Design and Development of SelamDrone Underwater ROV Manoeuvring Control

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Abstract. The present study explores the underwater remotely operated vehicle (ROV) control named SelamDrone. The manoeuvring which include forward-reverse and rise-sink control is designed and developed. Beforehand, various factors in designing and fabricating first prototype of underwater ROV namely functionality, stability and motor efficiency need to be considered. The description of the SelamDrone ROV and its equipment, manoeuvring equipment control setup and controller algorithm design are presented. The developed algorithm controller for forward-reverse and rise-sink is presented and discussed. Manoeuvring investigation which include trial run and full test run show that the SelamDrone able to function and can be controlled by using joystick of radio controller. In order to overcome the lagging in rising, an introduction of ballast coupled with smaller wire for its umbilical is suggested for future work.

1. Introduction

Recently drone and remote operated vehicle (ROV) have become a handy tools in making human live easier and simpler. The applications of drones and ROVs are not limited to on the ground but also under the sea. The research will focus on the applications of ROV below the sea level especially for search and rescue purposes.

ROVs are used in a variety of subsea work tasks. From small hand deployable ROVs to large work class ROVs for heavy intervention work at subsea offshore installations to full ocean depth research ROVs. Common for all types is that many applications instead of being manually controlled could have been performed with higher accuracy and faster with an automatic positioning control system. Today most industrial ROVs are equipped with automatic heading and depth control only [1]. A pilot controls the thrust from a command console with joystick to move the ROV.

An unman ROV was developed with sensor for data collection and control manoeuvring by dc bushless motor [2]. A real time camera provides a video observation and makes manoeuvrings of the device using a joystick control system mechanism smooth either for tilting, forward and reverse. In order to stabilise the movement, the control system was a processing program for GUI and Arduino microcontroller as to control and combine all sensors data such as accelerator, gyro meter and meter speed control. Similar designed underwater ROV weighed 15.46 kg using six bushless motors controlled by Proportional

Integral Derivatives (PID) and video data capture via Raspberry Pi 3 [3]. The ROV is claimed to reach down to 100 m underwater.
Inspection of underwater structure purposes ROV was designed using non-linear Dynamic Surface Controller (DSC) and Proportional Integral Derivatives (PID) controllers [4]. The performance of DSC controller was found to be better than PID controller. Another underwater ROV was designed and fabricated using a low cost material such as polyvinyl chloride (PVC) pipe with camera network video powered by 12V battery operated 3 motors [5]. It is manoeuvred using a joystick controller and it managed to dive submerge up to 20 meters deep.
A low level control system for underwater ROV named Visor3 with 6 DOFs mathematical model with two coordinated systems either earth-fixed or body-fixed frames [6]. The simulation of navigation, guidance and control was conducted by Simulink® and experiment of x, y and yaw components trajectory. Both tasks were assisted with two algorithms of multiloop PID and PID with gravity compensation. This control and navigation systems are fundamentals to the low-level control system that might be used in inspection at port facilities, hydroelectric dam, and others.
An upgraded version of control system of 6000 m rated ROV for search and rescue purposes was using a Programmable Logic Control (PLC) [7]. The previous version was using PLC and it showed success in 16 years of service. The upgraded version also using PLC by adding few modules.
A good and efficient ROVs should have automated control modes such as maintaining position and tracking. This will ease an unman ROVs monitoring and planning of operations that demand human intervention or decision making. The degree manoeuvring interaction can depend on the control mode.
In this paper, the design and development of SelamDrone manoeuvring controller is discussed. Trial run in a small water tank and full run in 30-feet depth pool to proof its function is presented in this paper.

2. Methodology

This section will elaborate further on the UC TATI SelamDrone start with the description of the equipment, followed by manoeuvring of the forward-reverse and rise-sink control, equipment control setup and finally controller algorithm design.

2.1. Description for ROV and Equipment

UC TATI SelamDrone is a first prototype ROV developed by UC TATI researchers. It is powered and communicates with a surface through 30 feet umbilical. All systems needed for operation such as power supply, navigation and monitors are fitted in a box. It was delivered with a joystick command console with control functions. Specification of the SelamDrone is given in Table 1. While Figure 1 show the complete build-up of the SelamDrone.

