Study on the Effect of Shifting 'Zero' in Output Membership Function on Fuzzy Logic Controller of the ROV using Micro-box Interfacing

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Abstract

This paper investigates a study on the effect of shifting 'zero' membership function on Fuzzy Logic Controller (FLC) design of Remotely Operated Vehicle (ROV) for depth control using Microbox 2000/2000C interfacing based on thrusters system. The main issue with the thrusters system in a ROV design was the current from the power supply (e.g. battery source or power bank) is easily drain up and this will reduce the performance of thrusters system and decreased the ROV operation time. Besides, FLC also do not have a rigid tuning approach and it may cause the process of tuning become highly time consuming. Therefore, a simple control method by a study on the effect of shifting 'zero' membership function will act as a technique to tune the FLC for future references. The ROV Trainer was developed to test the proposed control method using Microbox 2000/2000C. The ROV Trainer consists of aluminium box, thrusters, drivers, interface connector, and etc and interfacing with Microbox which act as microcontroller. Fuzzy logic toolbox in MATLAB is used to study the shifting zero membership function so that the effect of the adjustment can be investigated. The result of this project shows that, by shifting zero membership function of the fuzzy logic controller, the performance of the fuzzy logic controller is normally improved.

Keywords: Depth control; Unmanned Underwater Remotely Operated Vehicle; Neural Network Predictive Control

1. Introduction

ROV is one of the underwater unmanned vehicles where it 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 [1]. In addition, ROV is also being used for black box searching for the famous MH370 mysterious incident. Without ROV, it is never possible for the search of black box to be carried out because of the weather of the deep water sea is highly vicious and sending in human for the operation is considered unrealistic [2 -5]. Nevertheless, the importance of ROV is highly underrated as it never received high public appreciation. The development of fuzzy logic controller is considered an aged approach for control system, but because of there are no accurate ways to tune it adequately, a simple technique to tune FLC will be introduced [6]. Thus, this research is carried out to design an intelligent controller for depth control of ROV using Micro-box 2000/2000C interfacing almost similar in [7]. This study will be focused on how zero output membership function affects the result matters.

The conventional control system for the ROV 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 [8 - 9]. Because it is crucial for ROV 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 the conventional PID controller. Thus, intelligent control system such as fuzzy logic controller is needed in order to solve this problem but fuzzy logic controller is considered complicated because there are no specific ways to tune it. Trial an error is the common approach to do this and it often results in a great waste of time [10 -11]. Therefore, a simple overview on how zero output membership function of the fuzzy logic can affect the results become one simple contribution for this field of study.

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This project will be carried out in a controlled environment where the environment disturbance will be assumed to zero. For this limitation, a ROV Trainer was built for testing the proposed control system before implemented it in real time operation. This ROV Trainer was built mainly to overcome issue where it is troublesome to carry out the experiments in the water [12]. Since the project is about depth control, the vertical thrusters system for up and down movement will be considered throughout the project. As this project is mainly about control system, the paper will only brief the information of control system for ROV. This project will implement the intelligent control system by using Micro-box 2000/2000C. The experiments 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.

2. ROV Trainer

Micro-box 2000/2000C is an expensive controller, thus, it is highly undesirable to test it underwater as water leakage may happen to the ROV. Therefore, an ROV Trainer will be built to test it [12]. The Trainer has a pressure sensor to obtain data of pressure where it will then being converted to depth and the pressure will be provided by a 12V mini air pump through a pressure regulator. Other than that, there will be 4 thrusters with propeller and its driver attached 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.

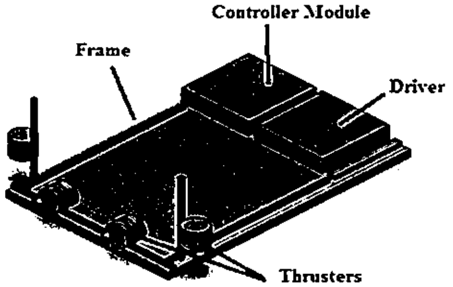
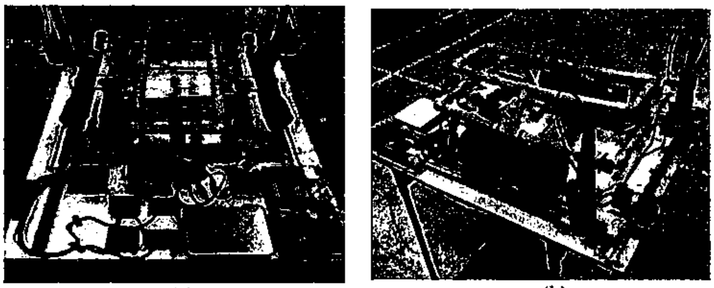


Fig. 1: The ROV Trainer using Solidworks



(a) (b)

Fig. 2: The ROV Trainer: (a) Front view; (b) Isometric view [12]

3. Hardware

3.1 Pressure Sensor

The definition for pressure is difference when it's come to water pressure. This is because the pressure of water should consider the depth of water and its density [13].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.

