UNIVERSITI TEKNIKAL MALAYSIA MELAKA

FACULTY OF ELECTRICAL ENGINEERING

FINAL YEAR PROJECT 2

REPORT

Design an Intelligent Controller for Depth Control of ROV using Micro-box 2000/2000C

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" I hereby declare that I have read through this report entitle "Design an Intelligent Controller for Depth Control of ROV using Micro-box 2000/2000C" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Mechatronics Engineering with Honors"

Signature :...

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DESIGN AN INTELLIGENT CONTROLLER FOR DEPTH CONTROL OF ROV USING MICRO-BOX 2000/2000C

LEE DAI CONG

A report submitted in partial fulfillment of the requirements for the degree of Bachelor of Mechatronics Engineering with Honors

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2014

I declare that this report entitle “Design an Intelligent Controller for Depth Control of ROV using Micro-box 2000/2000C” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :...

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Date :...

Dedication

To my beloved father and mother

Thanks for the support and understanding

Acknowledgement

In the process of doing this final year project, I was helped by many peoples. They are all being helpful and contributed their time to me without second thought. I would like to take this opportunity to show my sincere appreciation to Pn. Fadilah binti Abdul Azis for accepting me as her final year project student. She always correct my mistakes and teach me whenever she can even during her rest time.

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Last but not least, I would like to thanks all my fellow friends who helped me while I doing my final year project. It was them who always reminded me for what should I do and never hesitate to teach me whenever they can.

Abstrak

Projek ini adalah mengenai mencipta dan membina pengawal pintar kawalan kedalaman ROV menggunakan Micro-Box 2000/2000C. Terdapat beberapa masalah ROV masa kini, yang paling penting ialah masalah kebocoran air. Kebocoran air disebabkan oleh haus dan kesan air mata apabila seseorang membuka badan kapal tekanan. Masa selepas masa, badan kapal tekanan longgar dan akan membolehkan air untuk pergi ke dalam badan kapal tekanan dan merosakkan bahagian elektronik di dalamnya. Masalah lain adalah bateri ROV senang dihabiskan menyebabkan terhad masa untuk menguji dan menggunakan ROV. Masalah perparitan semasa akan menyebabkan pengguna perlu kerap membuka badan kapal tekanan untuk tukar bateri. Pengawal 'fuzzy logic' adalah sangat baru dalam bidang pengawal dan tidak mempunyai panduan yang formal untuk tuning dan menyebabkan masa berharga dibazir. Oleh itu, kajian mengenai kesan mengalih fungsi keahlian sifar akan dilakukan sebagai panduan umum untuk tuning pengawal 'fuzzy logic' untuk kerja-kerja masa depan. Untuk menyelesaikan masalah ini, ROV Simulator yang tidak berfungsi bawah air akan dibina. Kawalan kedalaman akan menggunakan pengawal 'fuzzy logic' dengan Micro-Box 2000/2000C. Pengawal 'fuzzy logic' akan digunakan untuk mengalihkan fungsi keahlian sifar supaya kesan pelarasan boleh dikaji dan diguna sebagai satu garis panduan umum tuning pengawal 'fuzzy logic'. Hasilnya akan dianalisis untuk menentukan hasil projek. Hasilnya menunjukkan bahawa pengawal 'fuzzy logic' boleh digunakan simulator ROV itu. Hasil projek ini menunjukkan dengan mengalihkan fungsi keahlian sifar pengawal 'fuzzy logic' prestasi pengawal 'fuzzy logic' umumnya.

Abstract

This project is about the design and develop of intelligent controller of ROV depth control using Micro 2000/2000C. There are some problem while developing a ROV and the most significant is the water leakage problem. The water leakage problem is highly cause by the wear and tear effect whenever someone open up the pressure hull. Time after time, the pressure hull will loose and enable the water to go into the pressure hull and damage the electronics part in it. The other major problem with a ROV is the thruster can easily drain up current from the battery source or power bank and this will limited the time to test and use the ROV. The current drainage problem will also cause the user to have the need to change the power source frequently by open up the pressure hull. The fuzzy logic controller is very new in the field of controller and thus do not have a proper guide to fine tune it and cause the tuning of it to be highly time costing. Therefore, a study on the effect of shifting the zero membership function will act as a general guide to further tune the fuzzy logic controller for future works. To solve the problem stated, a ROV Simulator which will not work underwater will be develop to test the control system. To build a ROV simulator, there will be need of using aluminum trial, thrusters, drivers, interface connector, and also controller. The depth control will be implement using Micro 2000/2000C with fuzzy logic controller. The tuned fuzzy logic controller will be adjust by shifting the zero membership function so that the effect of the adjustment can be study and act as a general guideline while tuning fuzzy logic controller. The result was being tabulated, plotted and analyze to determine the outcome of the project. The result shows that the fuzzy logic controller can be implement to the ROV simulator. The result of this project shows that, by shifting the zero membership function of the fuzzy logic controller the performance of the fuzzy logic controller generally decrease compare to that of the original “center” position of the zero membership function.

Table of Content

List of Figures

List of Table

Chapter 1

Introduction

1.1 Overview

ROV is an underwater unmanned vehicle where main purpose is to observe underwater condition and perform underwater operation where divers cannot reach. ROVs are highly implement in offshore underwater operation by oil and gas company and scientist whose main purpose is to do research and exploration of underwater knowledge. The final year project with the title of design an intelligence controller for depth control of ROV using Micro 2000/2000c thou is mainly about the control system for ROV depth control.

1.2 Motivation

The main motive to choose the title of 'design an intelligent controller for depth control of ROV using Micro 2000/2000c' out of all other final year project is that ROV is highly interesting. ROV is highly use for offshore operation including drilling, observation, and others. The famous Deepwater Horizon Macondo well uses ROV to seal the leaking well and also post mortem investigation was done by ROV to prevent similar tragedy to happen in the future. The accident had already affected almost the whole Gulf of Mexico ecosystem and without the ROV, the damage may be even worse than anyone can expected. The post mortem investigation of the ROV is as shown as figure 1.1 [8]. ROV also being uses for black box searching for the famous MH370 mysterious incident. Without ROV, it was never possible for the search of black box to be carry out. The weather of the deep water sea is highly vicious and sending in human for the operation is consider unrealistic. The assembly of the ROV for black box searching can refer to figure 1.2 [9]. Therefore, the importance of ROV is highly underrated as it never receive high public appreciation. To develop the fuzzy logic controller is consider a new approach for control system, and because of it, there are no exact ways to tune it nicely. Therefore, develop a simple overview on how will output membership function affect the result matters.

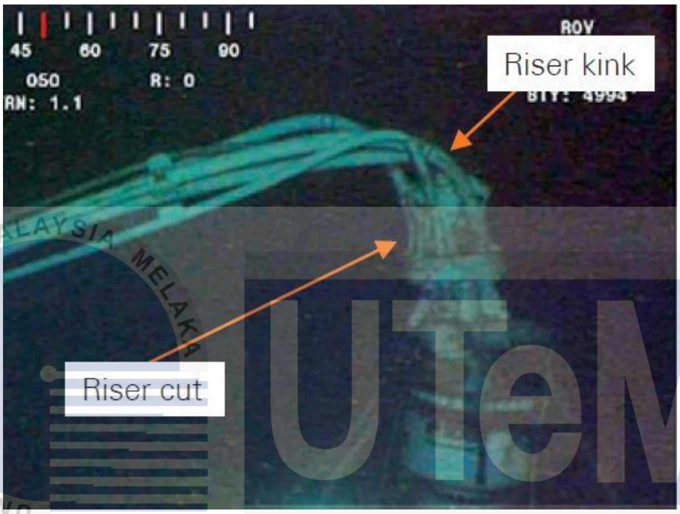

Figure 1.1- ROV post mortem investigation for Macondo well

Figure 1.2- ROV deployment for MH370 black box searching operation

1.3 Problem Statement

There are many problem encounter by remotely operated underwater vehicle and one of the most important problem is leaking. Because of the reason that remotely operated underwater vehicle is electronically controlled vehicle, leaking of water into the body of it means malfunction of it.

Other than that, because of the reason that the thruster consume a lot of current, normal battery can only last around 5 minutes underwater. When the battery run out of current, the operator will have to take out the ROV and replace its battery which cause another problem where wear and tear may happen during opening the body of ROV. Because of the limited time of the ROV in the water, some part of the control system may never have the chance to really be tested. It is highly undesirable especially for testing of control system purpose. Therefore, a ROV simulator which will not be place underwater should be made in order to test the control system designed and fine-tuned it.

The conventional control system for remotely operated underwater vehicle which is PID controller cannot function well when it is in the underwater environment. This is due to conventional PID controller do not suitable to work with non-linear environment. Because it is crucial for remotely operated underwater vehicle to not contact with the seabed which might cause damage to the remotely operated underwater vehicle, the control system of it should have minimum overshoot and it can hardly be done by conventional PID controller. Thus, intelligence control system such as fuzzy logic controller is needed in order to solve this problem.

Last but not least, fuzzy logic controller is consider new and there are no standards way to tune it. Trial an error is the common approach to do this and this often results in a great waste of time. Therefore, a simple overview of how zero output membership function of the fuzzy logic can affect the results is one simple contribution for this field of study.

1.4 Objective

The objectives of this final year project is to

1. Design and develop an intelligence controller for real-time ROV depth control.
2. Design and develop a ROV simulator in order to do testing, analysis of rise time, settling time, percent overshoot, and steady state error, and simulation of the fuzzy logic control system.
3. Analyze the effect of adjustment for output zero membership function by simulation and Micro 2000/2000C real-time control.

1.5 Project scope and limitation

This project will be carry out in a controlled environment where the disturbance will be assume to zero. To carry it out in a controlled environment, a ROV simulator will be built for this project to mimic the real life operation of ROV. This ROV simulator was built mainly to overcome issue where it is troublesome to carry out the experiment in water. Since the project is about depth control, only vertical up and down movement will be consider in the project. The project is mainly about control system. Thus, the final year report will only brief thru any other information other than control system related content for ROV. This project will implement the intelligence control system by using Micro 2000/2000c only. Because of the limitation where Micro 2000/2000c cannot be borrow out of CIA Lab, FKE. The experiment will be carry out in Lab CIA only. The experiment will be carry out for depth of 3 meters only as the controller is not robust enough to carry out experiment at different voltages, this is highly due to the reason that a robust fuzzy logic controller will require many membership function.

Chapter 2

Literature Review

2.1 Introduction

This topic will review related topic of ROV depth control. The topic which need to be review will be mainly about the performance of certain controller's works for ROV. The reason of certain controller is suitable for ROV and certain controller isn't will be study thru this chapter. Journal of implementation for selected controller will also be review and study in this chapter to help enhanced the knowledge which associated with the intelligent controller.

2.2 Related Previous Works

According to journal [1], to derive a system equation is to derive a general non-linear model that can be adopt by remotely operate vehicle to calculate its velocity and kinematic. According to Newtonian or Lagrangian formalism, this derivation consider the remotely operated vehicle as a six degree of freedom rigid body. The depth control are divided into two different control method as discussed in this journal. But both method main concern is to drastically limit the overshoot of the controller to a depth set-point change, while keep the response time at a reasonably range. The reason for this is to assure the vehicle's safety while working near water-bottom and to prevent cable stresses for remotely operated vehicles. Generally both controller consist of proportional-integral-derivative controller. The first controller introduce is a continuous input smoother (CIS) controller. This controller can pre-filter the input signal to prevent sudden change that causes overshoot. This filter is effective but the disadvantage is that it have to be tuned off-line and different tuning suit different working conditions. The second controller as to solve the problem faced by CIS controller, Fuzzy-PID controller is introduced in the journal. As of the journal, discrete fuzzy smoother (DFS) is chosen and the idea behind is that the vehicle working online can suit itself to system behavior. The DFS drive the system with a sequence of steps which can reduce the overshoot while still achieving a better response time as compare to CIS control system. [1]

According to journal [2], Proportional Integral Derivative (PID) controller is not suitable for underwater unmanned vehicle as underwater condition exhibits highly non-linear characteristic but PID controller can only process linearized characteristic best. The journal also shows that without the need of formal mathematical model, rule based fuzzy logic controller is suitable to work with non-linear dynamics. It also show that the equation of motion as of for an underwater unmanned vehicle named nonlinear underwater vehicles dynamic motion is [2]:

$$M\dot{v} + C(v)v + D(v)v + g(\eta) = B(v)u \tag{2.1}$$

Where,

M = 6 x 6 inertia matrix including hydrodynamic added mass

$C(v)$ = matrix of the Coriolis and centripetal forces

$D(v)$ = Hydrodynamic damping matrix

$g(\eta)$ = Vector of restoring forces and moments

$B(v)$= 6 x 3 control matrix

This journal contain experiments base on conventional PID controller and Fuzzy logic controller. The transfer function used is:

$$\frac{u(t)}{e(t)} = \frac{K_d s^2 + K_p s + K_i}{s} \quad (2.2)$$

Where,

$u(t)$= output

$e(t)$= error

K_d= derivative gain

K_p= proportional gain

K_i= integral gain

The proportional gain can reduce rise time and steady state error, integral gain to eliminate steady state error but mess up the transient respond, and derivative gain to stabilize the system by reduce overshoot while improve the transient response. For the fuzzy logic part thou, uses error and rate of change of error to decide the unmanned underwater vehicle action. According to figure 2.1, the experiments shows that the fuzzy logic controller work better than PID controller as its rise time is the shortest while both have no overshoot. PID controller thou have minor steady state error while fuzzy logic controller have no steady state error at all. [2]

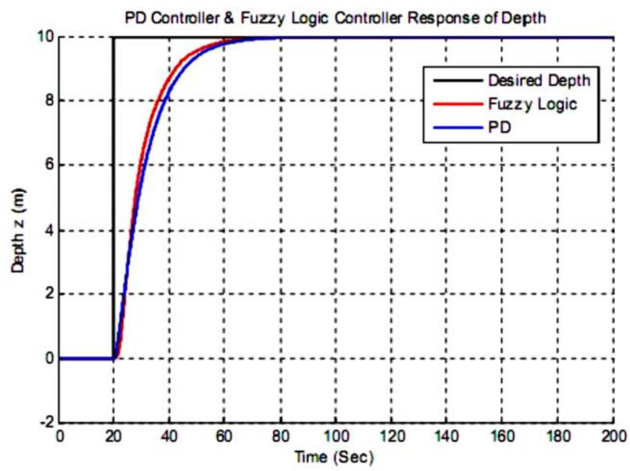

Figure 2.1PD and Fuzzy Logic Controller Response of Depth [2]

According to journal [3], to design a control system for unmanned underwater vehicle will need to determine the non-linear dynamic equation first. After determined them, linearization of the system equation will be perform for a finite range of set points. According to the linearized equation, a controller will be design to meet the equation requirements. Interpolation of the controller according to vehicle's speed will be perform and thus born the gain-scheduled controller. Lastly, the gain-schedule controller will be implement on the non-linear plant. Because of the interpolation is based on linearize system modelling equation but implement on non-linear plant, the result at figure 2.2 shows that there are still overshoot happening for gain-scheduled controller. [3]

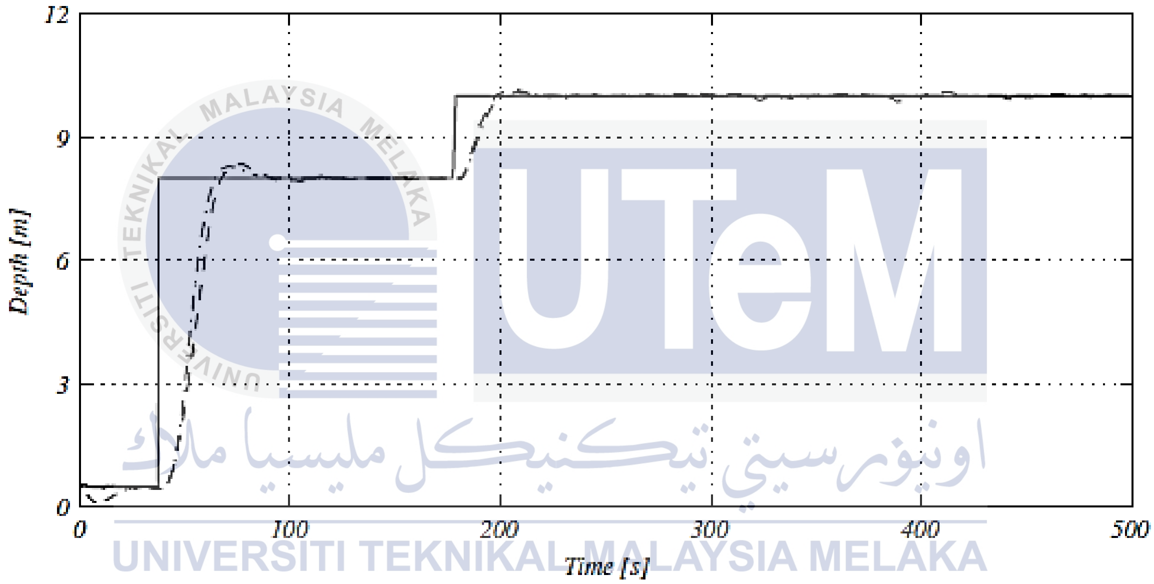

Figure 2.2- Response of Gain-Scheduled Reduced Order Output Feedback Controller[3]

