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System Identification of a Prototype Small Scale ROV for Depth Control

Mohd Shahrieel Mohd Aras, Fadilah Abdul Azis, Lim Wee Teck
Underwater Technology Research Group (UTeRG), Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka Malaysia.
shahrieel@utem.edu.my, fadilah@utem.edu.my, limwt@utem.edu.my

Shahrum Shah Abdullah
Department of Electronic System Engineering, Malaysia-Japan International Institute of Technology, Universiti Teknologi Malaysia KL Campus, Jalan Sultan Yahya Petra, 54100 Kuala Lumpur, Malaysia.
shahrum@fke.utm.my

Ahmad Fadzli Nizam Abdul Rahman
Faculty of Information and Computer Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka Malaysia.
fadzli@utem.edu.my

***Abstract*—This paper present the design and development of a small scale underwater Remotely Operated Vehicle (ROV) and modelling the depth response of this ROV using System Identification Toolbox. The design of a small scale ROV has been done to minimize the hydrodynamic force and increase energy efficiency compared to the previous model that was developed by Underwater Technology Research Group (UTeRG). The performance of the designed ROV will be tested in UTeRG laboratory (lab tank test). The output signal from the pressure sensor (MPX4250GP) and the Inertial Measurement Unit (IMU) sensor are interpreted via an NI-card which was used for the data transfer. The prototype ROV was compared with the previous version in terms of depth control performance. System identification toolbox in MATLAB was used to infer a model from open-loop experiments. Then the obtained model was used to design a controller for the ROV. The focus of the controller design will be to ensure that the ROV is stable and can maintain position at a certain depth in a real underwater environment. After all the experiment has been conducted, the ROV managed to operate in a certain depth underwater using the controller designed successfully.**

Keywords—Depth control; Unmanned Underwater Remotely Operated Vehicle; System Identification Toolbox.

I. INTRODUCTION

Remotely Operated Vehicle (ROV) is widely applied across many industries in today's world. This kind of Underwater Vehicle (UV) is easily operated by a single driver or operator. Moreover, this UV can save human life compared to conventional method that needs humans to dive to conduct a research, make observations or do an underwater task [1]. Human body can withstand to dive up to 30m depth before toxic reaction starts to react inside the body. However, ROV can go deeper than 30m without endangering its driver so that more underwater locations can be explored. The problem with the current working class ROV is that they are expensive, since they cost more than RM 200,000. For study and research purposes, a small scale ROV with lower cost is needed. The small scale ROV should have its behavior similar to the work class ROV. Furthermore, this prototype ROV should have automatic depth control similar to the ROV that is used for underwater pipelines surveillance. Essential too is to have a camera placed on board to provide live feed as a guide for the ROV operator. A prototype for this ROV is already done by the previous UTeRG team who has managed to design the ROV from scratch. The UTeRG team was able to complete the design and tested the prototype, where the ROV had been named "UTeRG-ROV 1" [2 - 5]. However, from MATLAB simulation, many improvements can be made such as increasing its moving speed and stability during operation. This improvement would help to make the ROV to be more reasonably priced than commercial ROV which are very expensive. An estimate of the total project cost is roughly about RM 15,000 which is small compared to buying a commercial one which cost more than RM 200,000.

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System Identification technique is one of the methods that can be used to infer a model of the prototype ROV [4 -6]. UTeRG SMART ROV 1 is the earlier model of the ROV that has been built and modelled using system identification as shown in Figure 1. This ROV can be classified as an observation class ROV. This model consists of 4 thrusters that allow it to have 4 DOF (degree of freedom). The dimension for this model is 0.3m in length, 0.6m in width and 0.45m in height. The overall weight for this model is 18 kg and was designed as an open-frame model. Its frame is made from aluminum while PVC was used for its pressure hull. This model is controlled using a PS2 controller while a 14' laptop was used to monitor and collect data from the ROV. It is required to add a 24V dc power supply to power the 4 thrusters and another 12V power supply is used to power up its vision and sensor system. This model is able to carry out 2.5 kg of payload. This ROV has the ability to go down below the water surface area up until 50m maximum. This model has been equipped with a depth sensor to monitor its depth during the operation and an IMU sensor to assist the driver when driving the ROV by giving essential information such as pitch and roll of the ROV [6 -7]. The main function for this ROV is for surveying or conducting inspection underwater. A transfer function was obtained using system identification that was later used to design an intelligent controller [7- 10].

