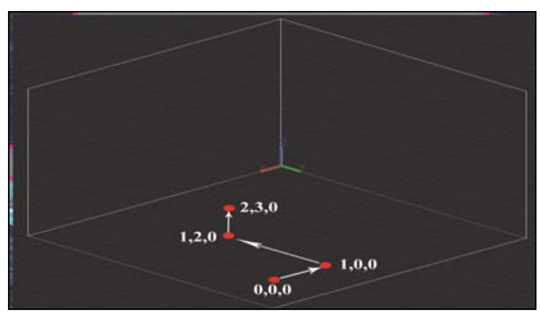

Fig. 16: Path Planning of UMR

By referring the **Fig.10** until **Fig.15**, it can be seen that the UMR successful operate as the path that has been a plan by the operator as shown in **(Fig.16)**and **(Table-2)**.

Table-2: Path Planning Control System

Point Location (x,y)	Angle Turn (°)	Distance (Meter)
0,0	-	-
1,0	0	1
1,2	90	2
2,3	45	1.414

5. CONCLUSION

Underwater Mobile Robot (UMR) is an example of the evolution of humanity into a better understanding of the vast sea. The interest of having a low-cost underwater vehicle can complement the fleet for carrying out scientific surveys. The collection of underwater information and accurate environment data from this underwater vehicle project will extremely useful. The possibility of applying this vehicle for massive underwater research is an interesting option when very advanced AUV features are not required.

The fact of having a vehicle based on commercial, not expensive modules increases the feasibility of conducting long-term surveys. The possibility of having a fleet of vehicles with the equivalent cost of only one commercial standard vehicle allows the possibility of operating in multi vehicular collaborative configurations. Although the capabilities and features of the project are obviously lower in some aspects than other commercial AUVs, the fact of its low cost provides an additional and important advantage when no extreme conditions of operation or high complexity of the mission are required. The fact of using open source hardware and software provides an excellent test-bed platform able to be expanded with future developments.

The research findings will be very useful for the AUV team to make a certain judgment on reliability and performances of the system. The results and overall performance of the UMR can prove that the project has achieved all the objectives and became the successful project. Finally, this UMR vehicle will be an excellent demonstrative equipment available for academic purposes and as a testbed for future student projects in electronic engineering, electrical engineering, and other related areas.

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