According to journal [4]. The journal introduce adaptive plus disturbance observer controller which make self-adjusting on position control be possible for ROV to happen. This journal also introduce neural-network controller as one of the control approach to control the ROV. It is stated that neural-network controller is highly suitable for non-linear control approach as of what happen to ROV operating condition. But, to test the control system will require real-life experiment to be done and no software simulation can replace it because there is no mathematical characterization exist. Fuzzy logic controller according to the journal is highly suitable for non-linear control purpose and can perform smooth approximation of non-linear mapping. But to determine the membership function and its linguistic rules is time consuming and require experimental data. Adaptive controller which will change the controller's gain according to the disturbance but there is limitation where the dynamic changing speed is too fast for it to control. The result as shown as figure 2.3 shows that the controller have overshoot issue and minor fluctuation of depth. [4]

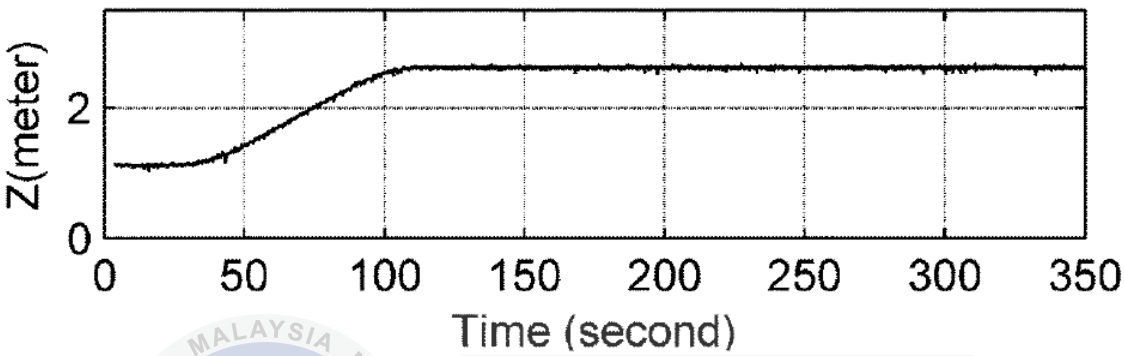

Figure 2.3 - Adaptive Plus Disturbance Observer response [4]

According to [5], it is stated that fuzzy like PD controller will need structures, rule-base, cause and effect membership function, inference mechanism, defuzzification strategy, and too the way to optimize the input and output scaling factors. The journal stated that the use of Takagi–Sugeno fuzzy system is implemented in the system and that singleton output can still perform well and do not consume too much times. Min and operation is used for the inference mechanism of the fuzzy like PD controller for this journal. Weight average defuzzification method is also being implemented in the system. The fuzzy-like PD controller is than being tested in a lake and shows the result that this control system can perform very well and stable in the lake. The ROV can stay at its desired depth with controlled amount of fluctuations of depth and a little bit of overshoot according to the journal. Showing from figure 2.4, it can be show that there are fluctuation but no overshoot from 0 meter to 10 meter depth and the same apply to from 10 meter to 5 meter depth. [5]

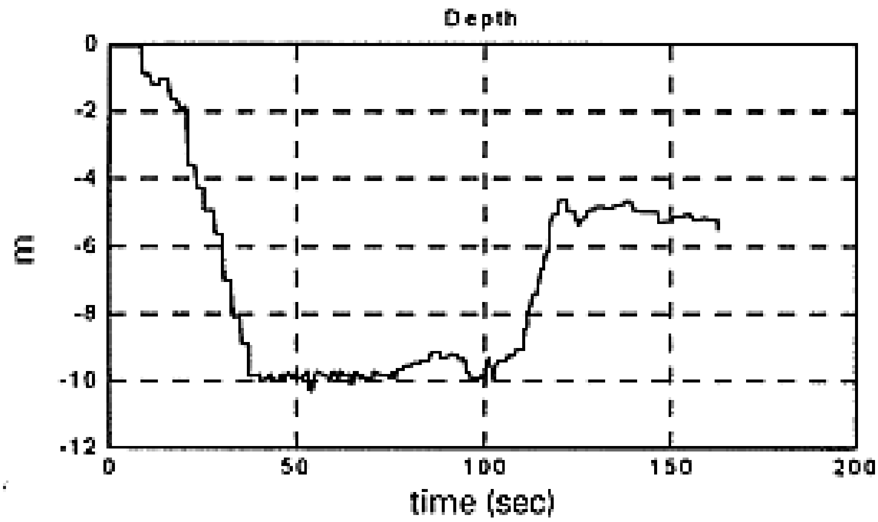

Figure 2.4 - Fuzzy Logic Controller Response [5]

According to journal [6], The journal shown that to decide the rule based of fuzzy logic controller, it is best to first obtain the time response graph of set point against time as shown as figure 2.5. Then according to graph, assign positive error and negative rate of change of error to the rise time until set point part, negative error and negative rate of change of error to the set point until maximum overshoot part, negative error and positive rate of change of error to the maximum overshoot until set point part, and positive error and positive rate of change of error to the set point until the part where it is under the set point again. According to these a rule based table is generated as of table 2.1.

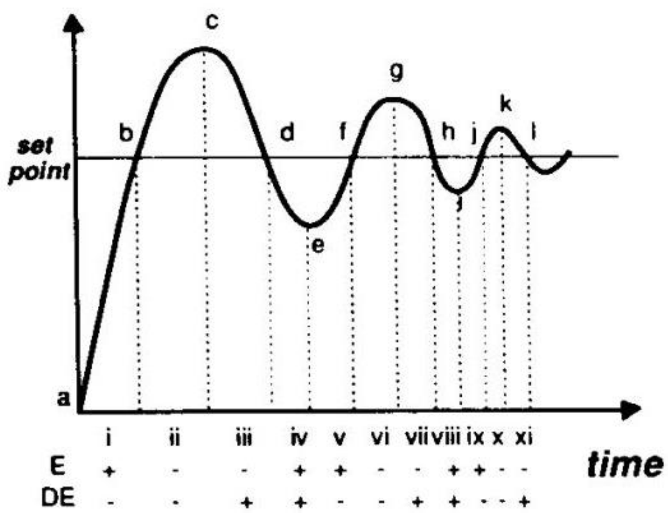

Figure 2.5 - C.C.Lee System Step Response Graph [6]

Table 2.1-C.C.Lee Rules Table [6]

Rule	Error	Rate of change of Error	Output
1	Positive	Zero	Positive
2	Zero	Negative	Negative
3	Negative	Zero	Negative
4	Zero	Positive	Positive
5	Zero	Zero	Zero

According to the table shown above, the linguistic rule based is then programmed into MATLAB for simulation and testing purposed. [6]

Referring to journal [7], The rules needed for a fuzzy logic controller can be determined by the input membership function. 7 X 7 input membership function will produce 49 rules, 6 X 6 input membership function will produce 36 rules and so on. The rules can then be determined by drawing a table as table 2.2.

Table 2.2-Rule Based Table

de/dt \ e	PL	PM	PS	Z	NS	NM	NL
NL	Z	NS	NM	NL	NL	NL	NL
NM	PS	Z	NS	NM	NL	NL	NL
NS	PM	PS	Z	NS	NM	NL	NL
Z	PL	PM	PS	Z	NS	NM	NL
PS	PL	PL	PM	PS	Z	NS	NM
PM	PL	PL	PL	PM	PS	Z	NS
PL	PL	PL	PL	PL	PM	PS	Z

Noted that for table 2.2,

P = Positive

N = Negative

Z = Zero

S = Small

M = Medium

L = Large

Journal [7] also stated that to reduce the noise of the result, it can be done by using rules viewer and adjust the output membership function according to which membership function involved during the time where the noise happen.

2.3 Summary of Literature Review

Table 2.3-Summary of Controller

Controller	Advantages	Disadvantages
Conventional PID Controller [2]	Easy to implement.	Not suitable for non-linear operation.
Continuous Input Smoother (CIS) Controller [1]	Pre-filter signal to prevent sudden change.	Require tuning for every different condition.
Neural-Network Controller [4]	Suitable for non-linear operation.	Difficult to simulate.
Adaptive Plus Disturbance Observer Controller [4]	Change controller's gain according to disturbance.	Can't handle fast dynamic changing speed and exist error at certain depth.
Fuzzy Logic Controller [1][2][4]	Suitable for non-linear operation and better response time compare to CIS controller.	Fine tuning process is highly time consuming.

According to journal [1], continuous input smoother (CIS) controller can pre-filter the input signal to prevent sudden changes that cause overshoot but is very troublesome as it require tuning for every different condition of operation. Journal [4] shows that the neural network controller is very suitable for non-linear operating condition but possess difficulties to simulate as there is no formal mathematical expression to operate it. Adaptive plus disturbance observer controller which will change the controller's gain according to the disturbance is also suitable but there is limitation where the dynamic changing speed is too fast for it to control, it also built based on approximation of non-linear experiment time response data which will cause error at certain point of depth. According to journal [1][2][4], fuzzy logic controller is suitable for ROV depth control as it is suitable for non-linear characterize operation, have a better response time compare to CIS controller, but require a very lengthy time to fine tune the controller. Therefore, fuzzy logic controller is chosen for this final year project.

Chapter 3

Methodology

There is many field of study for remotely operated underwater vehicle (ROV) according to the K-chart shown at figure 3.1. But, this final year project will only be focus on control system part of the ROV. Also, the experiments procedure can be found at appendix A if needed.

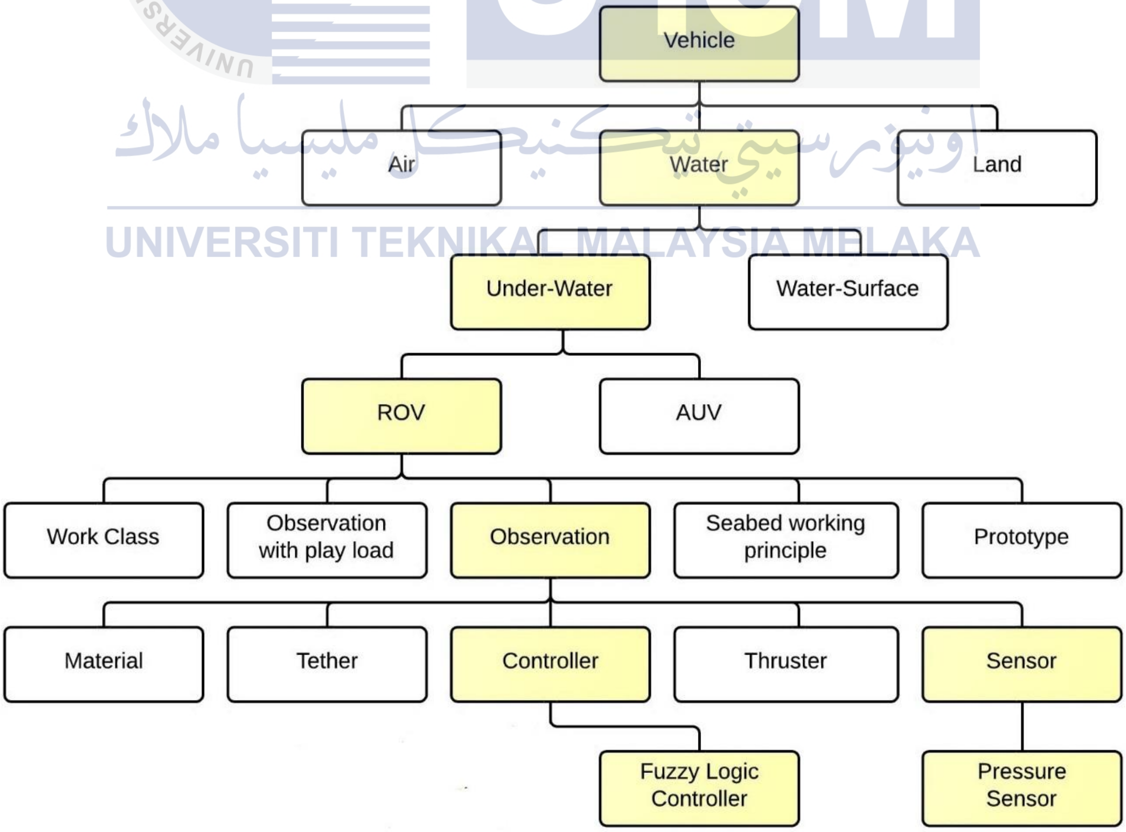

Figure 3.1-K-Chart of Vehicle

The Project flowchart is as shown as figure 3.2.

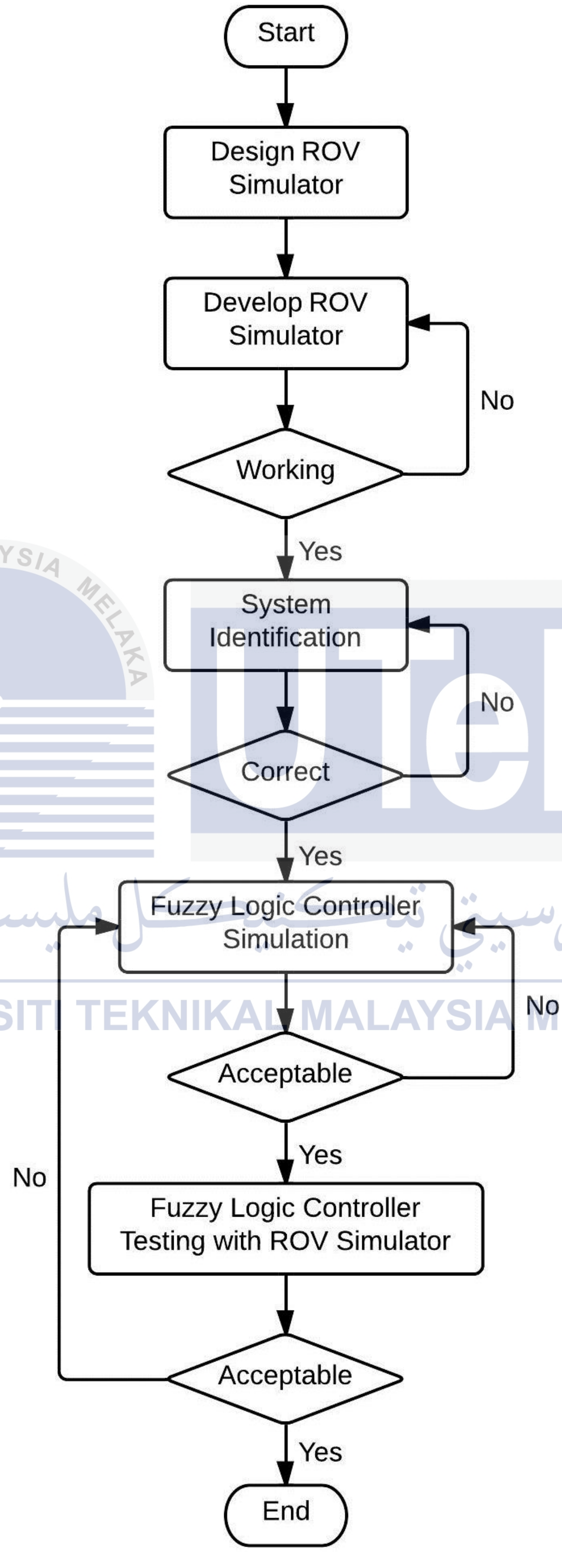

Figure 3.2- Project Flow Chart

3.1 ROV Simulator

Because of the reason that Micro 2000/2000C is very expensive, it is highly undesirable to test it underwater as water leakage may happen to the ROV. Therefore, a ROV simulator will be built to test it. The simulator have a pressure sensor to obtain data of pressure where will then being convert to depth and the pressure will be provided by a 12V mini air pump thru a pressure regulator. Other than that, there will be 4 thruster with propeller and its driver which will be attach to the railway on a frame. The railway will be at 2 feet long, 2 feet wide, and 1 feet tall. A controller module which included the PIC controller, National Instrument DAQ board, and Micro 2000/2000C will also be available.

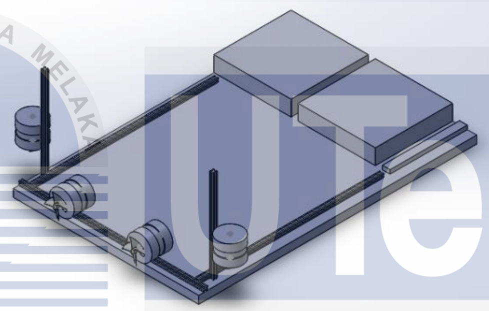

Figure 3.3-ROV Simulator

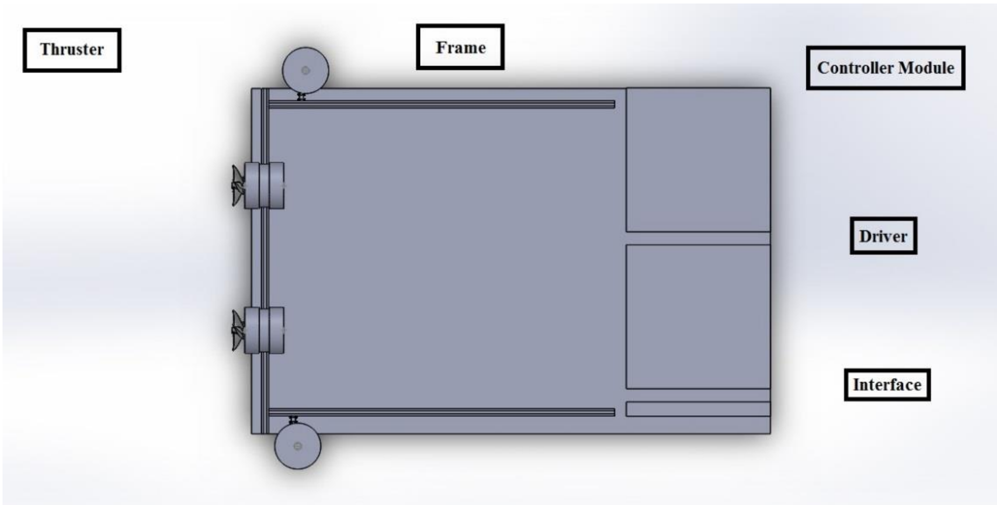

Figure 3.4-Layout of ROV Simulator

3.1.1 Pressure Sensor

The pressure sensor use in this project is MPX4250GP. This sensor can provide analog output signal and function-able in the water. It is commonly used in automotive field.