Table 1. SelamDrone Specifications

Specifications	Details
Weight	13kgs
Dimensions	550mm x 500mm x 150mm
Battery	Lippo 4S 10,000mAh 14.8v x 4 pcs
Max depth	10 meters
Motor max power	150W
Motor rpm	5200 rpm (max)
Camera	Underwater camera 1/3 / F3.6 / 92 degree

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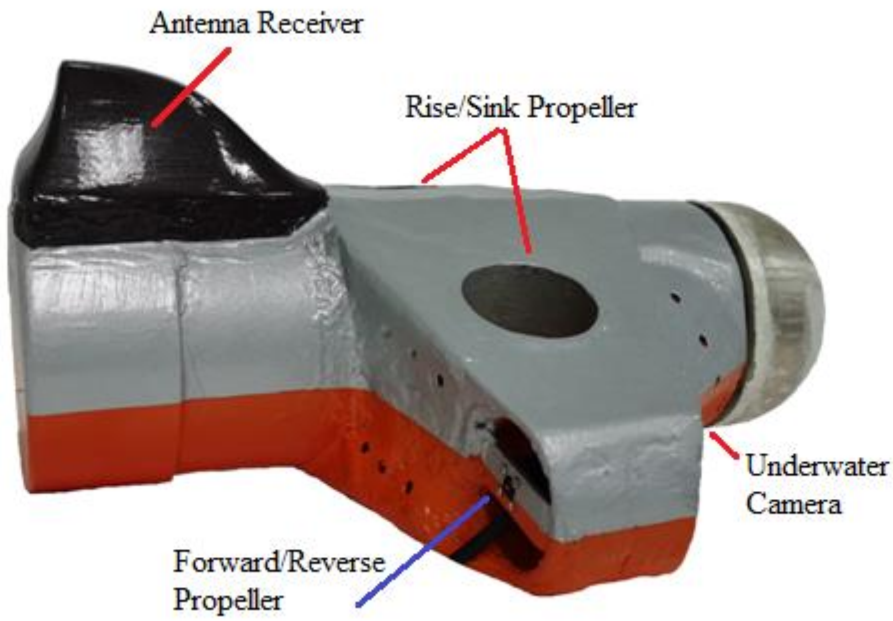


Figure 1. Design and build-up of SelamDrone

2.2. Maneuvering Control

The UC TATI SelamDrone is controlled by joystick radio controller as shown in Figure 2. For ease of manoeuvring, the right joystick is assign is to control forward-back movement which specifically controlling the propeller 1 (left and right). On the other hand, left joystick is assigned to control rise-sink of SelamDrone which in turn controlling the propeller 2 for either side (left and right). The detail location of propeller 1 and propeller 2 is depicted in Figure 3. As shown in Figure 4, Channel 1 (Ch1) and Channel 2 (Ch2) represent the joystick for the Forward-reverse movement while Channel 3 (Ch3) and Channel 4 (Ch4) represent the movement for rise-sink. The allocation of each channel is vital in developing the manoeuvring control algorithm.

Figure 2. Radio controller of the drone

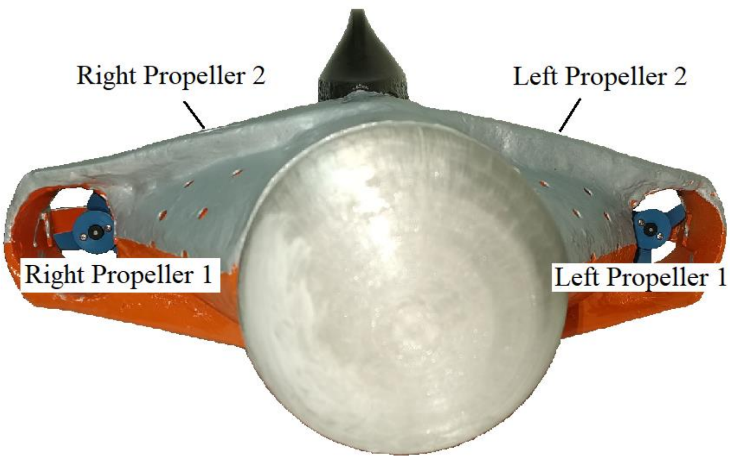


Figure 3. Location of propeller

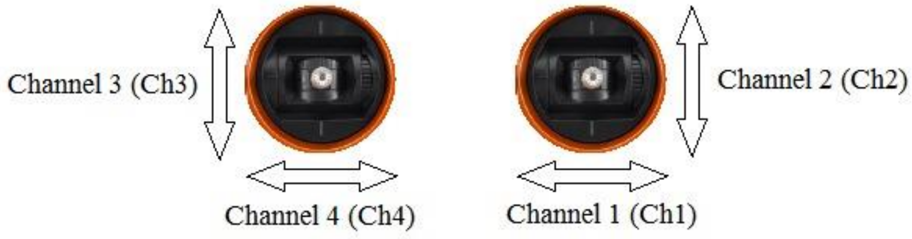


Figure 4. Allocation of the input channel

The detail of forward-reverse direction and rotation of left propeller 1 and right propeller 1 is tabulated in Table 2.