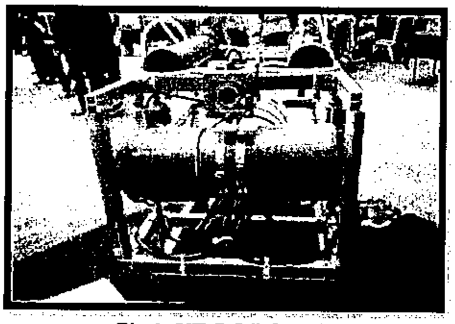


Fig.1: UTeRG ROV 1[8]

II. UTeRG-ROV 2

The hardware development for this new ROV started by drawing the proposed design using Solidworks software. The complete design is illustrated in Figure 2. The design of the ROV includes the design of its body, thrusters, vision system, and depth sensors to be used to move and give feedback of the environment to the ROV during its operation underwater. The description for this small scale ROV is provided in Table 1. Figure 3 shows the ROV ready for testing. The body of the ROV is made up from fibre glass and prospect.

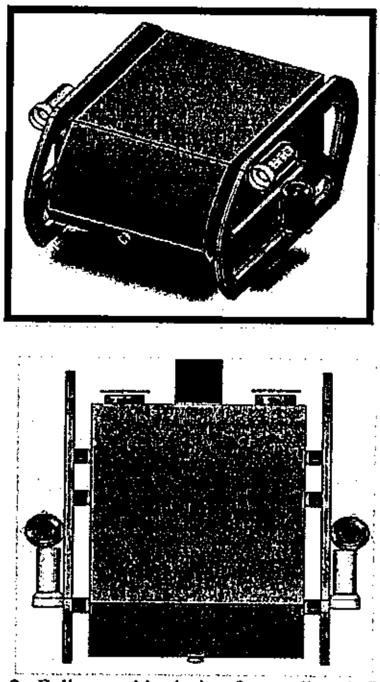


Fig. 2: Full assembly design for small scale ROV

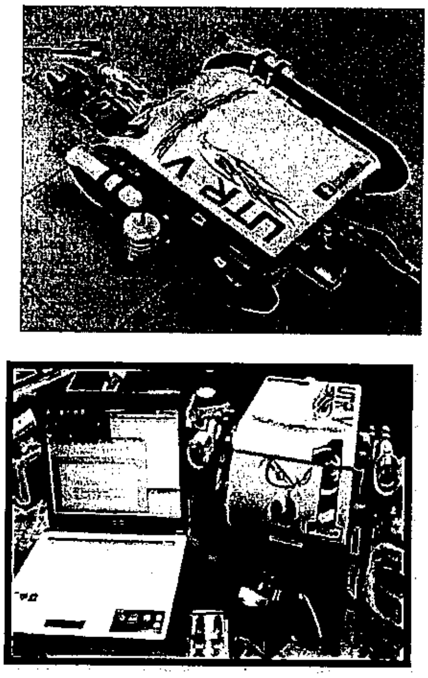


Fig. 3: The ROV is ready for testing

TABLE 1. THE CHARACTERISTIC OF THE ON BOARD EQUIPMENT

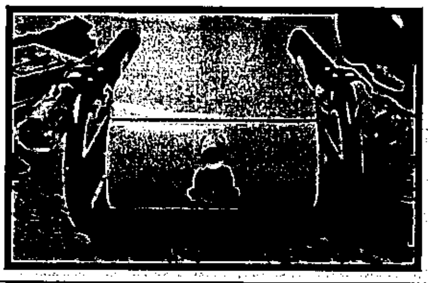
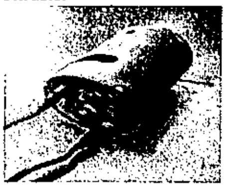
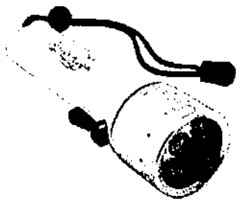
Part	Description
Body of ROV 	Name : ROV body • The body is made using prospect and covered with glass fiber to provide stronger bond. • This mixture of material can withstand bigger pressure and provide a water proof surface. • Cement is used to smoothen the surface of the ROV body. • The length is 352 mm with height of 250 mm and 130mm of width. • The ROV body total volume is 12,478,949 mm^3. • Total weight is 12.478 kg. • Total surface area for this body is 673,732.33 mm^2.
Thruster  	Name : Thruster • This thruster is made using 12V DC motor and propeller. • The 12V DC performance is improved with the placement of a capacitor which helps to deal with voltage fluctuations that can affect the speed of motor rotation. • The propeller used is 2 blade propeller with 45 degree pitch angle. • Both 12V DC motor and the propeller is joint together using coupling which helps to holds the propeller to the shaft of the motor.
Underwater Torch Light 	Name : Underwater LED light • Can provide enough light up to 25 meters under the water. • This lamp can work under extreme condition and is build to resist the impact onto it. • The body is made up of aluminum alloy and plastic. It also has been sealed with rubber to avoid the water from flowing into inside part of the lamp. • The light intensity is up to 180LM and powered by 4 AA batteries. • The dimension of this lamp is 16 cm length, 4.2 cm of head diameter and 3.5 cm for body diameter. Its weight is around 95 grams.[11]