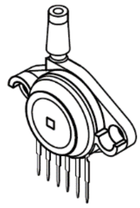

Figure 3.5-MPX4250GP Pressure Sensor

3.1.2 Driver

Driver used in this project is a Single Pole Double Throw type driver. It is basically a relay which works to operate the thruster. A signal is given to the driver to activate the relay and the driver will give the thruster external power source to operate. This is very crucial as thruster will draw many current to operate.

Figure 3.6-Thruster Driver

3.1.3 Thruster with Propeller

The thruster is the kinetic source of the ROV. Without the thruster with its propeller, the ROV cannot move underwater. Most thruster is brushless DC motor because no precision of thruster position is needed. The propeller is attach to the thruster to "cut" thru the water and move forward.

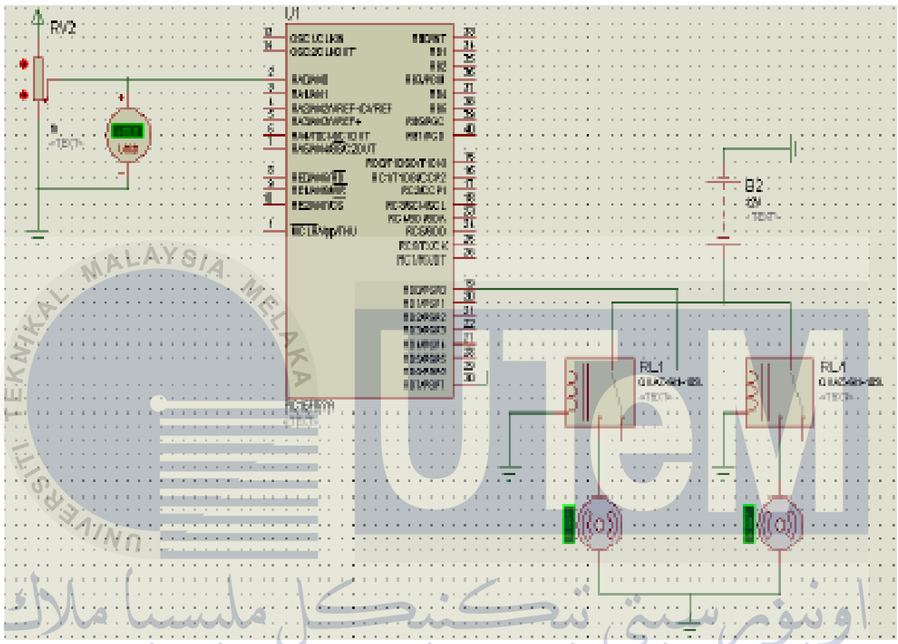

Figure 3.7-Thruster PROTEUS Circuit Simulation

3.2 Micro 2000/2000C

Micro 2000/2000C is a high performance, fan-less, low power consumption industrial PC. The Micro have interfaces for analog to digital input and digital to analog output. This industrial PC can works with MATLAB and Simulink which makes it a top choice for intelligent controller to work with. The size of it is merely 255mm X 152mm X 82mm and weight of 2.0KG only.

Figure 3.8-Micro 2000/2000C

3.3 Fuzzy Logic Controller

To implement the fuzzy logic controller to Micro2000/2000C it is require to write the programs in MATLAB and Simulink first. To design a close loop fuzzy logic controller, there will be need to perform experiment to obtain data from the pressure sensor's pressure input and voltage output accordingly. The data is then being process by MATLAB using system identification tools so that the transfer function can be obtain [8]. After obtain the transfer function, draw the block diagram as figure 3.8 for fuzzy logic controller using Simulink and insert the transfer function into the plant.

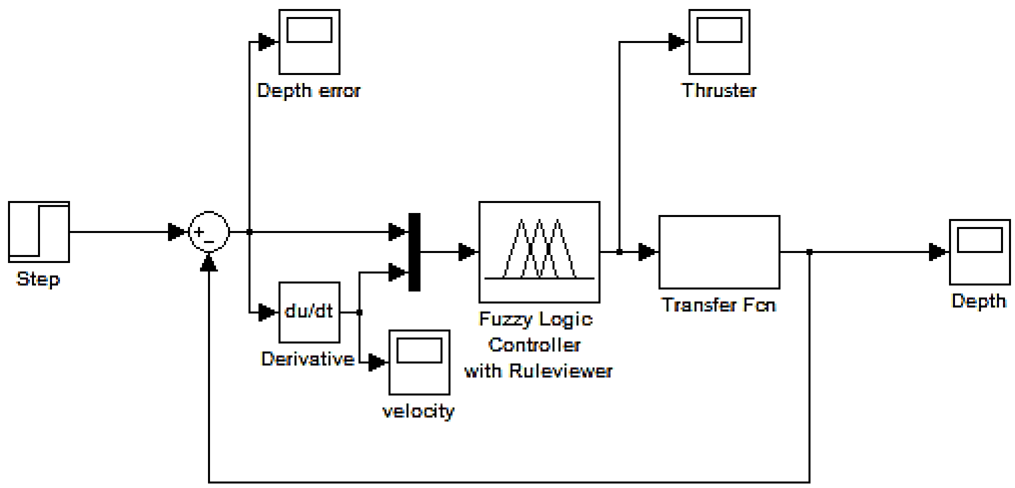

Figure 3.9-Fuzzy Logic controller Simulink Block Diagram

A 5X5 input membership function is chosen and the rule based is obtained using principle as of journal [7]. Using the fuzzy tool box in MATLAB, there will be a window which show FIS editor as shown as figure 3.9. Insert the input membership function and output membership function to the membership function editor of FIS editor as shown as figure 3.10 Rules editor in FIS editor is used to insert the rule based of the system as shown as figure 3.11. After saving the FIS file and export it to the Simulink fuzzy logic controller block diagram, run a simulation of it and obtain the result of it. Fine tune of the fuzzy logic controller by adjusting the output membership function have to be done if the result of the simulation is not suitable. The fine tune process have to be done according to journal [7] in order to ease the process of fine tuning as fine tuning a fuzzy logic control system is based on trial an error method and is very time consuming.

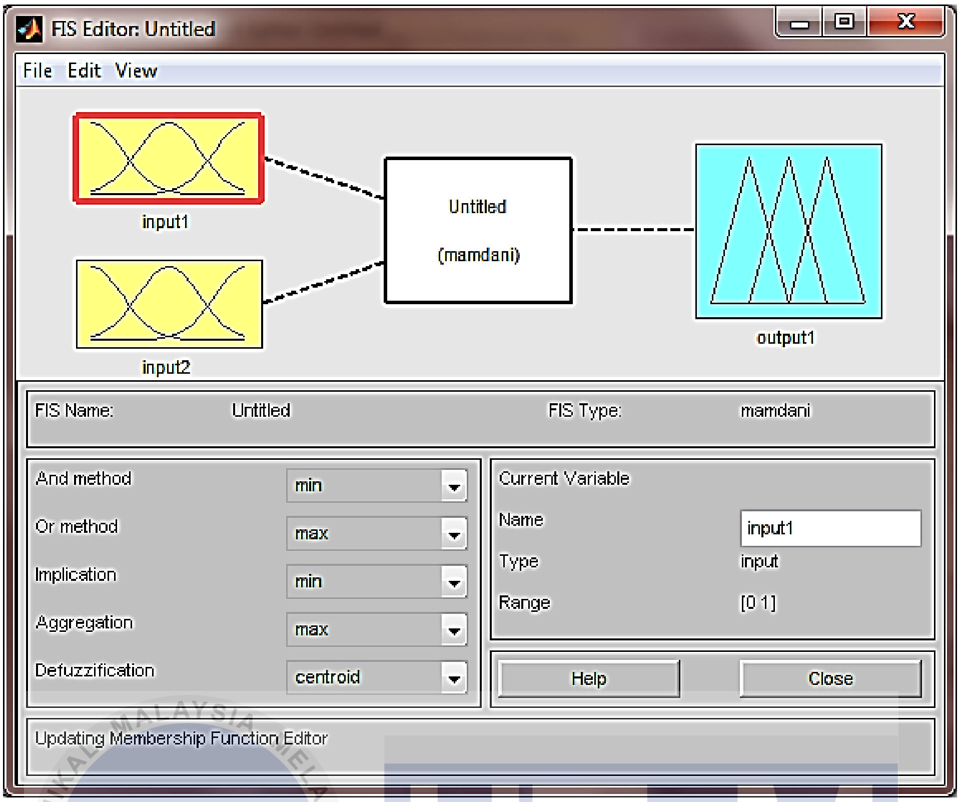

Figure 3.10-FIS Editor

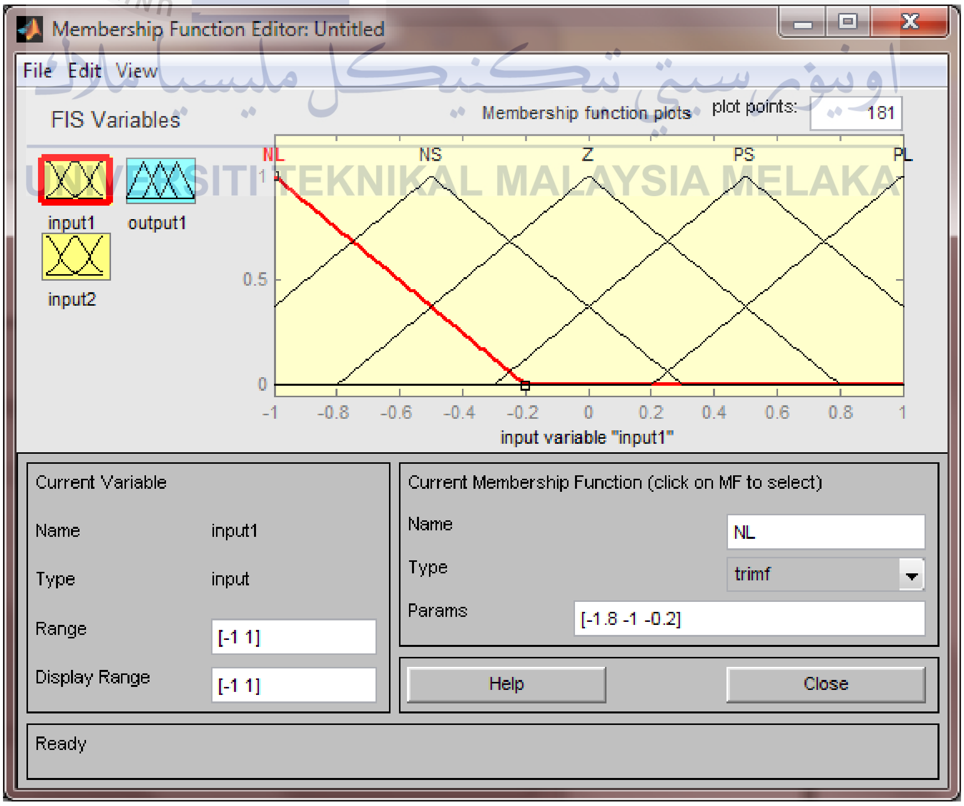

Figure 3.11-Membership Function Editor

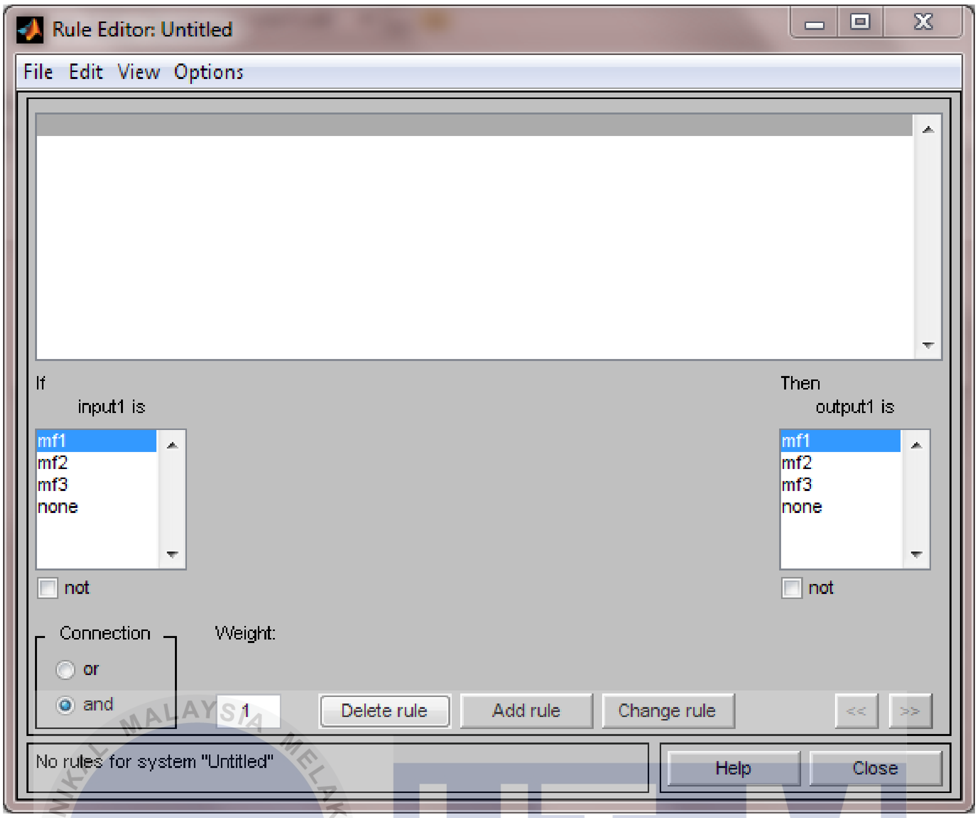

Figure 3.12-Rule Editor

3.4 Experiment

3.4.1 Experiment 1: ROV Simulator

This experiment was meant to design a ROV Simulator which will not be place underwater. The simulator consist of PIC manual controller, PIC autonomous controller, NI DAQ board, Hilink module, manual driver, and autonomous driver.

3.4.1.1 Flow Chart

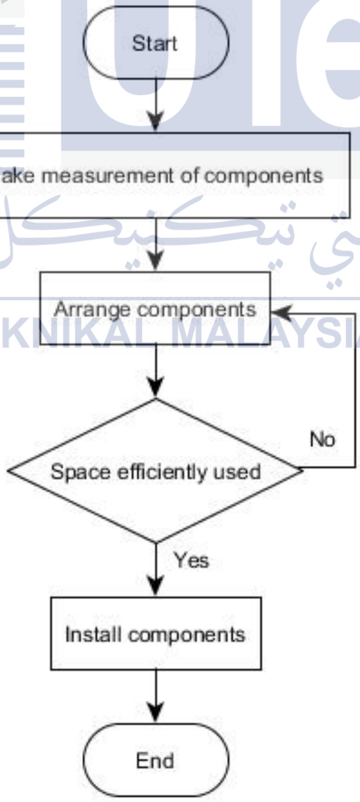

Figure 3.13- Flow chart for experiment 1

3.4.2 Experiment 2: Pressure sensor

This experiment was designed so that the pressure sensor's characteristic can be determined. For this pressure sensor, the most important factor is what output voltage value is correspond with what pressure value. When the characteristic of the pressure sensor being determined, the data will be used while convert the output voltage value to pressure accordingly.