Table 2: Forward-Reverse direction control

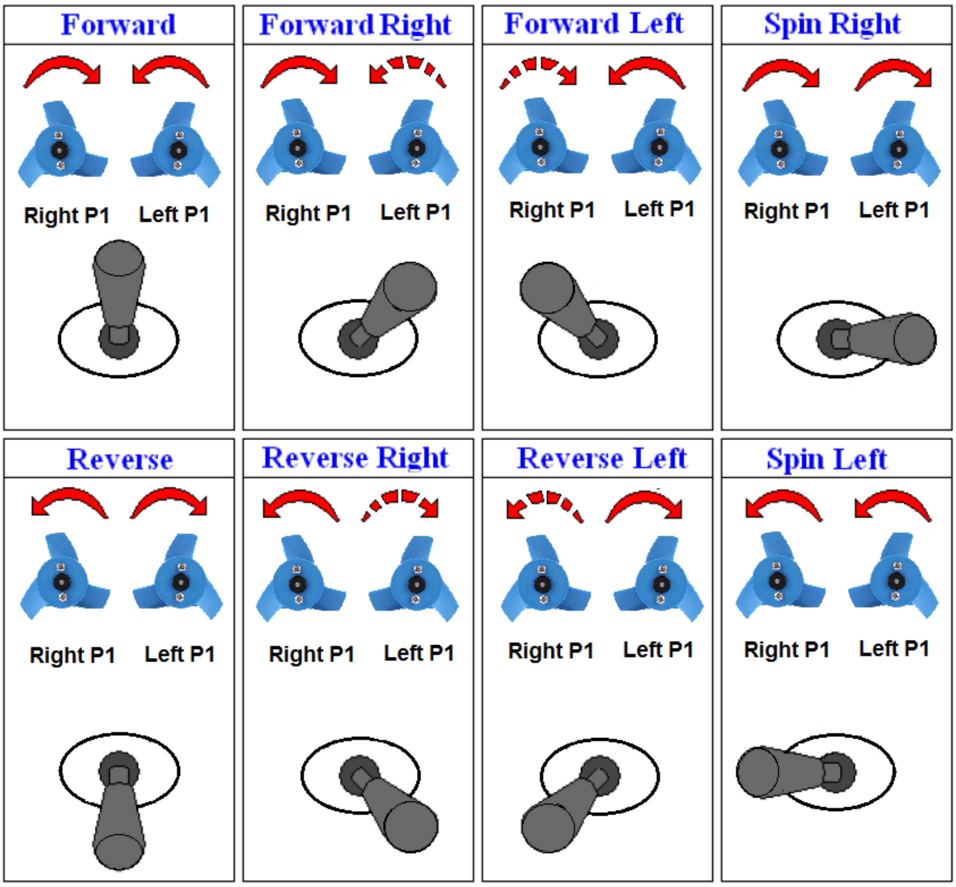
Direction	Left Propeller 1	Right Propeller 1
Forward	Clock Wise	Counter Clock Wise
Reverse	Counter Clock Wise	Clock Wise
Forward-Right	Clock Wise	Clock Wise
Forward-Left	Counter Clock Wise	Counter Clock Wise
Reverse-Right	Clock Wise	Clock Wise
Reverse-Left	Clock Wise	Clock Wise

On the other hand, the rise-sink direction and rotation of left propeller 2 and right propeller 2 is tabulated in Table 3.

