INTELLIGENT CONTROL OF DIVING SYSTEM OF AN UNDERWATER VEHICLE

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ABSTRACT

The design of a depth control of an underwater vehicle is described in this thesis. A mathematical model of an underwater vehicle namely, Deep Submergence Rescue Vehicle (DSRV) is developed. Four types of controllers are designed which include PD, Pole Placement, Conventional Fuzzy Logic (CFLC), and Single Input Fuzzy Logic (SIFLC). The CFLC gives satisfactory results. However, the design is complex because there are a large numbers of rules and parameters that need to be tuned. To overcome the problem an alternative to CFLC known as SIFLC is proposed in this thesis. The controller is based on Signed Distance method, which reduces the numbers of rules and tuning parameters without compromising its performance. In effect it reduces the system to a SISO model which results in simple tuning. Faster computation is also expected because the controller can be constructed using a look-up table. All of the four controllers are designed based on overshoot, settling time, and steady state error specification criteria. Based on these criteria, a comparison study is performed to show the effectiveness of the designed controllers. All of the four controllers other than PD controller are found to give satisfactory results. The proposed SIFLC exactly resembles the CFLC in transient and steady state response which shows the effectiveness of the designed controller.

ABSTRAK

Projek ini melibatkan kajian rekabentuk dan ujian prestasi bagi sistem kawalan kedalaman bagi sebuah Kenderaan Dalam Air Kawalan Jauh (ROV). Permodelan matematik bagi sebuah ROV yang dikenali sebagai *Deep Submergence Rescue Vehicle* (DSRV) telah dikaji. Empat jenis pengawal berbeza yang terdiri dari pengawal PD, Penentuan Kutub, Logik Kabur Biasa (LKB) dan Logik Kabur Satu Input (LKSI) telah berjaya direkabentuk. Prestasi pengawal LKB adalah baik, walau bagaimanapun, pengawal ini adalah kompleks kerana melibatkan banyak peraturan dan pembolehubah yang perlu dilaraskan. Untuk mengatasi masaalah ini, pengawal alternatif bagi LKB iaitu LKSI telah direkabentuk. Pengawal ini dihasilkan menggunakan kaedah *Signed Distance*, yang membolehkan sistem asal diringkaskan kepada sistem satu masukan sahaja yang memudahkan pelarasan pembolehubah yang ada dalam sistem. Kaedah pemprosesan yang lebih cepat adalah dijangkakan kerana pengawal LKSI boleh direalisasi menggunakan jadual rujukan sahaja. Kesemua empat pengawal direkabentuk berdasarkan spesifikasi asas kawalan iaitu lampau lajak, masa pengenapan dan ralat keadaan mantap. Berdasarkan spesifikasi ini, perbandingan telah dibuat terhadap keempat-empat pengawal dan kesemuanya memberikan prestasi yang memuaskan. Adalah didapati bahawa LKSI memberikan prestasi yang sama dengan pengawal LKB dan ini menunjukkan yang LKSI adalah sangat sesuai digunakan bagi sistem ini kerana pelaksanaannya yang lebih ringkas dan memerlukan masa pemprosesan yang lebih singkat daripada pengawal yang lain.

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CHAPTER 1

INTRODUCTION

1.1 Overview

An Autonomous Underwater Vehicle (AUV) is a robotic device that is governed through a propulsion system, controlled and piloted by an onboard computer, and maneuverable in three dimensions. This level of control, under most environmental conditions, permits the vehicle to follow precise preprogrammed trajectories wherever and whenever required. Sensors on board the AUV sample data continuously as the AUV moves through the ocean, providing the ability to make both spatial and time series measurements. Sensor data collected by an AUV is automatically geospatially and temporally referenced and normally of superior quality. Multiple vehicle surveys increase productivity, can insure adequate temporal and spatial sampling, and provide a means of investigating the coherence of the ocean in time and space. These submarines normally being deployed for various dangerous underwater tasks that include search and rescue operation. The fact that an AUV is normally moving does not prevent it from also serving as a Lagrangian, or quasi Eulerian, platform. This mode of operation may be achieved by programming the vehicle to stop thrusting and float passively at a specific depth or density layer in the sea, or to actively loiter near a desired location. AUV's may also be programmed to swim at a constant pressure or altitude or to vary their depth and/or heading as they move through the water, so that undulating sea saw survey patterns covering both vertical and/or horizontal swaths may be formed. AUV's are also well suited to perform long linear transects, sea sawing through the water as they go, or traveling at a constant pressure. They also provide a highly productive means of performing seafloor surveys using acoustic or optical imaging systems.

Underwater vehicles can be classified into two basic categories; Manned Underwater Vehicles and Unmanned Underwater Vehicles (UUVs) [21]. Unmanned Underwater Vehicles (UUVs) is the term referring to Remotely Operated Underwater Vehicles (ROV) and Autonomous Underwater Vehicles (AUVs). This can be shown in Figure 1.1 below. These two types of UUVs contribute to the same control problems [22]. These vehicles have subsisted for over 100 years and have known as an interesting area from researchers and industries [22], [23].