3.4.2.1 Flow Chart

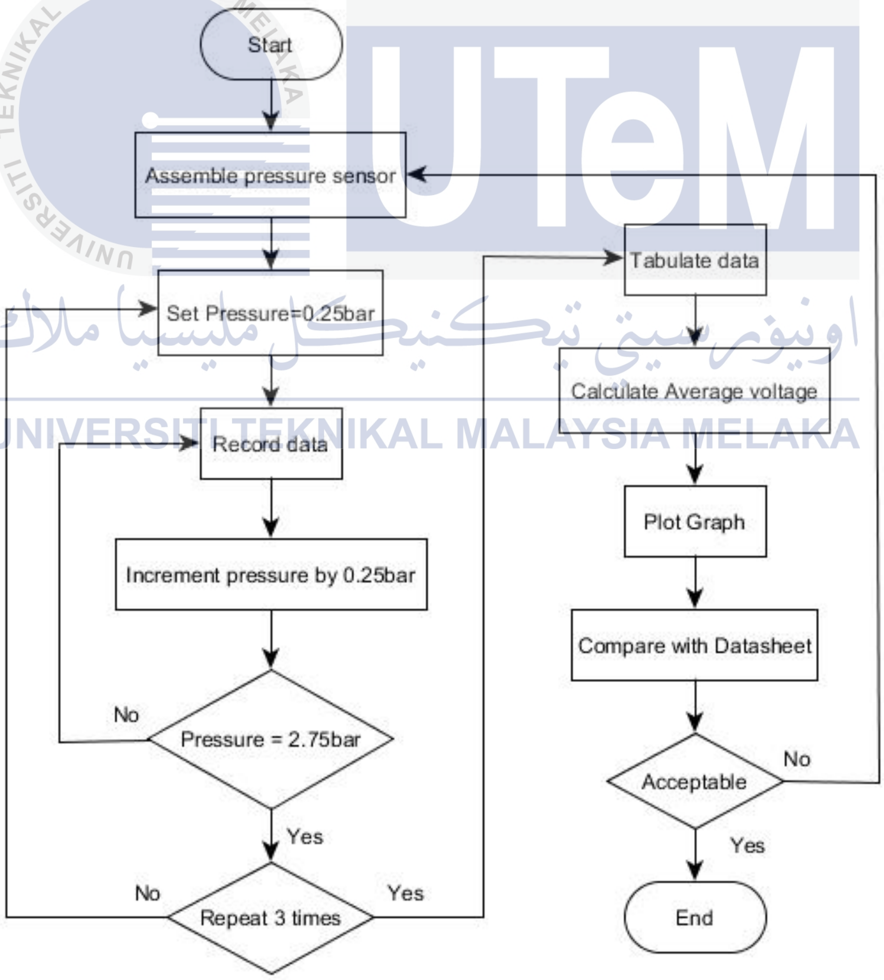

Figure 3.14- Flow chart for experiment 2

3.4.2.2 Experiment record

The equipment needed was prepared as follow,

Figure 3.15 - Multimeter

Figure 3.16 –Pressure sensor regulating circuit

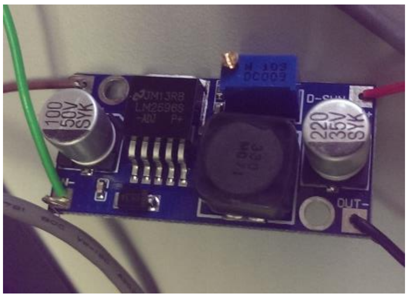

Figure 3.17 – Step-down voltage regulator

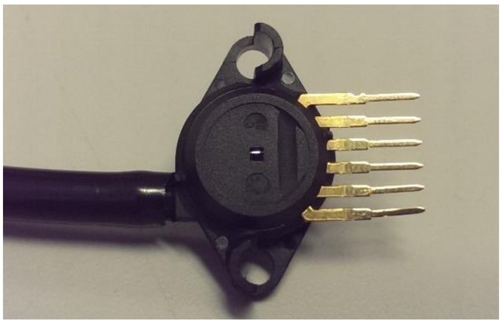

Figure 3.18 – Pressure Sensor

The Assembly of the equipment was done as follow,

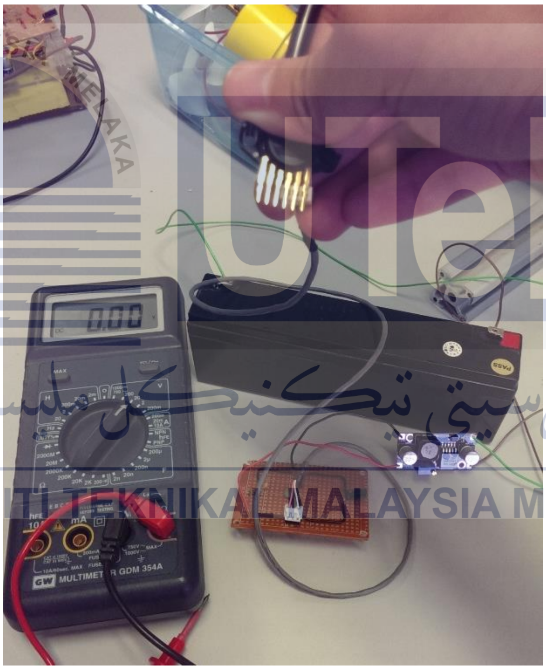

Figure 3.19 – Experiment set up for pressure sensor experiment

After assembly the components, the data was recorded and repeated for 3 times to get an average value. The data is then tabulated in Microsoft Excel and plot it as a graph. The sensor's real voltage value versus pressure was then compare and shown in Chapter 4.

3.4.3 Experiment 3: Fuzzy Logic Controller simulation using MATLAB

3.4.3.1 Flow Chart

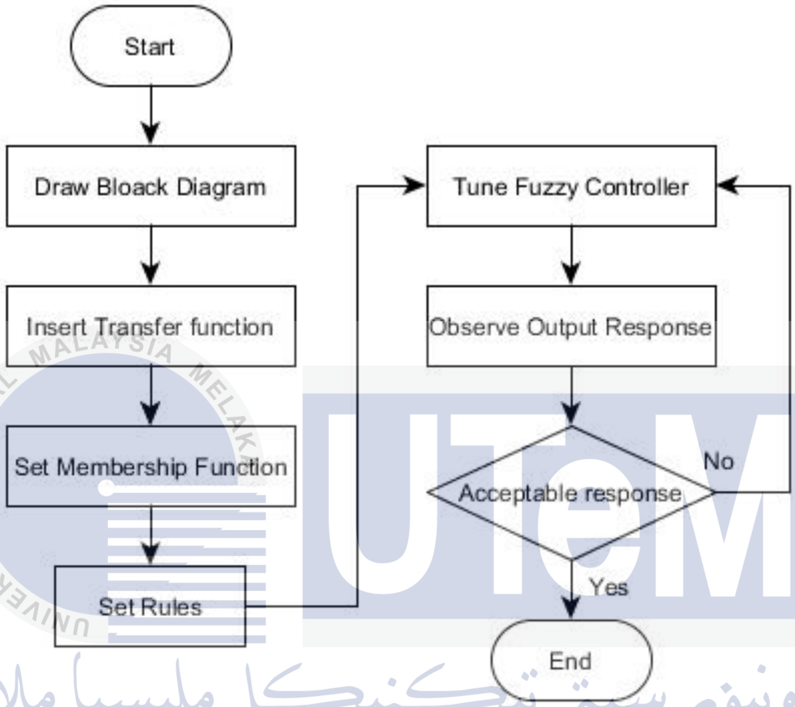

Figure 3.20- Flow chart for experiment 3

3.4.3.2 Experiment record

The block diagram was built by using MATLAB Simulink as figure 3.21 and the membership function was set as figure 3.22 to figure 3.24. The transfer function,

$$\frac{0.4147S^2 + 25.42S + 22.59}{S^3 + 3.78S^2 + 54.62S + 28.9} \tag{3.1}$$

was obtain from journal[11]. The rules was set by rules editor as according to table 3.1. Tick the 'save data to workspace' option and set it to 'structure with time' for the scope parameters of scope under data history tab as shown as figure 3.25. Set the step input to 3 which indicates 3 meters. Run the simulation after export the fuzzy logic controller setting to the block diagram. After that, plot the graph by using MATLAB ‘plot(ScopeData.time, ScopeData.signals.values)’ command. By doing so, the y-axis of the graph will show the set point meter and x-axis for time as figure 3.26.

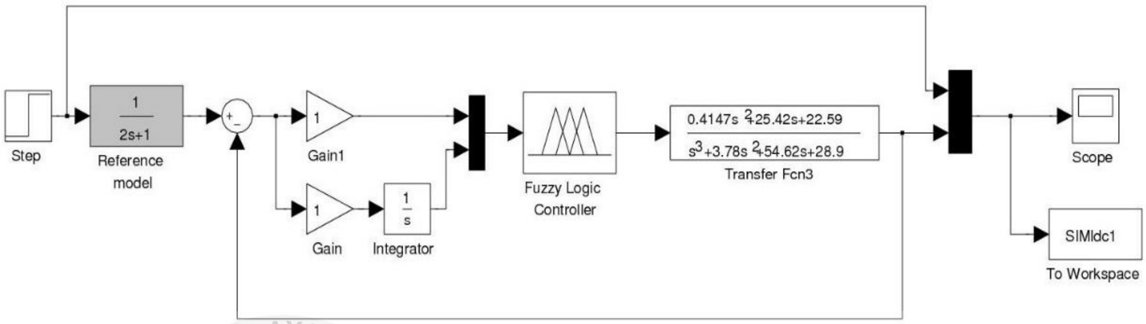

Figure 3.21 - Simulink Block Diagram

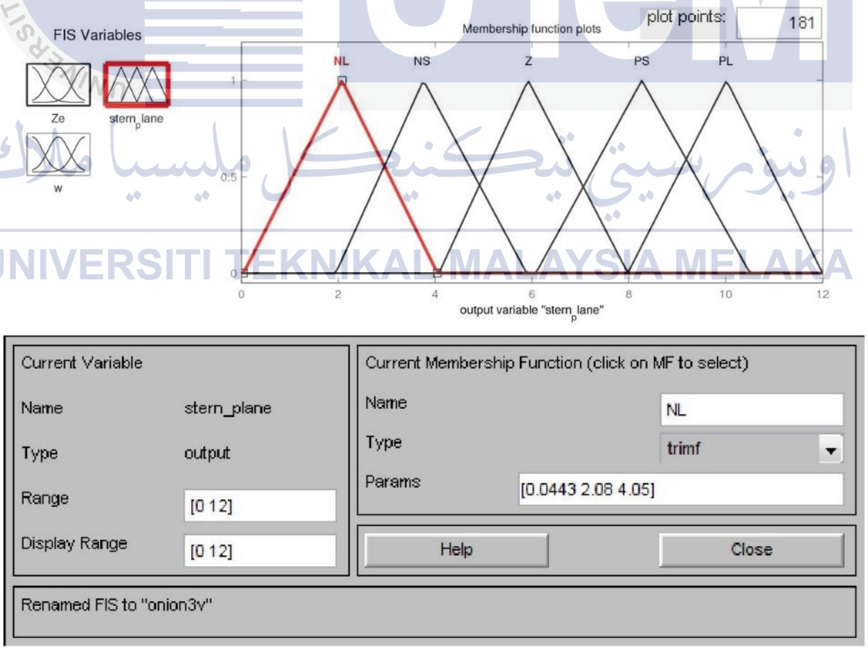

Figure 3.22- Output membership function

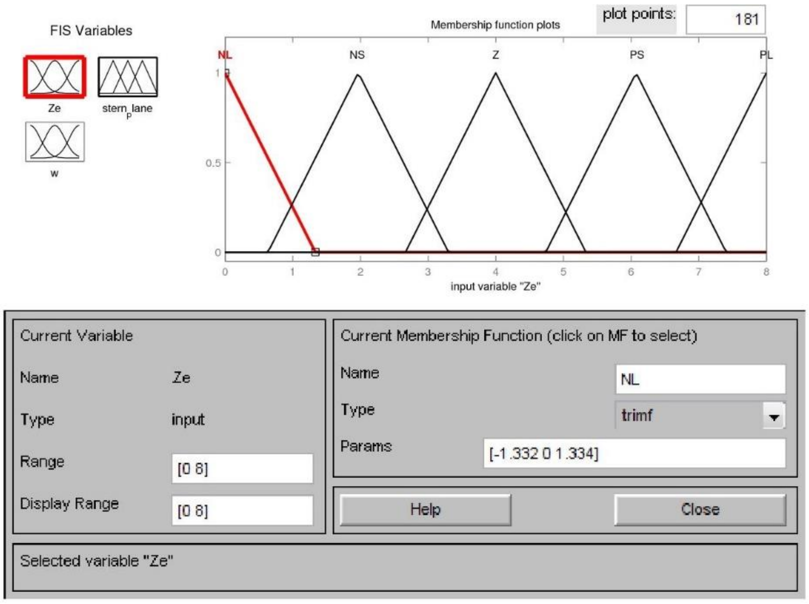

Figure 3.23-Input membership function (error)

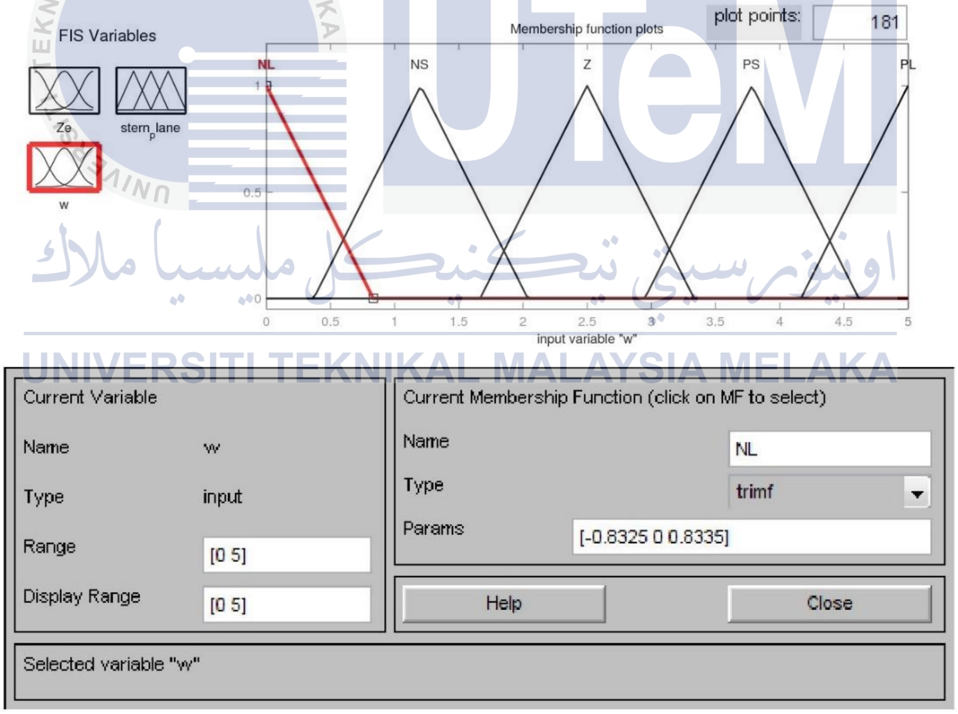

Figure 3.24-Input membership function (Integral of error)

Table 3.1- Fuzzy logic controller rules

e/s \ e	NL	NS	Z	PS	PL
NL	NL	NL	NL	NS	Z
NS	NL	NS	NS	Z	PS
Z	NL	NS	Z	PS	PL
PS	NS	Z	PS	PS	PL
PL	Z	PS	PL	PL	PL

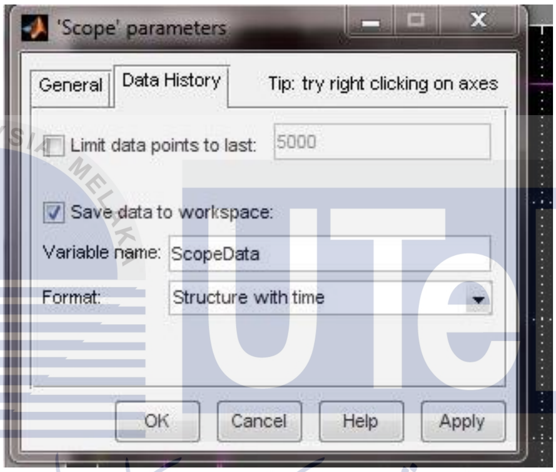

Figure 3.25- Scope parameters setting

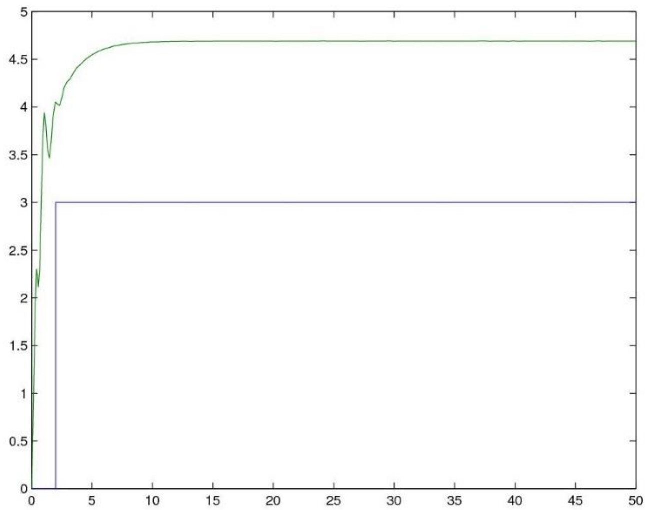

Figure 3.26- Initial output response

3.4.4 Experiment 4: Effect of zero output membership function of transfer function Fuzzy Logic Controller using MATLAB

This experiment was meant to use the tuned fuzzy logic controller to simulate and study the effect of adjusting zero output membership function. The zero membership function is the middle membership function labeled “Z” from output membership function plot. The data will be analyze and the general overview on the effect of the adjustment of zero output membership function will be determined. The general overview of the adjustment will be able to provide others finite help on what should be done while tuning fuzzy logic controller.