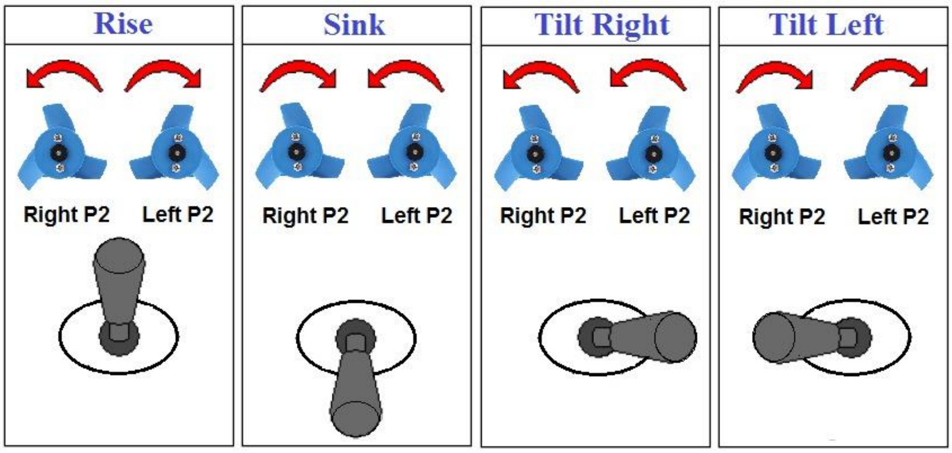
Table 3: Rise-sink direction control

Direction	Left Propeller 2	Right Propeller 2
Rise	Clock Wise	Counter Clock Wise
Sink	Counter Clock Wise	Clock Wise
Tilt-Right	Counter Clock Wise	Counter Clock Wise
Tilt-Left	Clock Wise	Clock Wise

For clearer explanation on the direction and its corresponding rotation of the propeller is best depicted in Figure 5.



(a) Propellers rotation base on forward-reverse joystick



(b) Propellers rotation base on rise-sink joystick

Figure 5. Propeller rotation base on joystick direction

2.3. Equipment controller setup

Figure 6 show the schematic diagram of the controller equipment setup which use in the research work. The component of the controller which include propeller and motor, electronic speed controller (ESC), Arduino UNO, Lippo battery and remote-control receiver.

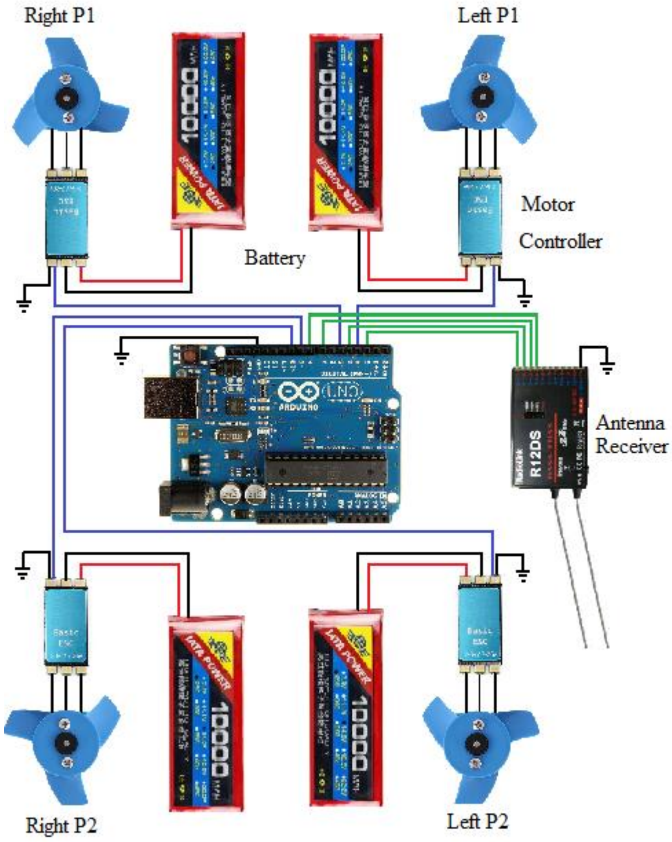
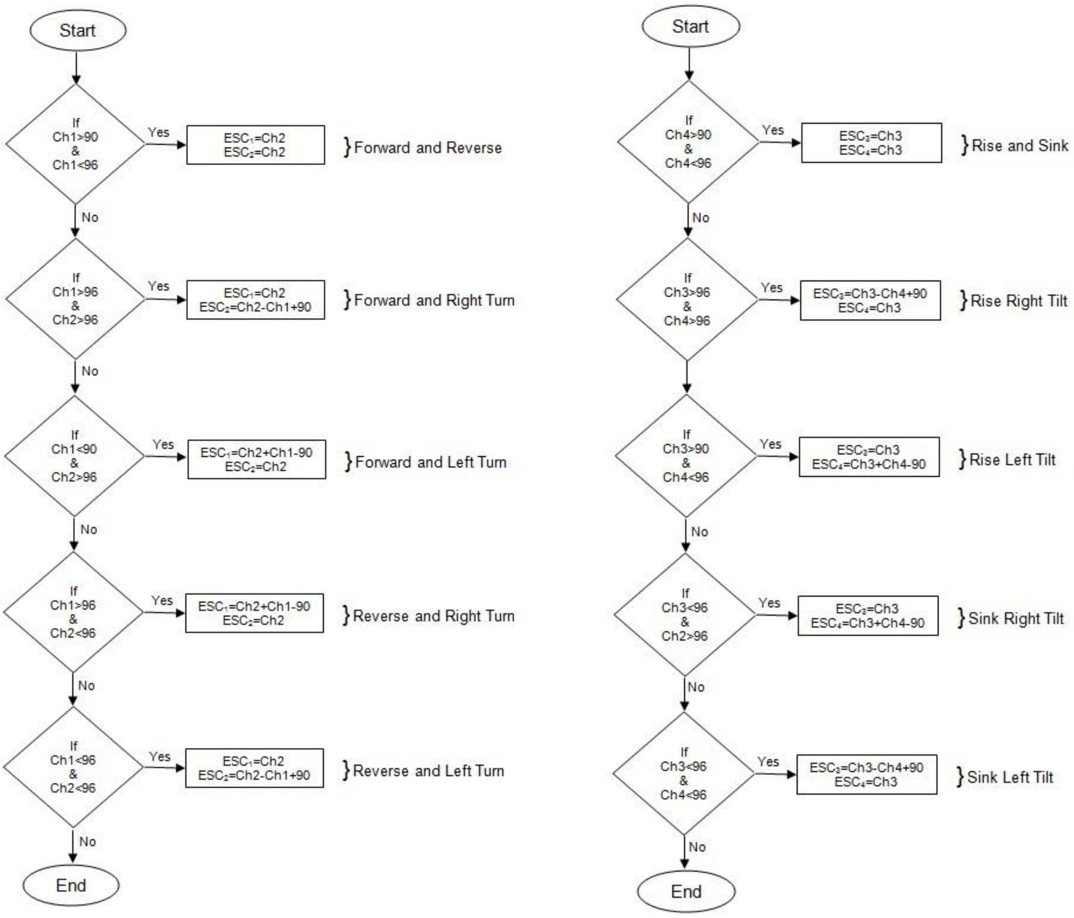