3.2 Driver

Driver used in this project is a Single Pole Double Throw type driver as shown in Fig. 3(a). 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 thrusters will draw up current to operate.

3.3. Thruster

The thruster is the kinetic source of the ROV as shown in Fig. 3(b). Without the thruster with its propeller, the ROV cannot move underwater. Most thrusters are brushless DC motor because no precision of thruster position is needed. The propeller is attached to the thrusters to "cut" thru the water and move forward.

3.4 Microbox 2000/2000C

Micro-box 2000/2000C is a high performance, fan-less, low power consumption industrial PC as shown in Fig. 4. The Micro-box has 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 [14 -15].

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(a) (b)
Fig. 3: Thruster system: (a) driver, (b) 2-blades propeller

Fig. 4: Micro-box 2000/2000C

4. Fuzzy Logic Controller

Block diagram in MATLAB Simulink is required to implement the fuzzy logic controller at the Micro-box 2000/2000C. To design a closed-loop fuzzy logic controller, an experiment is performed to obtain the data from the pressure input and voltage output of the pressure sensor accordingly. The data is then being processed by using system identification tools in MATLAB to obtain the transfer function [16]. After that, block diagram is drawn as in Fig. 5 for fuzzy logic controller using Simulink and the transfer function is inserting into the plant.

A 5X5 input membership function is chosen and the rule based is obtained by using principle as in journal [16]. FIS editor is taken from the fuzzy toolbox in MATLAB, then both the input membership function and output membership function is inserted to the membership function FIS editor. Rules editor in FIS editor is used to insert the rule based of the system. Then, FIS file is saved and exported to the FLC block diagram in Simulink and the result is obtained after run the simulation. Finally, fine tune the FLC by adjusting the output membership function and this should be done if the result of the simulation is not suitable. The fine tune process have to be done according to journal [11] 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.

4.1 MATLAB Simulation

The block diagram was built by using MATLAB Simulink as shown in Fig. 5 and the membership function was set as shown in Fig. 6 to Fig. 8. The transfer function was obtained from paper [16].

$$\frac{0.414s^2+25.42s+22.59}{s^3+3.78s^2+54.62s+28.9} \tag{1}$$

The rules were set up by rules editor as according to Table 1. Set the step input to 3 which indicates 3 meters. Run the simulation after export the fuzzy logic controller setting to the block diagram as shown in Fig. 5.

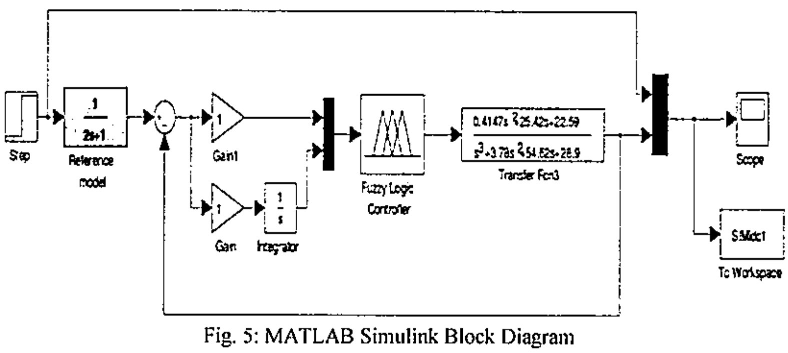

Fig. 5: MATLAB Simulink Block Diagram

Table 1: 5x5 Matrix rules

Δe	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

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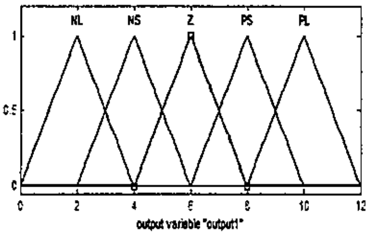

Fig. 6: Output membership function

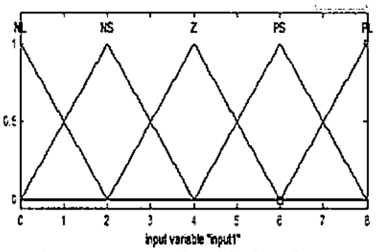

Fig. 7: Input membership function (e)

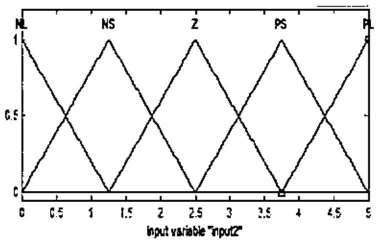

Fig. 8: Input membership function (Δe)

5. Results and Discussion

The ideal voltage referring to Fig. 9 is obtained from datasheet [17] and real voltage refers to the output voltage is obtained from experiment. 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. The pressure sensor do work almost as the same as expected from datasheet although the average error is 8.73%. This was because, the graph as shown in Fig. 9 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.