Unmanned underwater vehicles (UUVs) have provided an important tool in pilot free under water operations due to the increased operating range and depth. Additionally operation survival and less risk to human life are also important factors. Typical applications of UUVs today incorporate; survey, search and reconnaissance, surveillance, inspection, recovery, repair and maintenance, construction etc. Particularly in the offshore industry, UUVs have become indispensable [21].

Effective control schemes require relevant signals in order to accomplish the desired positions and velocities for the vehicle. A suitable controlling method of underwater vehicles is very challenging due to the nature of underwater dynamics [24]. The outgoing project will focus in controlling the vehicles in a vertical motion in order to maintain the desired depth position.

This project will try to develop several controllers of depth dynamics starting from conventional to intelligent control like fuzzy logic. This project will begin with mathematical modeling to illustrate the dynamics of underwater vehicles followed by controller design. The implementation phase will be verified through MATLAB SIMULINK platform.

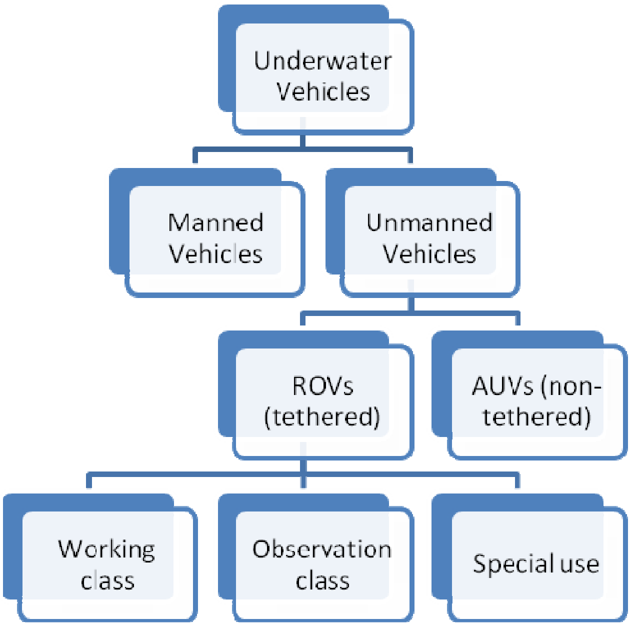

Figure 1.1: Underwater Vehicles.

1.2 Project Background

The design of an autopilot for the control of underwater vehicles is of interest both from the view of motion stabilization as well as maneuvering and tracking performance [20]. The demand for the autonomous underwater vehicles has been growing because of the fact that the use of manned vehicles are limited due to high cost and risk in working area [21].

Today's ongoing research activities are aiming at enhancing the autonomy of the underwater vehicle including better design of communication, higher power density and more reliable navigation and control for deep water operation. Due to the complex nature of the underwater vehicle dynamics, oceanic disturbance and uncertainty pertaining to changes in centre of gravity and buoyancy, ROVs demand control system that has a self-tuning ability. For this situation a simple autopilot will be designed to control the depth position of the vehicle.

1.3 Objectives of Project

- To model the diving system of a "**Deep Submergence Rescue Vehicle" (DSRV).**

- To design a diving control system for the DSRV by adopting some classical control techniques.

- To design an intelligent controller for the diving system of the DSRV.

1.4 Scope of Project

The emphasis of the research of this project will be on the aspect of controlling the ROV, which is to investigate the problem of depth control system. The objective in modeling of a depth controller is to develop an accurate model representing the actual system dynamics. The motion of the underwater vehicle consists of two movements; vertical and horizontal motion. However, as for the scope of this project is concerned, only the dynamics in the vertical motion will be considered in the following work. Development of mathematical modeling in this project is based on the previous study by T.I.Fossen, 1994 [25] and will be discussed in more details in Chapter 3.

There will be two types of controller scheme to be investigated in this project: conventional followed by intelligent control scheme. The conventional approach will consider PD and Pole Placement techniques and the later one will be using Fuzzy Logic controller followed by Single Input Fuzzy Control (SIFLC) to control the overall system dynamics. The control software will be implemented in MATLAB.

1.5 Organization of Thesis

This thesis is organized into eight chapters. Their contents are outlined as follows:

Chapter 2 provides an extensive review of modeling and control techniques used to control the underwater vehicle.

Chapter 3 discusses the mathematical modeling of the ROV. It contains the overview of the system and derivation of the mathematical model of system dynamics in differential and state space form.

Chapter 4 describes the design procedure of PD and Pole Placement Controller for Deep Submergence Rescue Vehicle (DSRV) using MATLAB/Simulink. Simulation and performance evaluation are carried out. Comparison between PD and Pole Placement controller are discussed.

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