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”

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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 :..

Name :..

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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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.

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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.

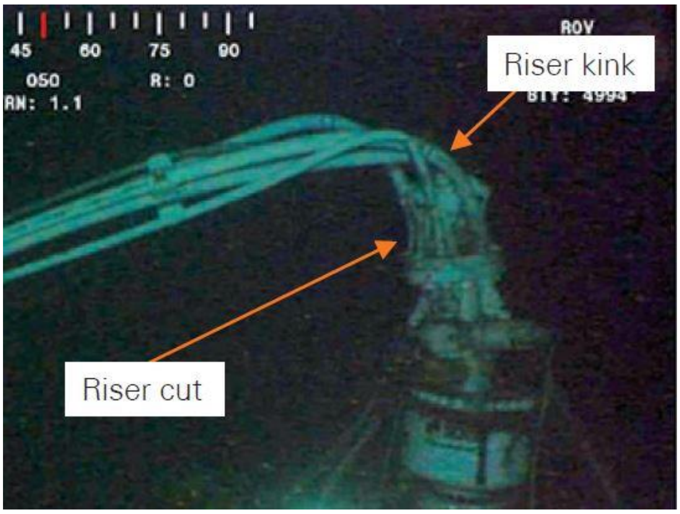

Figure 1.1- ROV post mortem investigation for Macondo well

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:

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

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]

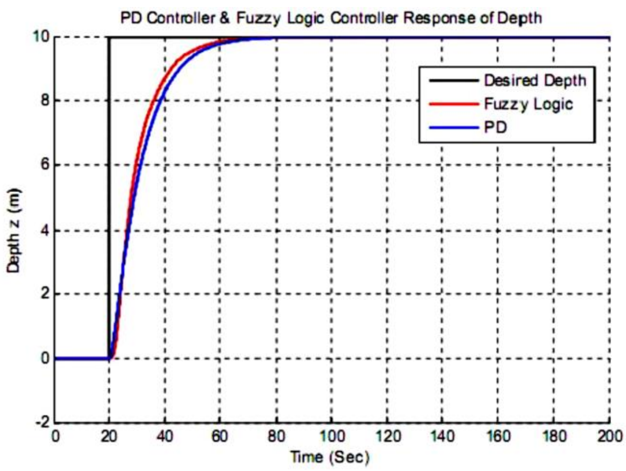

Figure 2.1PD and Fuzzy Logic Controller Response of Depth [2]

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]

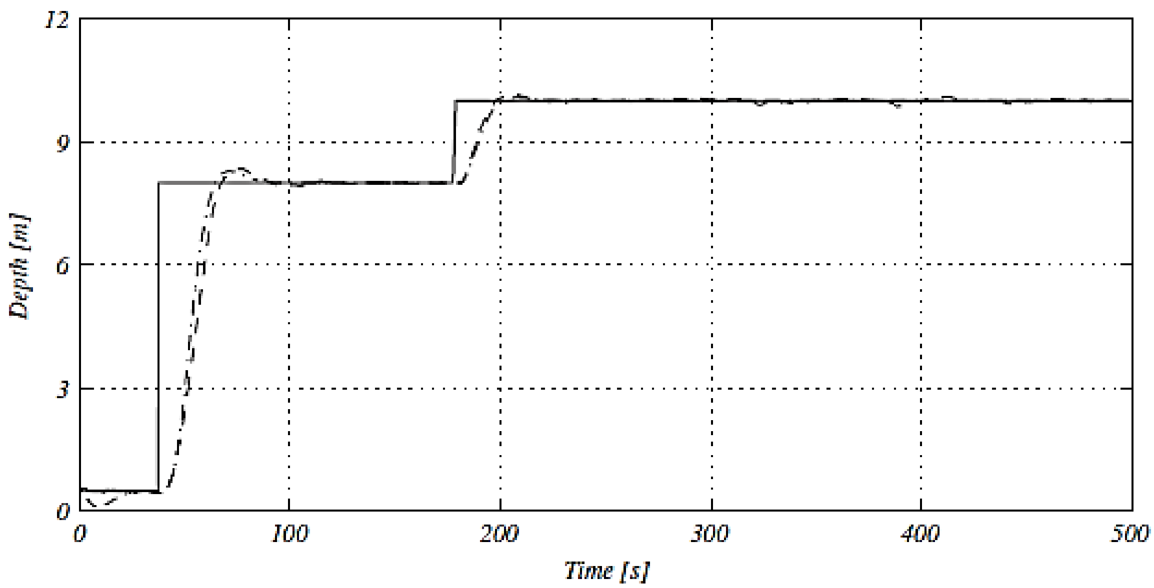

Figure 2.2- Response of Gain-Scheduled Reduced Order Output Feedback Controller[3]

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]

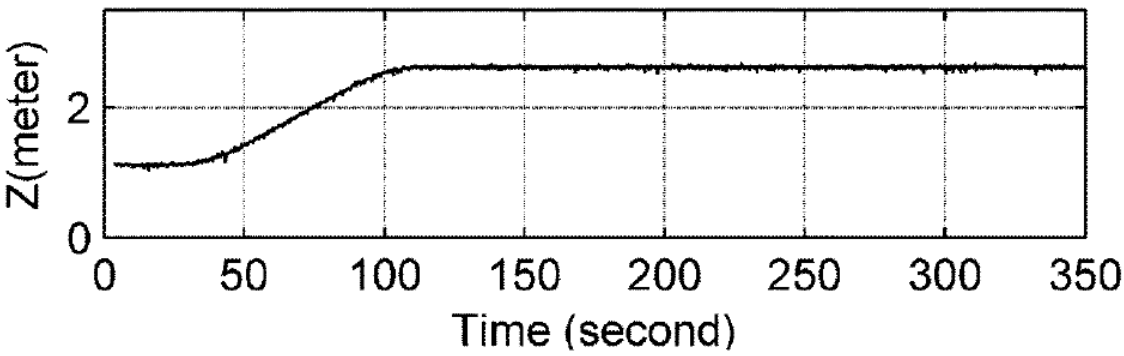

Figure 2.3 - Adaptive Plus Disturbance Observer response [4]

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]