3.4.4.1 Flow Chart

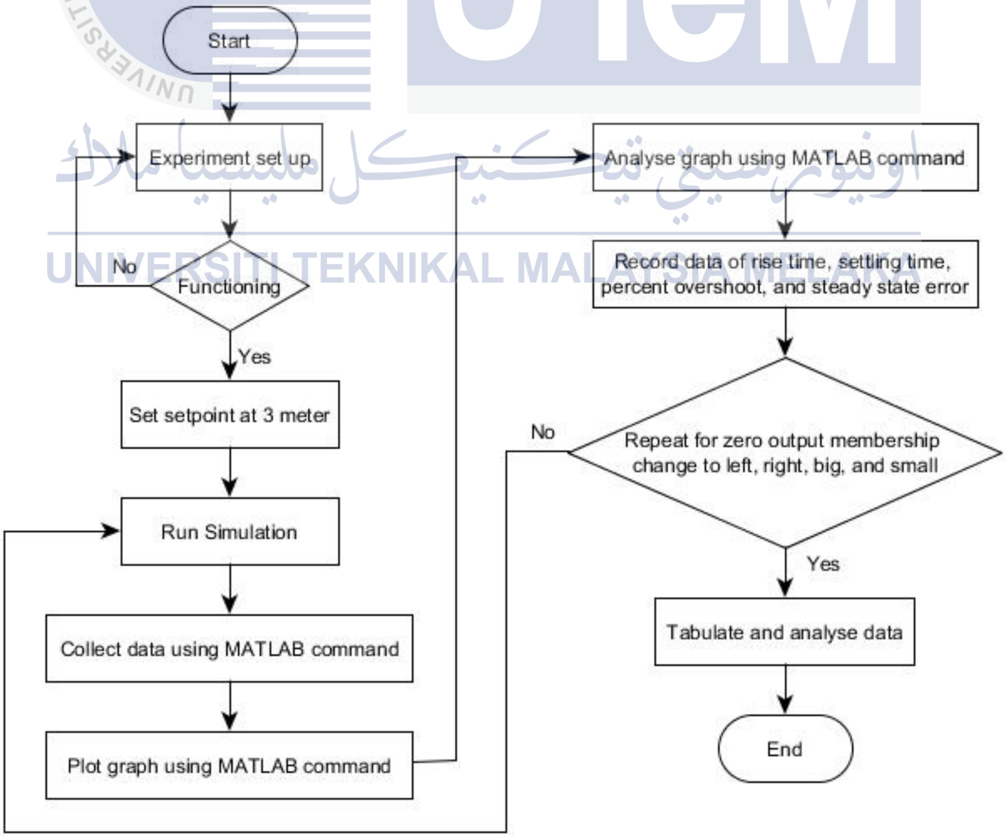

Figure 3.27- Flow chart for experiment 4

3.4.4.2 Experiment Record

The tuned fuzzy logic controller was simulated to obtain the data. Tick the ‘save data to workspace’ option and set it to ‘structure with time’ for the scope parameters of scope under data history tab as shown as figure 3.25. Run the simulation after export the fuzzy logic controller setting to the block diagram. After that, plot the graph by using MATLAB plot(x,y) command. The MATLAB ‘stepinfo(ScopeData.signals.values(row,column), ScopeData.time, set point)’ was used to obtain the data from the time response graph as shown as figure 3.28. Repeat the simulation for different zero membership function adjustment as shown as figure 3.29 to figure 3.38. The data is then being tabulated in Microsoft Excel and a comparison was made at Chapter 4. The naming for the shifting is as follow,

Center = Original zero membership function

Left = Zero membership function shifted to left

Right = Zero membership function shifted to right

Big = Scale of zero membership function enlarged

Small = Scale of zero membership function reduced


```
>> plot(ScopeData.time,ScopeData.signals.values)
>> S = stepinfo(ScopeData.signals.values(1:190,2),ScopeData.time,3)
??? Index exceeds matrix dimensions.

>> S = stepinfo(ScopeData.signals.values(1:189,2),ScopeData.time,3)

S =

        RiseTime: 10.2403
    SettlingTime: 18.2300
     SettlingMin: 2.3881
     SettlingMax: 3.1143
       Overshoot: 3.8098
      Undershoot: 0
            Peak: 3.1143
        PeakTime: 17.9364
```

Figure 3.28- MATLAB command

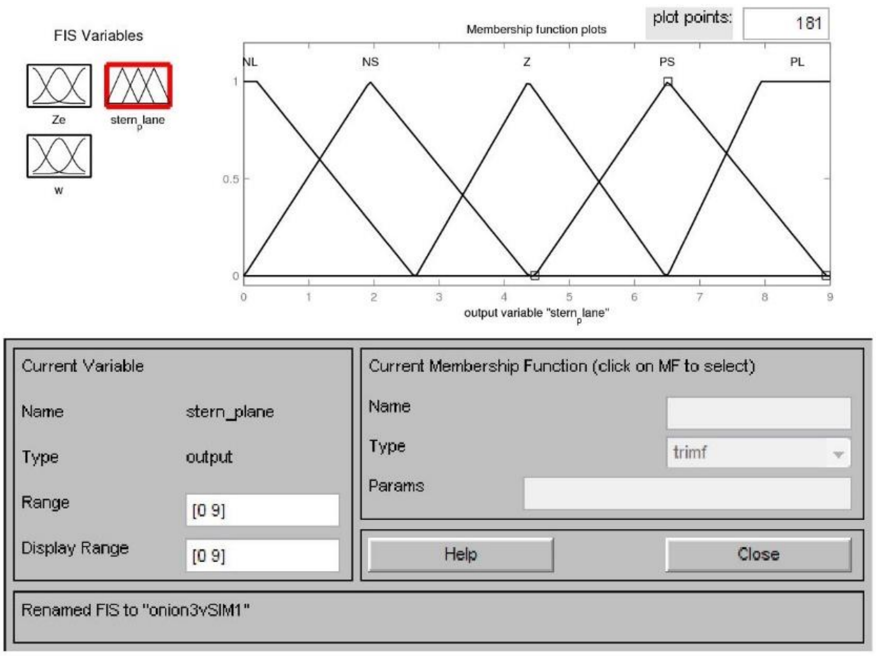

Figure 3.29- Original output membership function "center"

Figure 3.30- Original graph of depth vs time for "center"

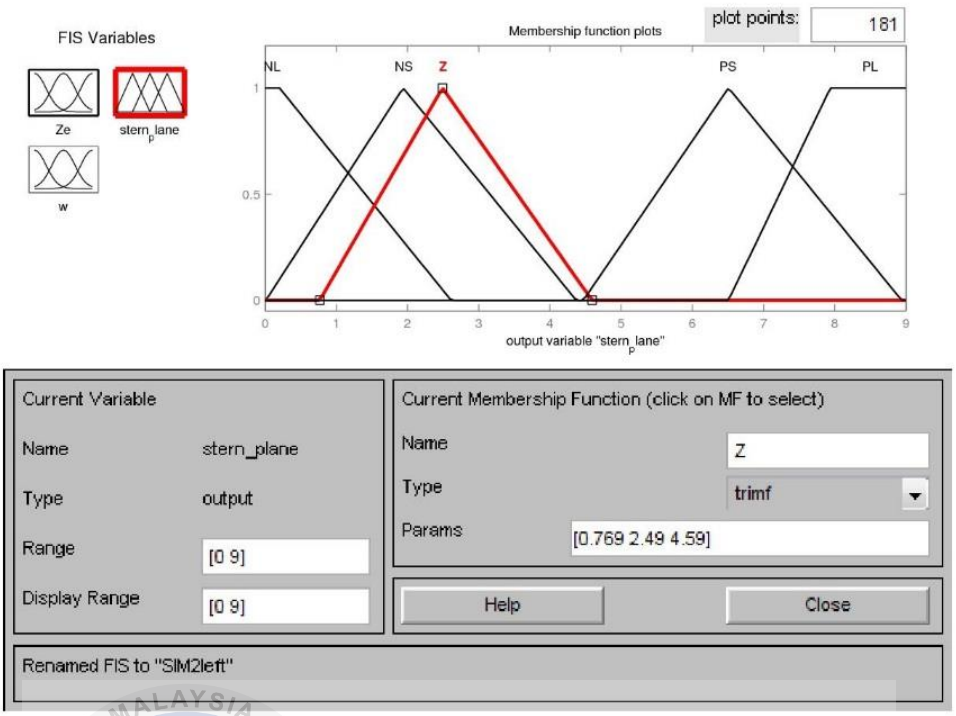

Figure 3.31-Output membership function "left"

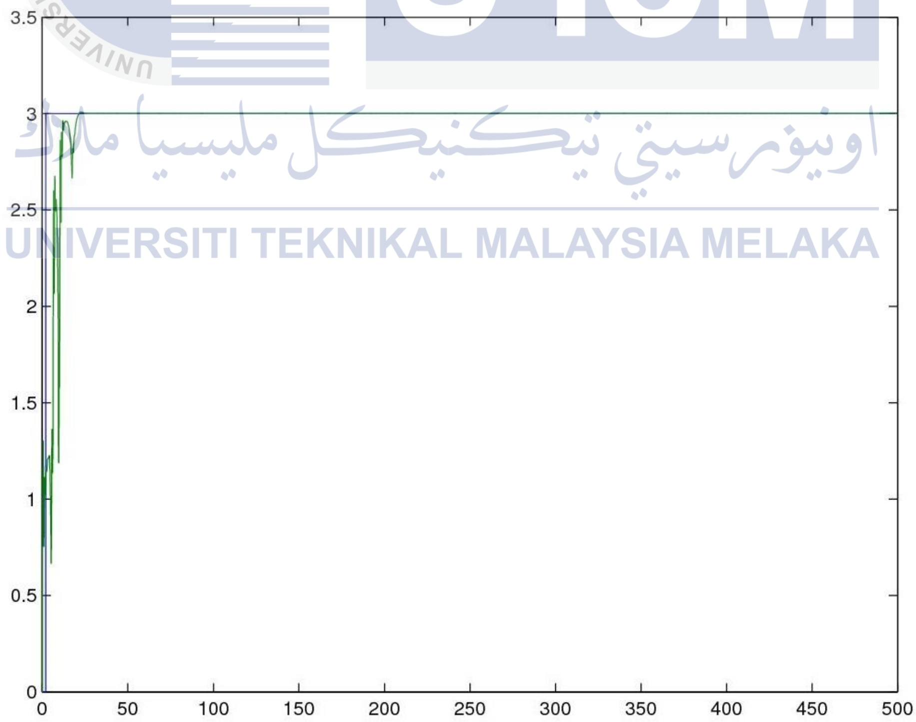

Figure 3.32- Graph of depth vs time for "left"

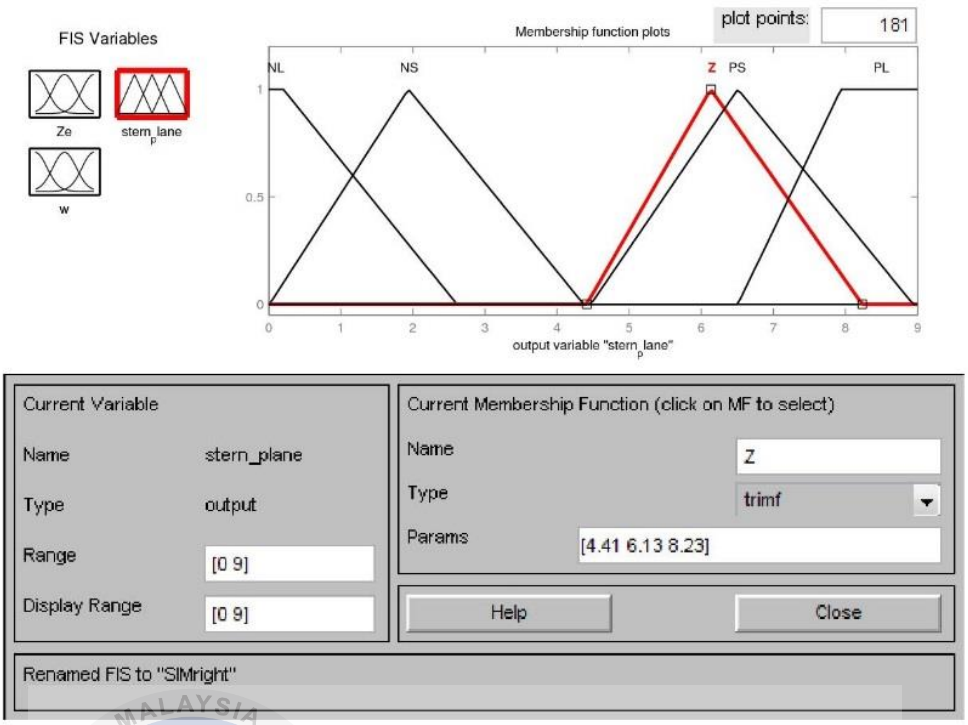

Figure 3.33-Output membership function "Right"

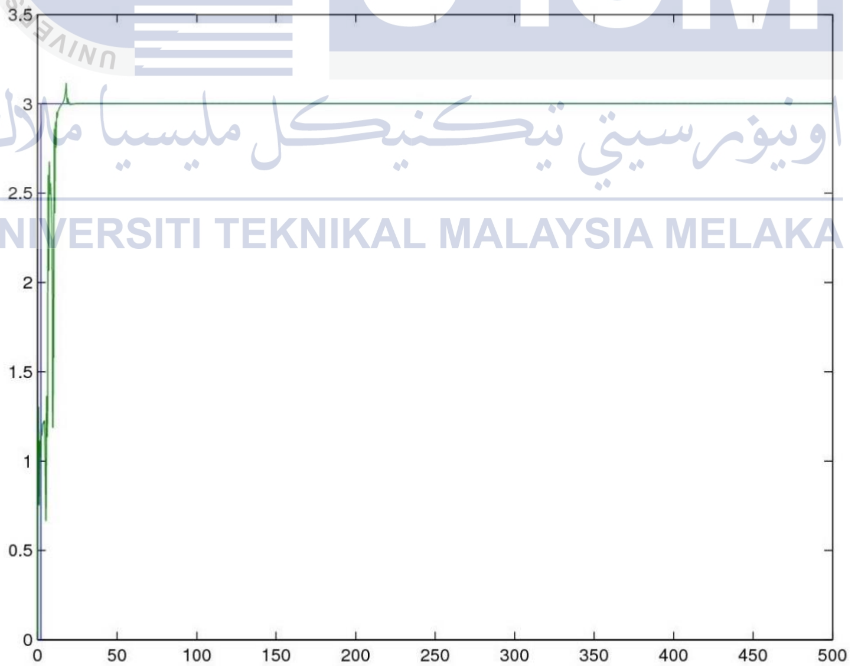

Figure 3.34- Graph of depth vs time for "right"

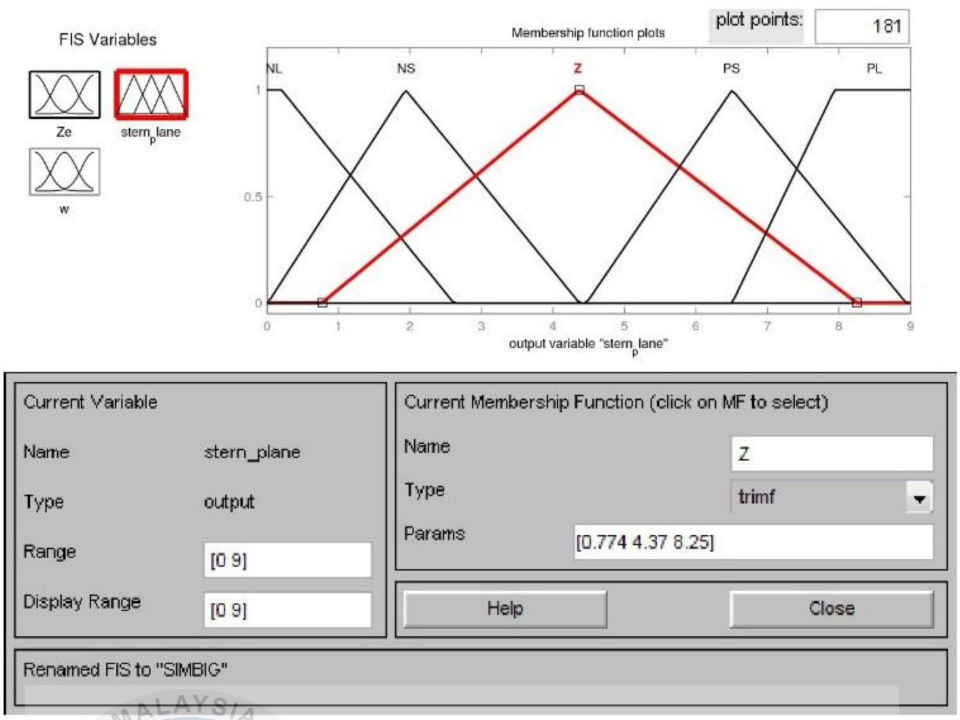

Figure 3.35- Output membership function "big"

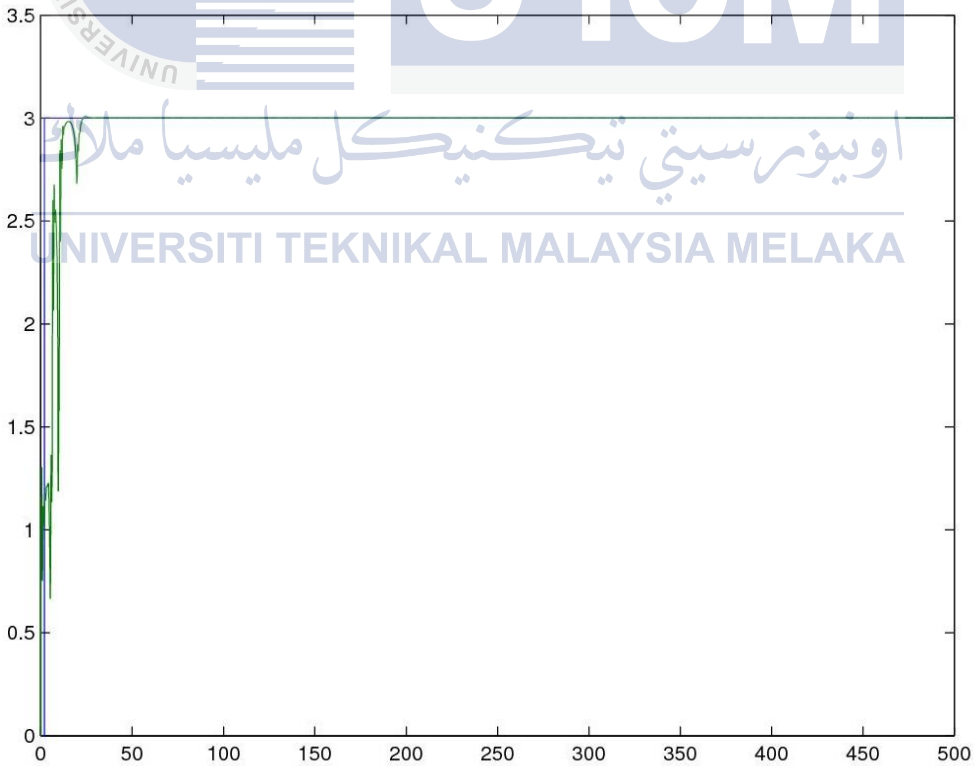

Figure 3.36- Graph of depth vs time for "big"