Underwater Camera 	Name : Underwater inspection camera • The camera uses the concept of plug n play and is very easy to be used. • The camera comes with a low light operation which helps to give a live feed about what is happening underwater to the operator when the ROV is on the move. • The camera is also equipped with 3 IR leds to work in the low light conditions. • The live feed also come with zoom function and the screen can be rotated when necessary. [12]

Figure 4 shows the electric circuit inside the ROV. Here, the controller box used to control or operate the ROV is shown. The Electrical circuit inside the ROV consists of integrated sensors, pressure sensors and electrical fuel pump. The integrated circuit consists of the sensors such as IMU sensor, temperature sensor, switches, and voltage regulators. This entire sensor is controlled by the circuit which was also placed inside the sensor box along with the integrated sensor. The pressure sensor is located outside the box but the output and input voltage for the sensor are coming from the integrated sensor box. All this information is transmitted to the control box before the data can be recorded.

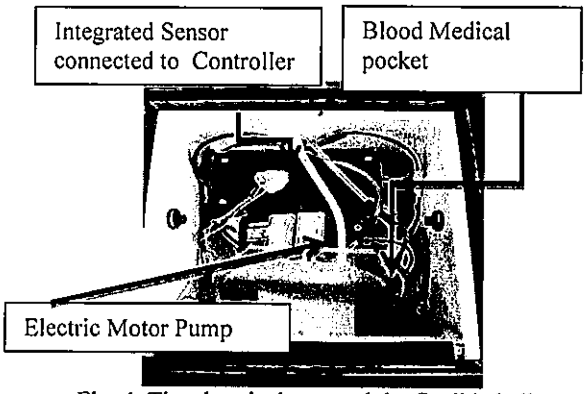


Fig. 4: The electrical part and the flexible ballast tank inside ROV

Fig. 5: ROV was tested on lab tank test.

III. RESULT AND ANALYSIS

The data are collected by using the NI card that has been connected to the pressure sensor onboard which is giving out the depth position in voltage [13-15]. The time taken for the ROV to reach the bottom of the pool has also been recorded to estimate the performance of the ROV itself. The data that has been used to generate the transfer function for the small scale ROV is the depth against time. Depth has been used as the input data for this small scale ROV. Therefore, the model that has been generated is focused only on the depth behavior for the small scale ROV [16]. The data recorded is then analyzed using system identification tools inside MATLAB as shown in Figure 6.

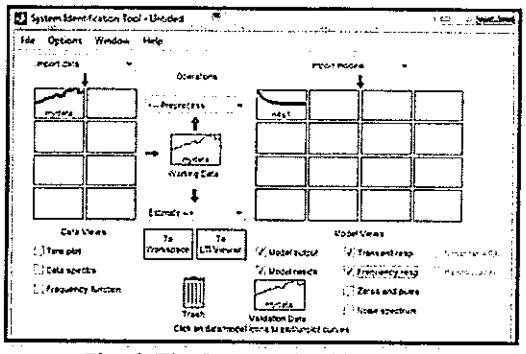


Fig. 6: The System Identification Tool in MATLAB

The transfer function obtained from system identification is stated in equation 1. This transfer function can be created by using the toolbox inside MATLAB™ [17- 19].