Figure 6. Schematic diagram for UC TATI SelamDrone controller

2.4. Controller Algorithm Design

Figure 7(a) and (b) shows the flow chart of forward-reverse and Rise-sink for controller algorithm design for the Arduino UNO, respectively. The algorithm starts with reading the input of channel 1, 2, 3 and 4. The input is converted to output electronics speed controller (ESC) which then controlling the rotation of the motor propeller. The output of this algorithm is then reported in the result and discussion.



(a) (b)

Figure 7. Flow chart of (a) forward-reverse (b) rise-sink direction use in designing the movement algorithm

3. Results and Discussion

The manoeuvring investigation of UC TATI SelamDrone namely forward-back and rise-sink is discussed. Beforehand, development of the algorithm controller and its developed equation for each movement/direction is shown.

3.1. Development of the algorithm controller

Based on two independent variables and using the regression method, the equation for algorithm controller is developed. Equation (1) to equation (8) reflect to the forward-reverse movement. For forward and right turn directions, the equation for ESC_1 and ESC_2 is depicted in equation 1 and equation 2. While for forward and left turn, the ESC_1 and ESC_2 is modelled as in equation 3 and 4. For reverse motion, the equation 5 to equation 8 modelled the reverse direction for right and left turn, respectively. Table 4 tabulated the developed equation to model the forward-reverse direction of the SelamDrone.

Table 4: Developed algorithm equation based on the propeller direction for forward-reverse direction

Direction	Propeller	Equation	
Forward – right turn	Right P1	$ESC_1 = Ch2$	(1)
	Left P1	$ESC_2 = Ch2 - Ch1 + 9$	(2)
Forward – left turn	Right P1	$ESC_1 = Ch2 + Ch1 - 90$	(3)
	Left P1	$ESC_2 = Ch2$	(4)
Reverse – right turn	Right P1	$ESC_1 = Ch2 + Ch1 - 90$	(5)
	Left P1	$ESC_2 = Ch2$	(6)
Reverse – left turn	Right P1	$ESC_1 = Ch2$	(7)
	Left P1	$ESC_2 = Ch2 - Ch1 + 9$	(8)

Equation 9 to equation 16 reflects the rise-sink movement, which also include left and right tilt. For Rise and right tilt direction, the equation for ESC_3 and ESC_4 is depicted in equation 9 and equation 10. While for rise and left tilt movement, the ESC_3 and ESC_4 are modelled as equation 11 and equation 12. The regression modelled for sink right tilt and sink left tilt are been modelled by equation 13 to equation 16, respectively. Table 5 summarize and tabulate the equation for each movement for rise and sink of the SelamDrone.