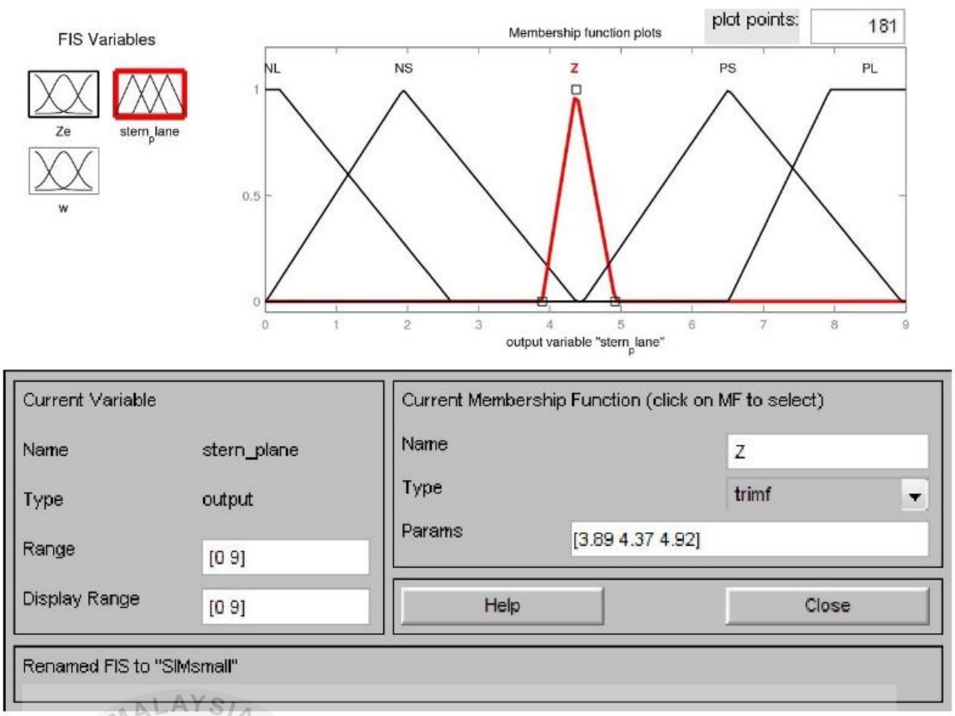

Figure 3.37- Output membership function "small"

Figure 3.38- Graph of depth vs time for "small"

3.4.5 Experiment 5: Effect of zero output membership function of real-time Fuzzy Logic Controller using Micro 2000/2000C with ROV Simulator

This experiment was design to use the tuned fuzzy logic controller to perform real-time control and study the effect of adjusting zero output membership function. The data will be analyze and the general overview on the effect of the adjustment of zero output membership function will be determined. This will also act as a medium to further verify the conclusion of experiment 4. The general overview of the adjustment will be able to provide others finite help on what should be done while tuning fuzzy logic controller.

3.4.5.1 Flow Chart

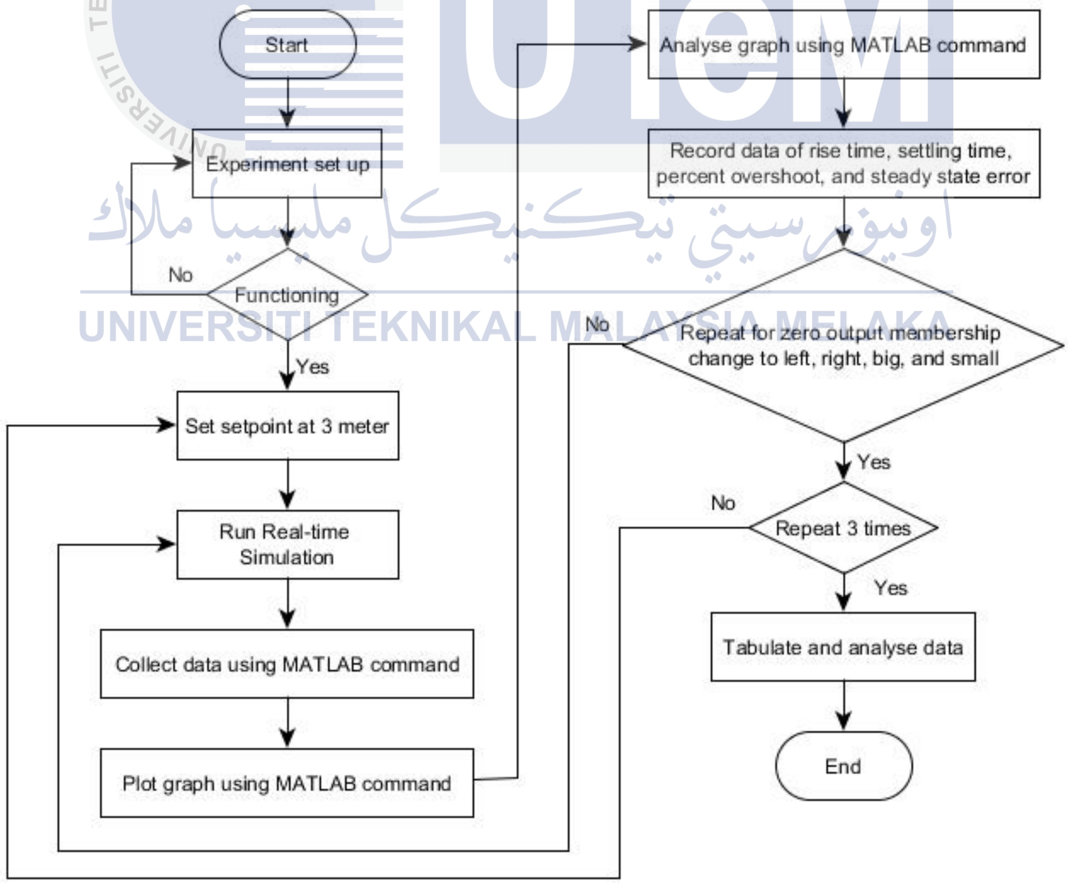

Figure 3.39- Flow chart for experiment 5

3.4.5.2 Experiment record

The needed equipment to perform the experiment such as Micro 2000/2000C, Thruster driver, mini air compressor, thruster, pressure sensor, and pressure sensor circuit is as figure 3.40 to figure 3.44. The thruster and sensor was connected to the connector of Micro 2000/2000C as shown as figure 3.45 and table 3.2. The assembled experiment setup is shown as figure 3.46. The block diagram used for the experiment was shown as figure 3.47 and figure 3.48 and the fuzzy logic controller setting is the same as for experiment 4. Figure 4.8 shows a voltage to meter conversion subsystem referring to mathematical derivation from equation 4.6 and equation 4.7 The Micro 2000/2000C was then being interfaced with MATLAB and the exact same MATLAB command as of experiment 4 was being used to collect the data. The data was then being analyze to obtain information of rise time, settling time, percent overshoot, steady state error and the effect of zero output membership function adjustment.

Figure 3.40-Micro 2000/2000C

Figure 3.41- Thruster driver

Figure 3.42- Mini air compressor

Figure 3.43- Thruster

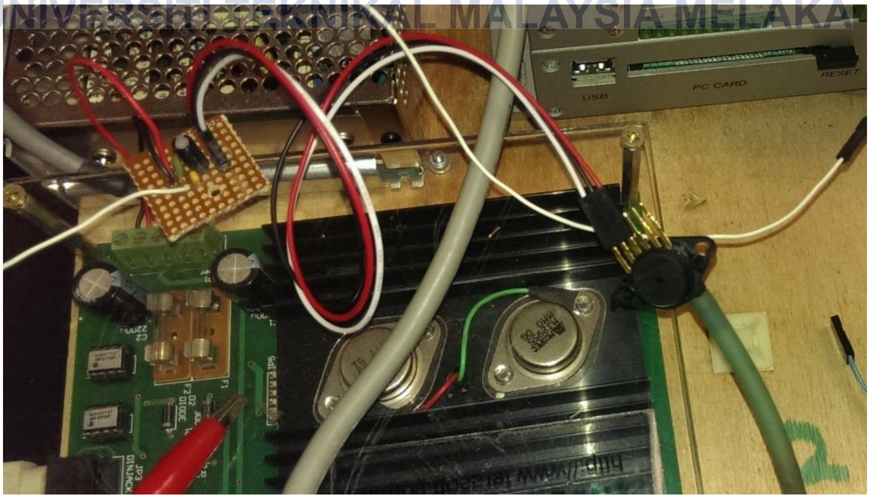

Figure 3.44- Pressure sensor and its circuit

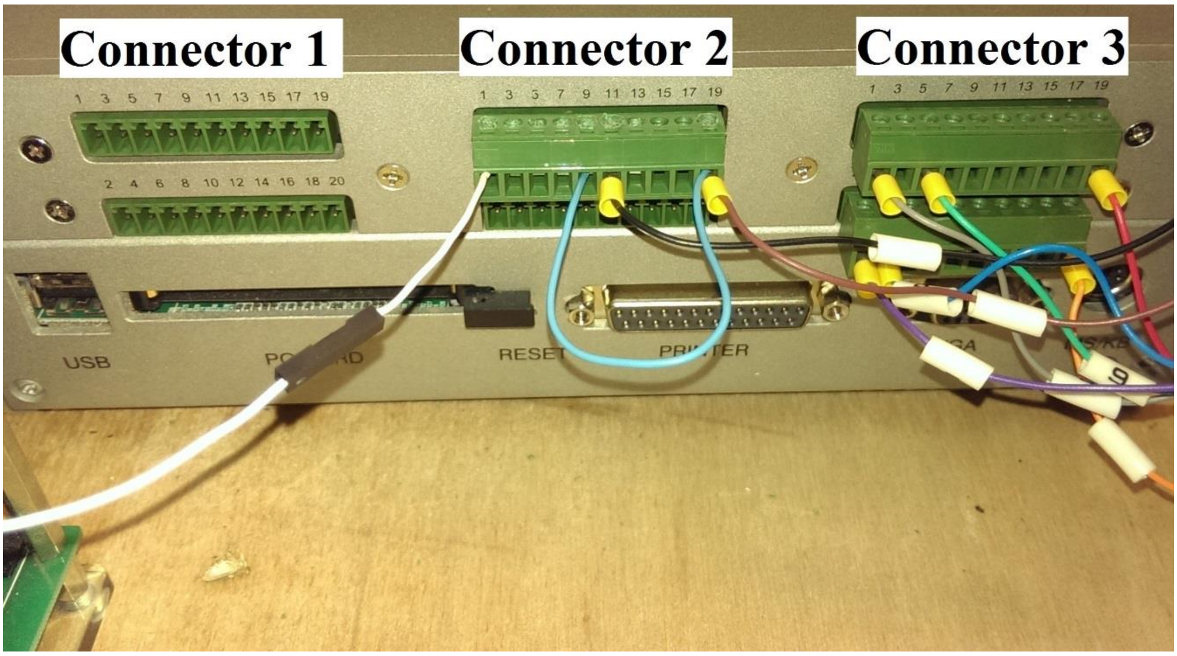

Figure 3.45- Micro connector arrangement

Table 3.2- Micro 2000/2000C connection with sensor and thruster

Component		Connector 2	Connector 3
Pressure sensor	Analog to Digital	1	
	AD ground	9	
Thruster	Digital to Analog	11	
	Ground	19	19

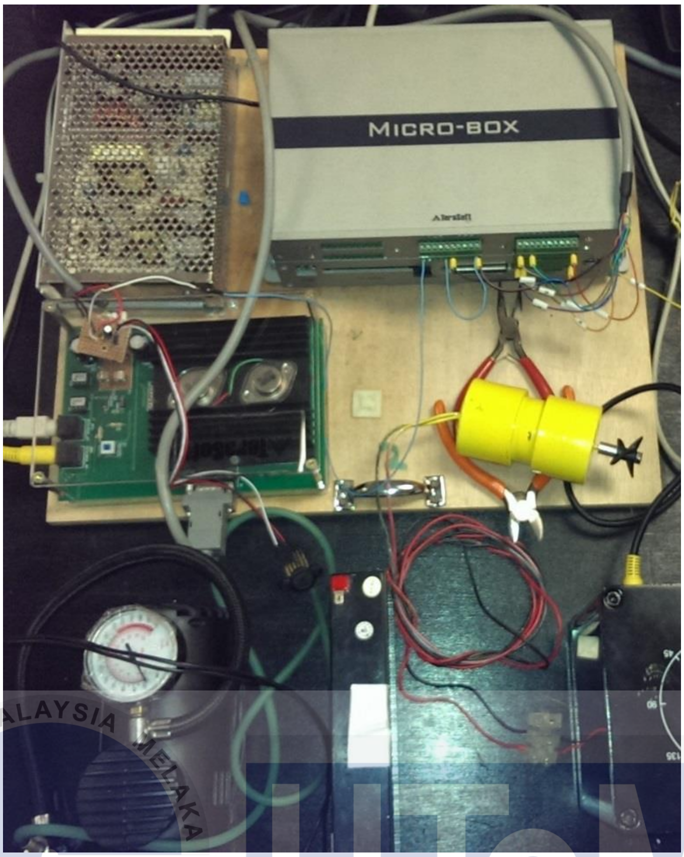

Figure 3.46- Setup for experiment 5

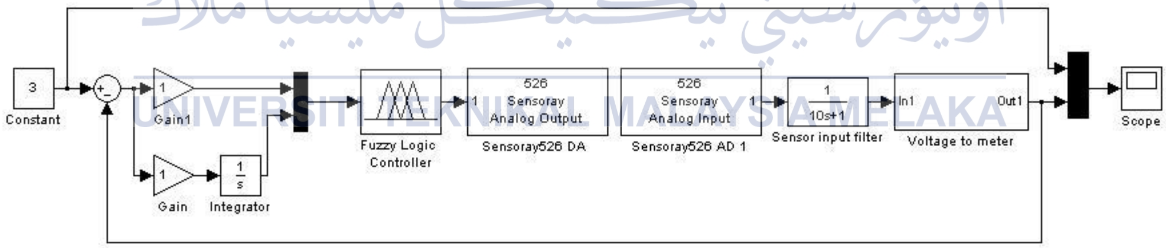

Figure 3.47- Block diagram for real-time control

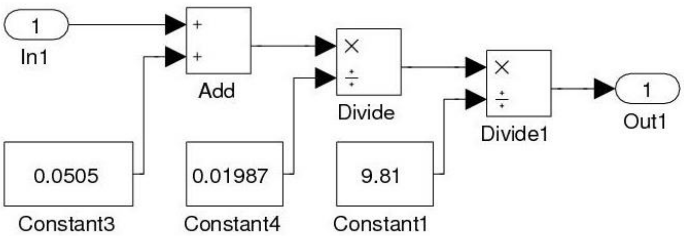

Figure 3.48- Voltage to meter conversion subsystem

Chapter 4

Results

4.1 Overview

This section will shows, tabulate, and analyze data being collected during the experiments

4.2 Experiment 1: ROV Simulator

To build the ROV simulator, the components was measured, arranged, and installed as shown as figure 4.1 and figure 4.2.