Fig. 10 shows the experimental set up in terms of hardware while Fig. 11 shows the MATLAB Simulink block diagram for real time experimental. From Fig. 12 (a) and (b), 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 has faster rise time and settling time, or lesser percent overshoot and steady state error. And it is 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 2 shows is that the simulation and real time results from adjusting the zero membership function increase, decrease, or maintain the performance of the output time respond.

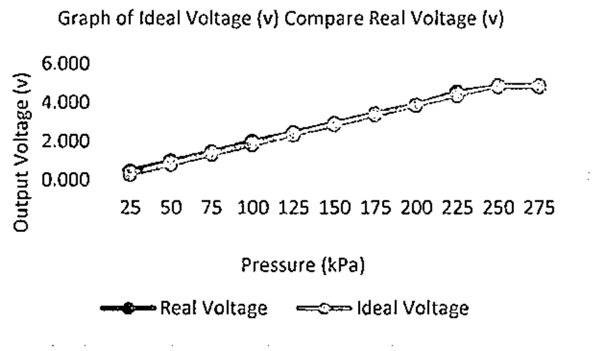

Fig. 9: Graph of Ideal voltage compare to real voltage

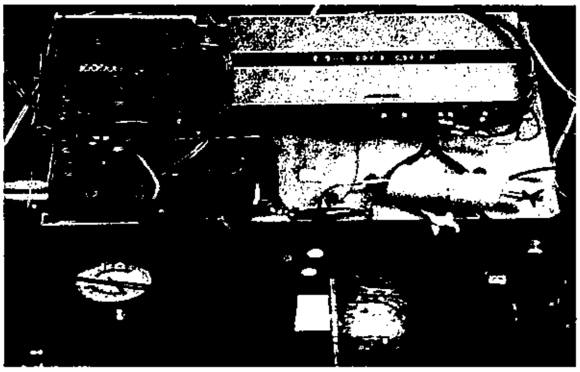

Fig. 10: Experiment Setup

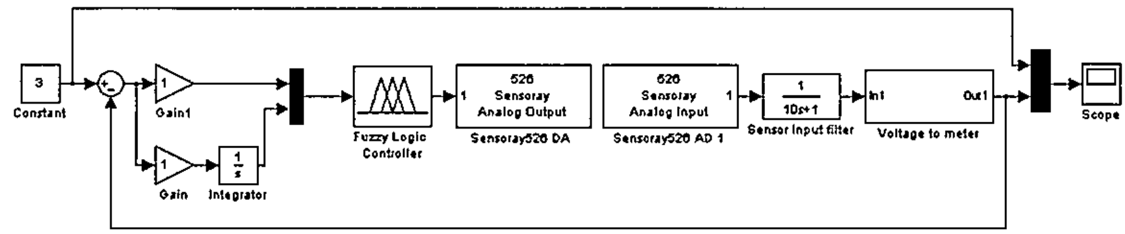

Fig. 11: Block diagram for real-time control

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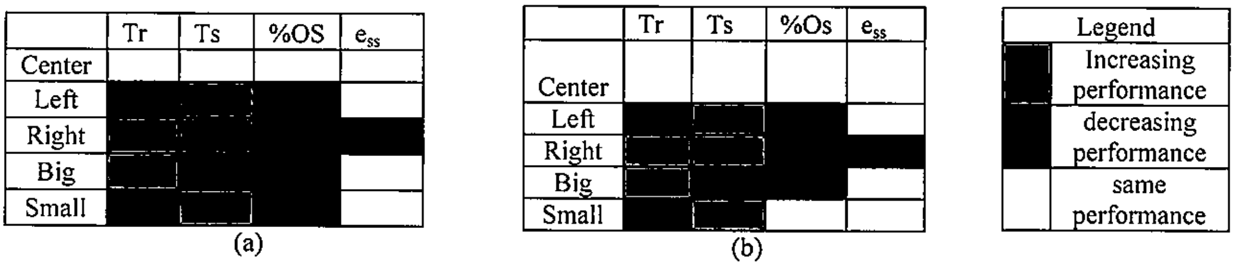

Fig. 12: Performance of shifting of zero membership function: (a) simulation; (b) real-time

Table 2: Simulation and real-time 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

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

6. Conclusion

It can be conclude that is possible to implement Fuzzy Logic Controller for ROV depth control using Micro-box 2000/2000C although the Fuzzy Logic Controller is extremely time costing to tune. The pressure sensor meets the standard and the sensor is eligible to be use throughout the experiment. The output membership function of the fuzzy logic controller will be tuned until the result meets 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. 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 common technique to fine tune the fuzzy logic controller. The different result for simulation and real time control using Micro-box 2000/2000C did not differ too much between each other. This means that the simulation is highly similar to that of the real-time Micro-box 2000/2000C interfacing.

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