$$\frac{156\,s+1199}{s^2+121.2+4660} \qquad (1)$$

$$A=\begin{bmatrix}-2.28 & -2.07 & -0.07178\\ 1 & 0 & 0\\ 0 & 1 & 0\end{bmatrix}\; B=\begin{bmatrix}1\\0\\0\end{bmatrix}\; C=\begin{bmatrix}0 & 4.736 & 3.749\end{bmatrix}\; D=0$$

The model are obtained from system identification technique will be analyse in terms of controllability and observability and also asymptotically stable. Based on state space matrices, the system is both controllable and observable because the system has a rank of 2. This system is asymptotically stable when all eigenvalues of A have negative real parts.

Based on the transfer function obtained, the controller has been designed and tested in order to make sure the system can adapt into any condition when the ROV is operating underwater as shown in Figure 7. The system response obtained from the graph in Figure 8 proved that the system can be controlled using simple conventional PID controller. The parameters used for the PID controller is provided in Table 2. As seen in Figure 8, the step response has been adjusted in order to see the response from the controller. Here, good result has been achieved since the output signal managed to follow the input signal fairly well. It can be concluded here that the transfer function representing the model for this small scale ROV is reliable and the controller design is acceptable.

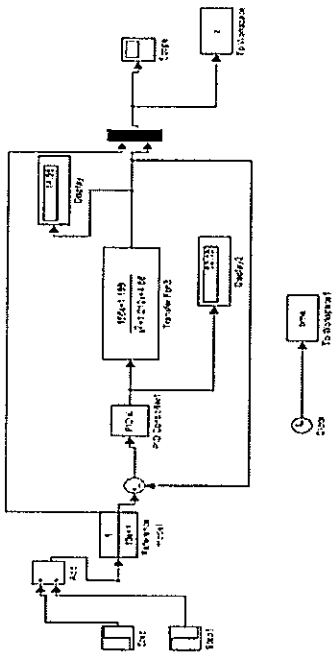
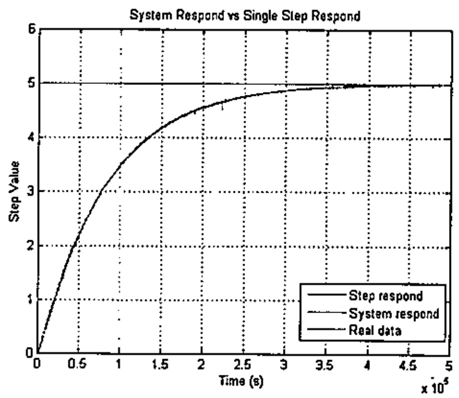


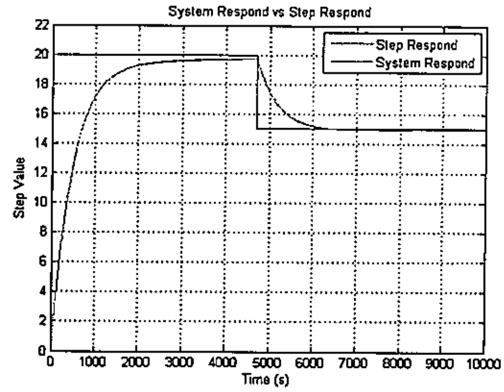
Fig. 7: The PID controller that was implemented for the ROV system

TABLE 2. PID CONTROLLER PARAMETER

Parameter	Proportional (P)	Integral (I)	Derivative (D)
PID controller	0.9	245	0



(a)



(b)

Fig. 8: The system response of the ROV for depth control

IV. CONCLUSION

The main objective for this project, that is, to develop a small scale ROV has been successfully achieved. Actual lab tank experiment was performed using the ROV and data from the pressure sensor and the IMU sensor was recorded successfully. The data was the used to model the ROV dynamics using system identification via MATLAB system identification toolbox. A PID controller has been successfully designed using this model and gave reasonably good performance during simulation.

The future planning is to test this ROV in the ocean to validate whether the ROV can be functional in real situation. Also implementing an intelligent controller such as simplified fuzzy logic controller or combined with conventional PID controller to improve the performances on system response will be done.

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