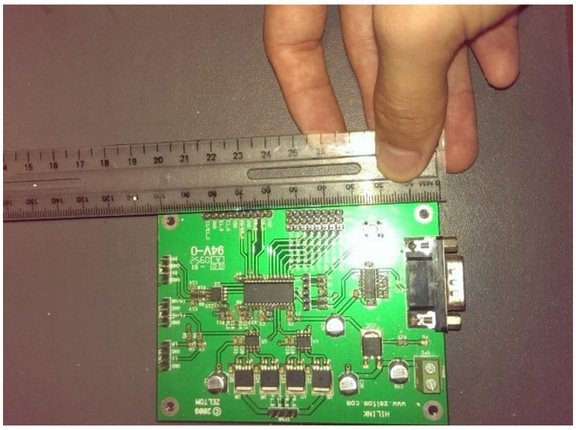

Figure 4.1- Measurement of components

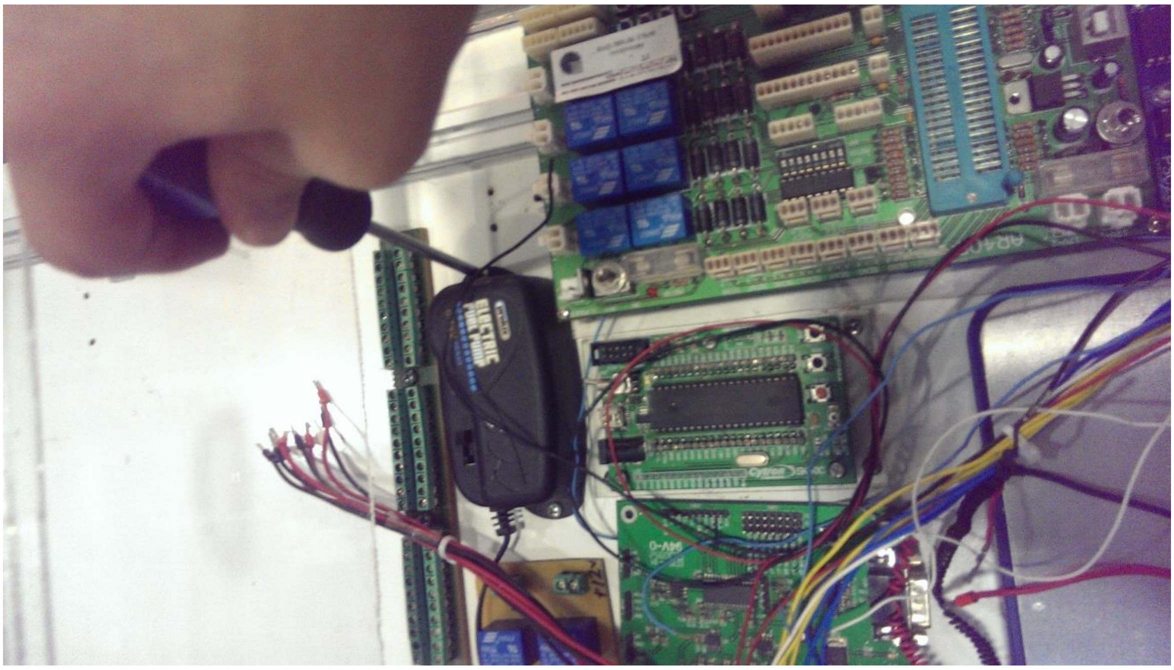

Figure 4.2- Installation of components

The ROV Simulator had been built according to the design and the thruster system function as expected.

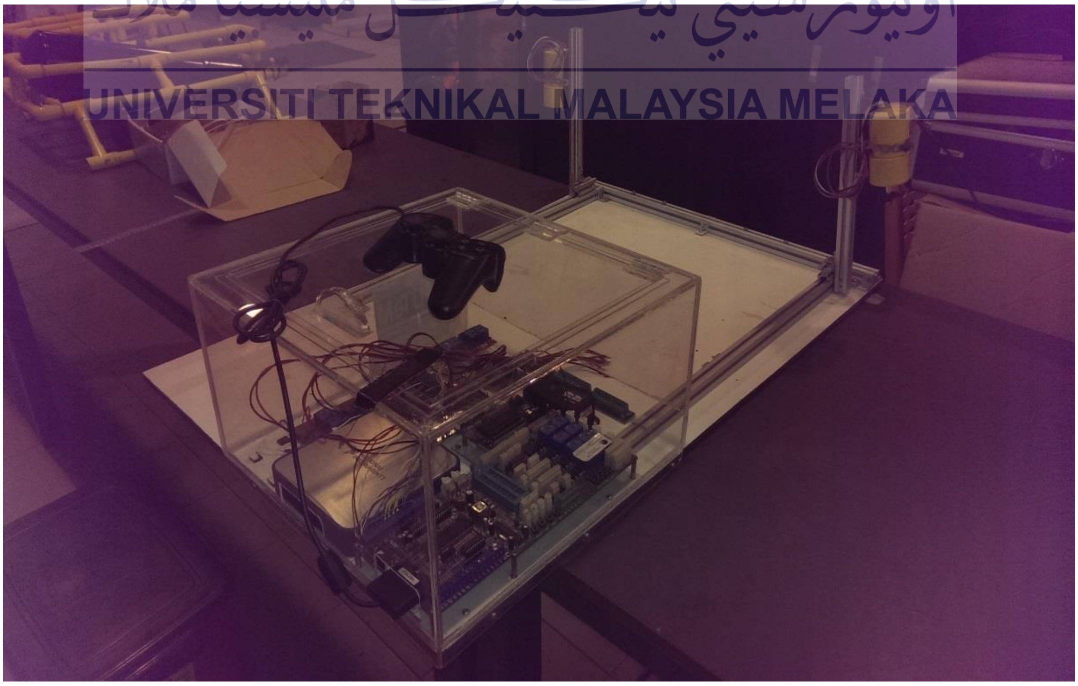

Figure 4.3-ROV Simulator

4.3 Experiment 2: Pressure sensor

The depth was converted using formula as refer to [12],

$$P = \rho g h \quad (4.1)$$

Where P = pressure (Pa)

ρ = density of water (1000 kgm^{-3})

g = gravity (9.81ms^{-2})

h = depth (m)

Therefore,

$$P = \rho g h$$

$$h = \frac{P}{\rho g}$$

$$h = \frac{P}{9810} \quad (4.2)$$

Table 4.1- Table of pressure to depth vs voltage

Pressure		Depth (m)	Voltage (V)			
Bar	kPa		V1	V2	V3	Average
0.25	25	2.55	0.44	0.46	0.46	0.45
0.50	50	5.10	0.96	0.98	1.00	0.98
0.75	75	7.65	1.44	1.45	1.44	1.44
1.00	100	10.19	1.99	2.00	1.98	1.99
1.25	125	12.74	2.46	2.44	2.46	2.45
1.50	150	15.29	2.93	2.92	2.93	2.93
1.75	175	17.84	3.43	3.42	3.43	3.43
2.00	200	20.39	3.89	3.89	3.88	3.89
2.25	225	22.94	4.56	4.54	4.54	4.55
2.50	250	25.48	4.84	4.83	4.85	4.84
2.75	275	28.03	4.85	4.84	4.85	4.85

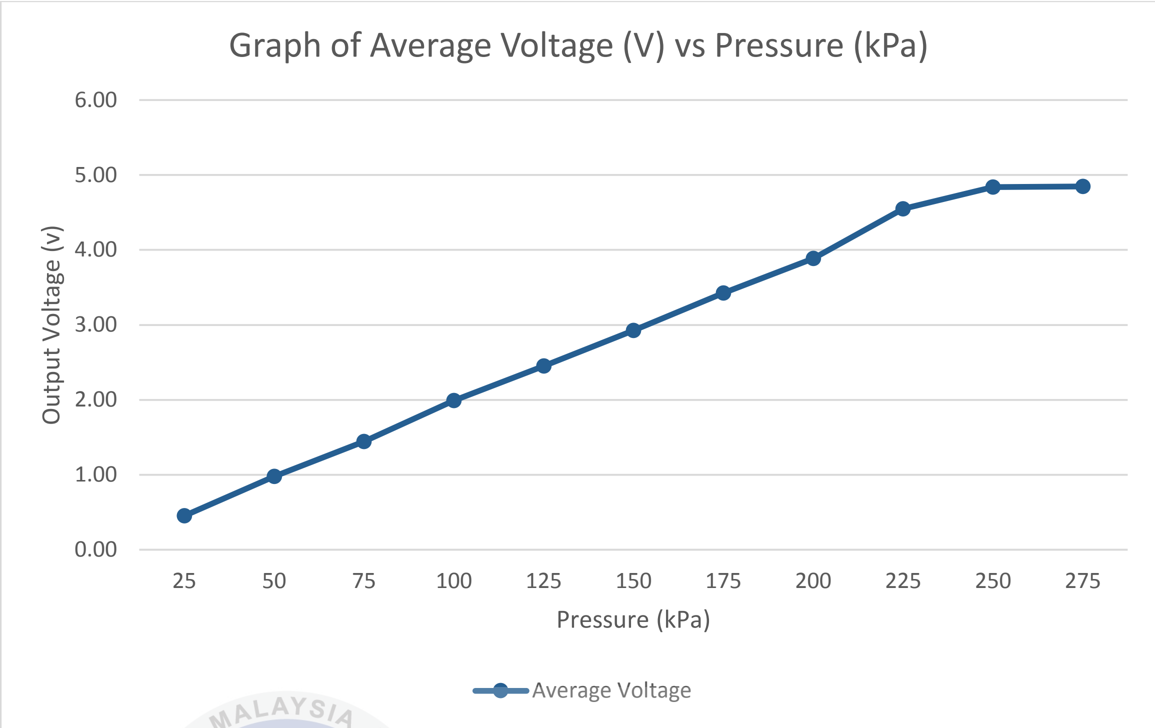

Figure 4.4- Graph of voltage vs pressure for pressure sensor

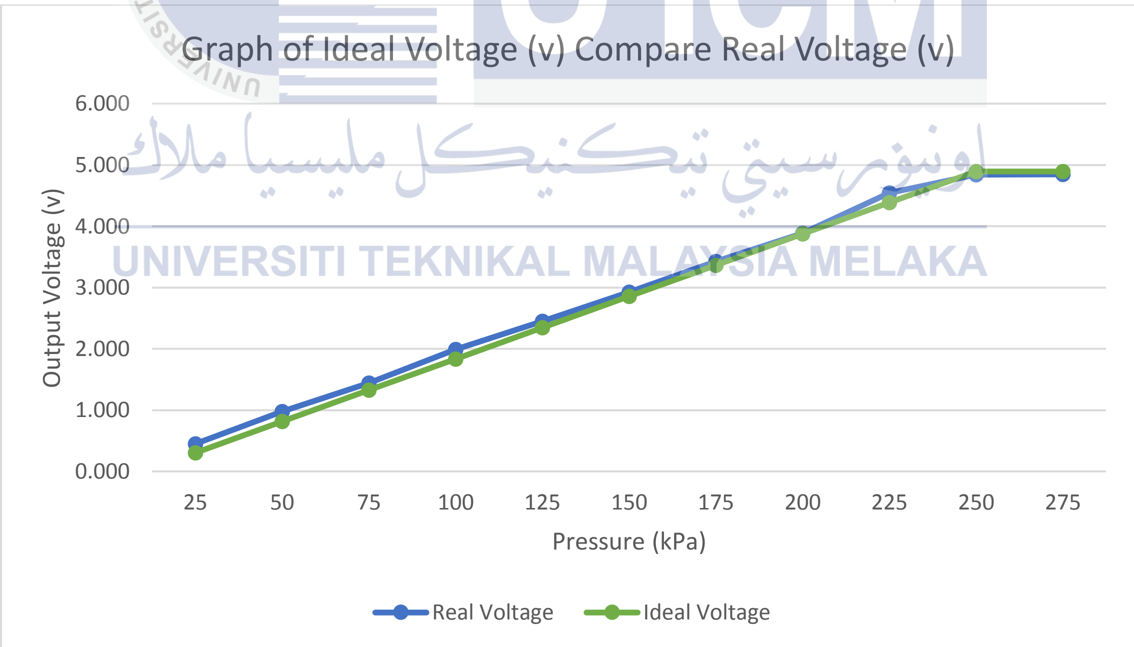

Figure 4.5- Graph of Ideal voltage compare to real voltage

The output voltage of the experiment was taken 3 times to ensure that random and systematic errors can be reduce as much as possible. To calculate the average value of the output voltage can refer to equation 4.3. The ideal voltage referring to figure 4.5 is obtain form datasheet [10] and real voltage refer to the output voltage obtained from experiment.

$$V_{average} = \frac{V_1 + V_2 + V_3}{3} \tag{4.3}$$

To implement the data for real-time control block diagram in MATLAB Simulink, the linear equation of the pressure sensor's characteristic have to be determined. Therefore,

$$Y = mX + c \tag{4.4}$$

Where Y = voltage output (V)

X = Pressure (kPa)

$$X = \frac{Y - c}{m} \tag{4.5}$$

Taking point (75, 1.44) and (150, 2.93),

$$m = \frac{2.93 - 1.44}{150 - 75}$$

$$m = 0.01987$$

$$Y = 0.01987X + c$$

Refer to point (150, 2.93),

$$2.93 = 0.01987(150) + c$$

$$c = -0.0505$$

Therefore,

$$Y = 0.01987X - 0.0505$$

$$X = \frac{Y + 0.0505}{0.01987} \tag{4.6}$$

Refer to equation 4.2,

$$h = \frac{X(1000)}{9810}$$

$$h = \frac{X}{9.81} \tag{4.7}$$

To calculate the error, a formula as according to [13] will be needed,

$$\text{Percentage of error} = \frac{Experimental - Theoretical}{Theoretical} \times 100\% \tag{4.8}$$

Which for this experiment will be,

$$\text{Percentage of error} = \frac{\text{Real voltage} - \text{Ideal voltage}}{\text{Ideal voltage}} \times 100\% \tag{4.9}$$

Therefore,

Table 4.2- Table of Pressure sensor error

Ideal Voltage	Real Voltage	Error (%)
0.306	0.453	48.04%
0.816	0.980	20.10%
1.326	1.443	8.82%
1.836	1.990	8.39%
2.346	2.453	4.56%
2.856	2.927	2.49%
3.366	3.427	1.81%
3.876	3.887	0.28%
4.386	4.547	3.67%
4.896	4.840	-1.14%
4.896	4.847	-1.00%
Total Error		96.02%
Average Error		8.73%

The equation for height appear twice as equation 4.2 and equation 4.3 in this experiment. The equation 4.2 refer to the equation to obtain height from sensor output voltage to tabulate the data for table 4.1. At the meantime, the equation 4.7 refer to the equation to obtain height which will be implement into subsystem for the fuzzy logic controller as of figure 3.48.

For experiment 2, the pressure sensor do work almost as the same as expected from datasheet although the average error is 8.73%. This is because, the graph of figure 4.5 shows that the value of pressure sensor generally do not deviate much from the ideal voltage reading. Therefore, the pressure sensor is highly applicable to be use in the following experiment. Also, using the formula derived to determine the depth from sensor output voltage will also help in the following experiments.

4.4 Experiment 3: Fuzzy Logic Controller simulation using MATLAB

The tuning procedure cost a lot of time as there are no standard or certain way to tune the fuzzy logic controller. After several attempts to tune the fuzzy logic controller, it was founded that by changing the PL and NL output membership function to trapezoid and change the range from 0 to 9, the acceptable but not yet perfect time response obtained. Figure 4.7 shows that after tuning, the time respond of the fuzzy logic controller can stop at set point of 3 meters which is a huge improvement compare to time respond of figure 3.26.

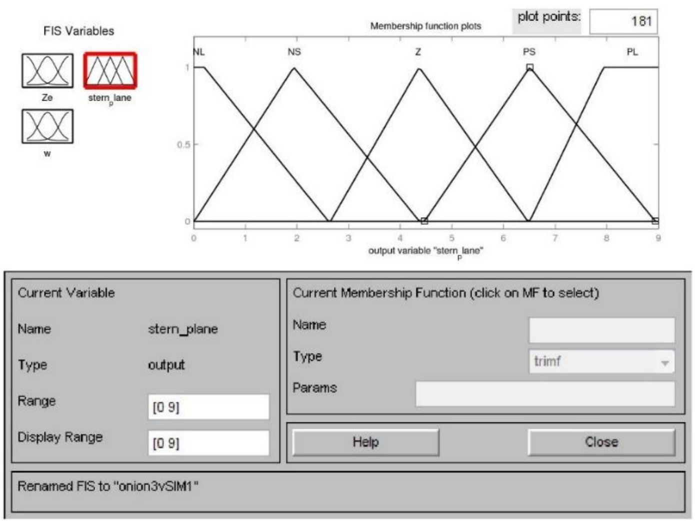

Figure 4.6- Tuned output membership function

Figure 4.7- Graph of depth vs time for tuned output membership function

After a costly time of tuning process, it can be show as of figure 4.7 that the time response for the controller is generally acceptable. The time response is unstable at the beginning of the graph which shows many ripples on it. Although the beginning of it is not as perfect as expected, it still manages to reach and stop at set point of 3 meters.

4.5 Experiment 4: Effect of zero output membership function of transfer function Fuzzy Logic Controller using MATLAB

The result was obtained by shifting the zero output membership function and the time response graph as shown as figure 3.29 to figure 3.38. The result was then being extract using MATLAB command and the rise time, settling time, percent overshoot, and steady state error was tabulated and analyzed in this chapter.

Table 4.3- Simulation result for effect of shifting of zero membership function

Simulation result for effect of shifting of zero membership function									
	Tr	diff.Tr	Ts	diff.Ts	%OS	diff.%OS	Settling max	Ess	diff.Ess
Center	10.26	NA	20.34	NA	0.20%	NA	3.01	0.01	NA
Left	10.28	0.02	19.56	-0.79	0.24%	0.03%	3.01	0.01	0.00
Right	10.24	-0.02	18.23	-2.11	3.81%	3.61%	3.11	0.11	0.11
Big	10.25	-0.01	21.53	1.18	0.27%	0.07%	3.01	0.01	0.00
Small	10.27	0.01	19.74	-0.60	0.22%	0.01%	3.01	0.01	0.00

Table 4.4- Table of simulation performance of shifting of zero membership function

	Tr	Ts	%OS	e_{ss}
Center				
Left				
Right				
Big				
Small				

Legend	
	Increasing performance
	decreasing performance
	same performance

Where, Tr = Rise time

Ts = Settling time

%OS = Percent overshoot

e_{ss} = Steady state error

Diff (Tr, Ts, %OS, e_{ss}) = Value of (Tr, Ts, %OS, e_{ss}) – value of center

From table 4.3, all the altered zero membership function was compared with original "center" zero membership function. The value of altered zero membership function will be minus with value of "center" zero membership function. Negative result from the comparison either shows that the system have faster rise time and settling time, or lesser percent overshoot and steady state error. Vice versa for the positive result from the comparison. As an example, the "left" zero membership function adjustment show that the performance will decrease as the result of comparison is 0.2 second. But, the "right" zero membership function adjustment show that the performance will increase as the result of comparison is negative 0.2 second.