Table 5: Developed algorithm equation based on the propeller direction for rise-sink direction

Direction	**Propeller**	**Equation**	
Rise-right tilt	Right P2	$ESC_3 = Ch3 - Ch4 + 90$	(9)
	Left P2	$ESC_4 = Ch3$	(10)
Rise-left tilt	Right P2	$ESC_3 = Ch3$	(11)
	Left P2	$ESC_4 = Ch3 + Ch4 - 90$	(12)
Sink-right tilt	Right P2	$ESC_3 = Ch3$	(13)
	Left P2	$ESC_4 = Ch3 + Ch4 - 90$	(14)
Sink-left tilt	Right P2	$ESC_3 = Ch3 - Ch4 + 90$	(15)
	Left P2	$ESC_4 = Ch3$	(16)

From the equations developed, the source code for controlling electronic speed controller 1 (ESC1) to ESC 4 is written and developed. Once the source code is completely developed, the test of each ESC against joystick movement is done. From the observation, it is found that each propeller moves in the desired direction as planned.

3.2. Maneuvering Investigation

UCTATI drone manoeuvring investigation is done in thirty-feet pool in Terengganu Safety Training Centre Sdn. Bhd. (TSTC). The manoeuvring investigation namely forward-back and rise-sink. Beforehand, the rotation of each propeller is tested against the movement of the joystick. The result of the propeller rotation against movement of the joystick is found satisfactory. Afterward, trial run is done in the small tank as shown in the Figure 8. The result is also satisfactory.

Figure 8. Trial run in the small tank

SelamDrone is ready for a real test. Thus, the manoeuvring of the SelamDrone is test in the TSTC pools with 30 meters depth as shown in Figure 9 and Figure 10.

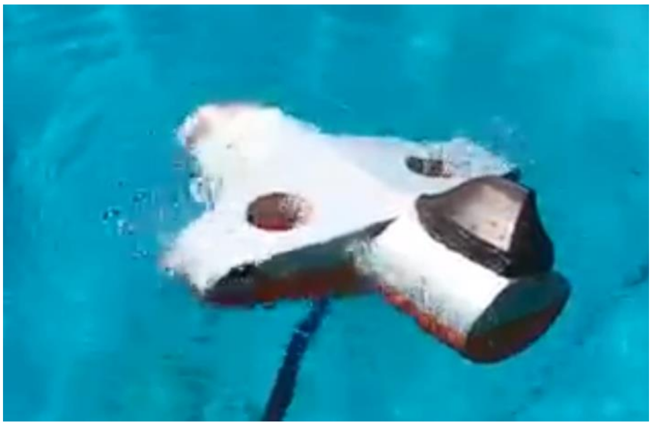


Figure 9. Test on the forward-reverse

Figure 10. Test on rise-sink

Figure 9 shown the forward and reverse manoeuvrings of the SelamDrone. It is observed that from the test, the SelamDrone is successfully move forward and back, right turn and left turn as well as reverse right and left turn which according to the movement of the joystick. While Figure 10 shows the rise and sink test. From the test it found that the SelamDrone able to dive up to 30 feet and stay in the floor of the pool. During rising movement though, the SelamDrone is found difficult to rise up due to weight of the cable. Further observation shows that the SelamDrone is not in the horizontal position but slightly in decline position. This is due to unbalance in the SelamDrone chamber.

4. Conclusions

Even though The SelamDrone is the first prototype of this research, it able to fulfil the objective of the study which able to move forward-reverse, and rise and sink direction as according to the joystick command. The SelamDrone able to dive up to the 30-feet depth of the pool. However, the rising of the SelamDrone require full throttle of the propeller and it takes sometime reach the surface due to weight of the cable. For future work, it is suggested to use tiny cable which reduce the overall umbilical weight. Introduction of water ballast is also suggested for future work to increase the efficiency of the rising-sink as well as maintaining the horizontal level of the SelamDrone under the water surface.

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