Table 4.4 shows is that the result from adjusting the zero membership function increase, decrease, or maintain the performance of the output time respond. Green indicates increasing performance, red for decreasing performance, and grey for that the performance remain unchanged.

The experiment conducted shows that by tuning the zero membership function, there are no absolute ways to increase all the performance. The combination of the zero membership function may increase all the performance of the fuzzy logic controller. From this experiment, only rise time for "right" and "big" indicates increasing performance while settling time for "left", "right", and "small" perform better. Other than that, all the others performance related to percent overshoot and steady state error only show decreasing performance.

4.6 Experiment 5: Effect of zero output membership function of real-time Fuzzy Logic Controller using Micro 2000/2000C with ROV Simulator

To verify the subsystem of the block diagram as shown as figure 3.48, an experiment was done as shown as figure 4.8 to figure 4.10. From the experiment, it was shown that the subsystem is a valid system as compare to table 4.1.

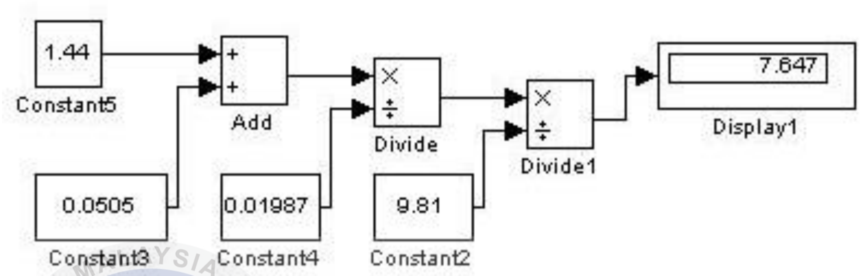

Figure 4.8- First verification of subsystem

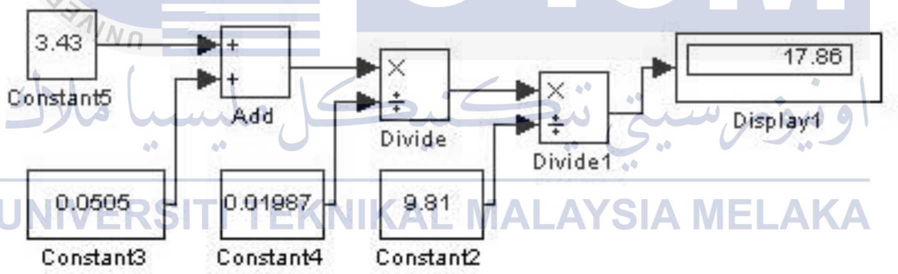

Figure 4.9- Second verification of subsystem

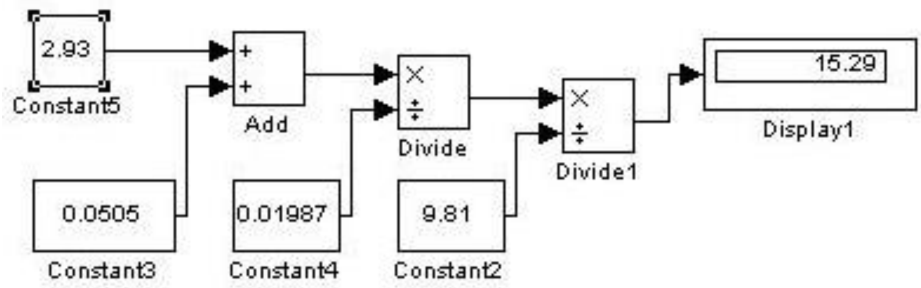

Figure 4.10- Third verification of subsystem

Table 4.5- Table of verification of subsystem

Input/ voltage (V)	Output/ depth (m)	Depth from table 4.1 (m)
1.44	7.647	7.65
3.43	17.86	17.84
2.93	15.29	15.29

Table 4.6- Table of average rise time and settling time

	Tr				Ts			
	1	2	3	average	1	2	3	average
Center	10.30	10.30	10.30	10.30	20.34	20.35	20.35	20.35
Left	10.33	10.32	10.33	10.33	19.56	19.55	19.55	19.55
Right	10.24	10.24	10.25	10.24	18.23	18.23	18.23	18.23
Big	10.29	10.29	10.29	10.29	21.53	21.53	21.53	21.53
Small	10.31	10.31	10.32	10.32	19.74	19.74	19.74	19.74

Table 4.7- Table of average percent overshoot and steady state error

	%OS				Max Settling				Ess
	1	2	3	average	1	2	3	average	average
Center	0.21%	0.20%	0.21%	0.21%	3.01	3.01	3.01	3.01	0.01
Left	0.25%	0.24%	0.24%	0.24%	3.01	3.01	3.01	3.01	0.01
Right	3.90%	3.88%	3.81%	3.86%	3.12	3.12	3.12	3.12	0.12
Big	0.30%	0.32%	0.28%	0.30%	3.01	3.01	3.01	3.01	0.01
Small	0.21%	0.20%	0.20%	0.20%	3.01	3.01	3.01	3.01	0.01

Table 4.8- Table of Real-time result for effect of shifting of zero membership function

Real-time result for effect of shifting of zero membership function								
	Ave Tr	diff.Tr	Ave Ts	diff.Ts	Ave %OS	diff.%OS	Ave Ess	diff.Ess
Center	10.30	NA	20.35	NA	0.21%	NA	0.01	NA
Left	10.33	0.03	19.55	-0.79	0.24%	0.03%	0.01	0.00
Right	10.24	-0.06	18.23	-2.11	3.86%	3.66%	0.12	0.12
Big	10.29	-0.01	21.53	1.18	0.30%	0.09%	0.01	0.00
Small	10.32	0.02	19.74	-0.60	0.20%	0.00%	0.01	0.00

Table 4.9- Table of real-time performance of shifting of zero membership function

	Tr	Ts	%Os	Ess
Center				
Left				
Right				
Big				
Small				

Legend	
	Increasing performance
	decreasing performance
	same performance

Where, Tr = Rise time

Ts = Settling time

%OS = Percent overshoot

e_{ss} = Steady state error

Ave = Average

Diff (Tr, Ts, %OS, e_{ss}) = Value of (Tr, Ts, %OS, e_{ss}) – value of center

Table 4.5 shows that the subsystem is able to convert the input voltage to meter as according to the sensor output voltage relative to its pressure. Table 4.6 and table 4.7 was use to record and calculate the average output time respond data such as rise time, settling time, percent overshoot, and steady state error. Table 4.8 has the same function as table 4.3.

According to table 4.9, the performance of rise time increases when the zero membership function shift to right and big, but decrease for left and small. The performance of settling time also increase for left, right, and small, but not for big. The performance of tuning zero membership function smaller doesn't change the performance for percent overshoot. But, the percent overshoot increase for other shifting method. Other than right shifting method increase the steady state errors, other shifting method didn't change the steady state error as compare to "center".

4.7 Summary of experiments

The result of all the experiments above shows that it is possible to design an intelligent controller for depth control of ROV using Micro 2000/2000C. For this project, fuzzy logic controller was a focus for the project. Experiment 2 shows that the pressure sensor MPX4250GP of the project can function near to the ideal performance as stated at datasheet and thus is suitable to be use throughout the experiment. Experiment 3 shows that the output time respond for the system to keep it at a height of 3 meter can be achieve by tuning the output membership function and changing the positive large and negative large membership function to trapezoid membership function help this tuning to be possible. After tuning the membership function, the tuned fuzzy logic controller is ready to be implemented to ROV using Micro 2000/2000C. Experiment 4 and experiment 5 makes a general guidance for fuzzy logic controller tuning by study the effect of the adjustment of zero membership function. But, experiment 4 is simulation done by MATLAB and experiment 5 is experiment done using real-time control function of the Micro 2000/2000C. Both experiments shows that by adjusting the zero output membership function, the time respond will be different. Although both experiments suggest the same outcome, but the result of both experiments are slightly different to each other.

Chapter 5

Conclusion and Recommendation

5.1 Conclusion

As a conclusion, it can be conclude that it is possible to implement Fuzzy Logic Controller for ROV depth control using Micro 2000/2000C although the Fuzzy Logic Controller is extremely time costing to tune. Experiment 1 successfully solve the issue of the ROV which is current drainage and pressure hull water leakage by built a ROV simulator that do not need to go underwater for initial testing and operating training. Experiment 2 shows that the pressure sensor meet the standard of. This suggest that the sensor is eligible to be use throughout the experiment. If this experiment wasn't conduct, the result of the experiment will not be reliable to conclude that the following experiments are consider a success. Experiment 3 fine tune the output membership function of the fuzzy logic controller until the result meet the requirement to keep the ROV at a depth of 3 meter. The result shows that by changing positive large and negative large membership function to trapezoid and set the output voltage range from 0 to 9, the simulation of the ROV can stay at a depth of 3 meters with acceptable time respond. Experiment 4 and experiment 5 show that by adjusting the zero membership output function, the time respond will change in term of rise time, settling time, percent overshoot, and steady state error. The result can use as a general guide to fine tune the fuzzy logic controller. Experiment 4 and experiment 5 have different result as experiment 4 is simulation and experiment 5 is real time control using Micro 2000/2000C but the different of result did not differ too much between each other. This means that the simulation is highly similar to that of the real-time Micro 2000/2000C control.

5.2 Recommendation

As a recommendation, the study for implementation of fuzzy logic controller into ROV should be continue. This is because the research of fuzzy logic controller gain a lot of fruitful result throughout the years in many other field and most probably will be a very important invention for ROV. Further implementation using fuzzy logic controller can also include the sensor to detect the wave pattern, water density, and so on to be implement into ROV depth control as this will highly increase the accuracy of depth control. Further study and research on the controller of neuro-fuzzy system or fuzzy neural network system for ROV control system may also be a fruitful field of study in the future.

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Appendices

Appendix A

Experiment 1: ROV Simulator

Objective: To design and develop a ROV simulator for testing of controller.

This experiment aim for build a ROV simulator which will not be place underwater solely for system identification of the transfer function and testing of controller purpose.

Material: 8 feet of aluminum trial, Micro 2000/2000C, 4 thrusters, 4 propellers, 4 drivers, 10 connector, sufficient jumper, sufficient cable, 8 inches of 1inch diameter PVC tube, 8 pieces of 1 inch diameter PVC end cap, pressure sensor, and 1 piece of 3 feet times 2 feet plywood.

Procedure:

1. The aluminum will be cut into 3 pieces of 2 feet long and 2 pieces of 1 feet long.
2. The cut aluminum trial will be place on the plywood as shown as figure 3.2.
3. The Micro 2000/2000C, connector, pressure sensor, and drivers will be place on the plywood as shown as figure 3.3.
4. The PVC tube will be cut into 4 pieces and the thruster will be place inside the tube.
5. The end cap will be drill with suitable diameter for the cable and shaft of the thruster to get out.
6. The propeller will be place on the thruster’s shaft and place on the aluminum trial.
7. The thruster will be connect to the driver and the driver will be connect to the micro 2000/2000C using suitable jumper.
8. The continuity will be check using multi-meter, the jumper will be reconnect until the continuity is perfect.

Experiment 2: Pressure sensor

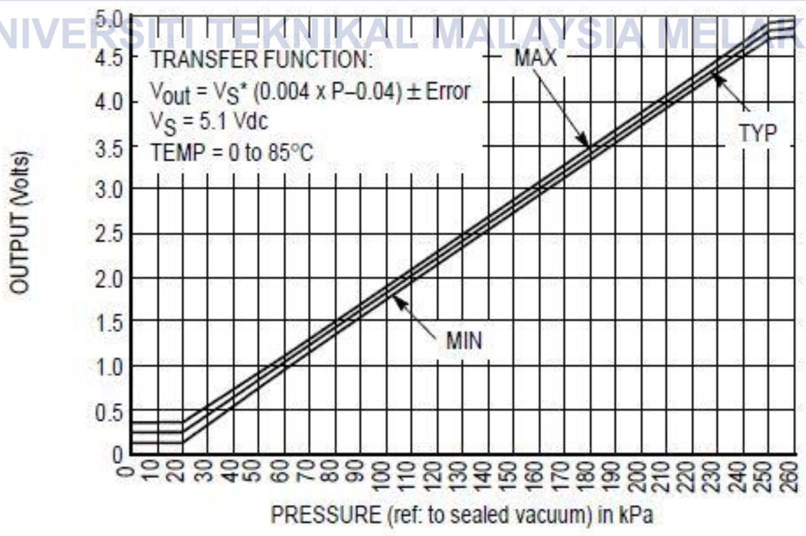
Objective: To determine the accuracy of the pressure sensor

This experiment will determine the accuracy of the pressure sensor as compare to the data provided as of data sheet for the pressure sensor

Material: Pressure sensor, portable air compressor, pressure regulator, and multi-meter.

Procedure:

1. The multi-meter will be connect to the pressure sensor output.
2. The portable air compressor will be connect to the pressure regulator and the pressure regulator will be connect to the pressure sensor.
3. The pressure will be set from 20 kPa to 250 kPa as according to figure 3.12.
4. The result will be tabulated with Microsoft Excel and the data will be compare with the data provided in data sheet of the pressure sensor.



Graph of Output versus Absolute Pressure of Pressure Sensor

Experiment 3: Fuzzy Logic Controller simulation using MATLAB

Objective: To design, fine tune, and simulate the fuzzy logic controller using MATLAB

The experiment was design to obtain the suitable fuzzy logic controller using the transfer function obtain by using MATLAB fuzzy toolbox and MATLAB Simulink simulation.

Software: MATLAB Simulink and MATLAB Fuzzy Toolbox

Procedure:

1. The block diagram of the fuzzy logic controller is insert into MATLAB Simulink as according to figure 3.8.
2. The transfer function obtained will be insert into the transfer function block.
3. Using fuzzy logic toolbox, the input membership function will be set to depth error and integration of depth error. The output membership function will be set to depth.
4. The range of depth error will be change to suitable range.
5. The number of membership function will be change to 5 representing positive large, positive small, zero, negative small, and negative large by using membership function editor.
6. A table as according to table 2.2 will be draw to determine the rules.
7. The determined rules will be insert using rules editor.
8. The input and output membership function will be adjust as according to journal [7].
9. The fuzzy logic controller will be export to the MATLAB Simulink and the simulation will be run.
10. Repeat steps 8 and 9 until the result satisfied.

Experiment 4: Effect of zero output membership function of transfer function Fuzzy Logic Controller using MATLAB

Objective: To study the effect of zero output membership function of transfer function fuzzy logic controller.

Materials: MATLAB

Procedure:

1. The Simulated fuzzy logic controller will be tune using MATLAB.
2. The desire depth will be set to MATLAB Simulink.
3. The desire depth will be of the depth of 3 meters for the pressure sensor by setting the constant in MATLAB Simulink.
4. The MATLAB Simulation will start to collect data from scope data by giving appropriate command using the MATLAB.
5. Plot the graph of data obtained using MATLAB command and obtain the data such as rise time, percent overshoot, settling time, and steady state error from the graph obtained.
6. Repeat step 4 to 6 for different zero membership function adjustment and tabulate the data of rise time, settling time, percent overshoot, steady state error of the fuzzy logic control logic.
7. Compare the results and draw conclusion from it

Experiment 5: Effect of zero output membership function of real-time Fuzzy Logic Controller using Micro 2000/2000C with ROV Simulator

Objective: To study the effect of zero output membership function of real-time fuzzy logic controller using Micro 2000/2000C.

Materials: Micro 2000/2000C, ROV Simulator

Procedure:

1. The Simulated fuzzy logic controller will be implemented into Micro 2000/2000C using MATLAB.
2. The Micro 2000/2000C will be connected to the ROV Simulator accordingly.
3. The desire depth will be set to Micro 2000/2000C and the mini air pump will start to provide the pressure sensor pressure.
4. The desire depth will be of the depth of 3 meters for the pressure sensor by setting the constant in MATLAB Simulink.
5. The MATLAB Simulation will start to collect data using 'out' block by giving appropriate command using the MATLAB command to Microbox 2000/2000c.
6. Plot the graph of data obtained using MATLAB command and obtain the data such as rise time, percent overshoot, settling time, and steady state error from the graph obtained.
7. Repeat step 4 to 6 for 3 times and tabulate the data of rise time, percent overshoot, settling time, and steady state error to obtain the accuracy of the fuzzy logic control logic.

Appendix B

FYP FULL

ORIGINALITY REPORT

9%	%	9%	%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Faruq, Amrul, S. S. Abdullah, M. Fauzi, and S. Nor. "Optimization of depth control for Unmanned Underwater Vehicle using surrogate modeling technique", 2011 Fourth International Conference on Modeling Simulation and Applied Optimization, 2011. Publication	1%
2	Che Soh, A.; Abdul Rahman, R. Z.; Sarkan, H. Md. and Yeo, L. T.. "Intelligent Control of Twin-Rotor MIMO System Using Fuzzy Inference Techniques", International Review of Aerospace Engineering, 2013. Publication	1%
3	Dhanalakshmi, R. and Palaniswami, S.. "Adaptive Gain Scheduling Fuzzy Logic PID Controller in Load Frequency Control of Wind Diesel Micro Hydro Isolated Hybrid Power System", International Review on Modelling & Simulations, 2011. Publication	<1%
4	Ropp, R.C.. "Group 16 (O, S, Se, Te) Alkaline Earth Compounds", Encyclopedia of the Alkaline Earth Compounds, 2013.	<1%