CONTROL AND MODELLING OF UNDERWATER FLEXIBLE MANIPULATOR STRUCTURE

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To my beloved family who always gives me strength to complete this thesis, believe in me and guide me all of my pursuits.

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ABSTRACT

The use of flexible structures in many engineering applications is expanding rapidly. Position control is delicate, such as angular position control of a flexible structure especially underwater condition. Flexible structure in an underwater condition often having the problem of the hub angle position as the hub angle is affected by the inline force of the flexible structure underwater. To develop an optimum control system for the horizontal motion of such condition, the operating system must first be identified. A system model of an experimental test rig representing the Underwater Flexible Single Link Manipulator System (UFSLMS), needs to be developed before designing a controller to control the hub angle position. The objectives of this project are to identify the model and develop the controller to control the hub angle position of a UFSLMS. Previous studies have shown that parametric modelling involving Auto Regressive with Exogenous Input model using Recursive Least Squares algorithm, and non-parametric modelling involving Evolution Algorithm are suitable to model the UFSLMS system, with acceptably low Mean Square Error. The project is done by reviewing the UFSLMS dynamic modelling and control methodology. The collection of data from the UFSLMS system will be simulated and identified as the dynamic UFSLMS. A Proportional-Integral-Derivative controller is developed based on the system identification model, using heuristic techniques within MATLAB environment and robustness test is carried out at different magnitudes to determine the robustness of the controller. The performance of the controllers thus developed is verified and validated by simulation on MATLAB SIMULINK. The objectives are achieved when the controller is proven to be stable by effectively control the hub angle position in the horizontal motion underwater.

ABSTRAK

Penggunaan struktur fleksibel dalam banyak aplikasi kejuruteraan sedang berkembang pesat. Kawalan kedudukan adalah halus, seperti kawalan kedudukan sudut struktur fleksibel keadaan terutamanya di dalam air. Struktur yang fleksibel dalam keadaan air sering mempunyai masalah mengenai kedudukan sudut hab sebab sudut hab dipengaruhi oleh kuasa sebaris struktur fleksibel di dalam air. Bagi membangunkan sistem kawalan yang optimum untuk gerakan mendatar syarat itu, sistem operasi yang pertama mestilah dikenal pasti. Model sistem pelantar ujian eksperimen mewakili Underwater fleksibel Single Link Manipulator System (UFSLMS), perlu dibangunkan sebelum pengawalan dibentuk supaya mengawal kedudukan sudut hub. Objektif projek ini adalah untuk mengenal pasti model dan membangunkan pengawal untuk mengawal kedudukan sudut hab untuk UFSLMS. Kajian terdahulu telah menunjukkan bahawa model parametrik melibatkan Auto regresif dengan model Input eksogen menggunakan Recursive Squares Least algoritma, dan pemodelan bukan parametrik melibatkan Evolution Algoritma adalah sesuai untuk model sistem UFSLMS, dengan rendah Ralat. Projek itu dilakukan dengan mengkaji model dan kawalan dinamik metodologi UFSLMS. Pengumpulan data daripada sistem UFSLMS akan disimulasikan dan dikenal pasti sebagai UFSLMS dinamik. Sebuah pengawal berkadar-Integral-derivatif dibangunkan berdasarkan model pengenalan sistem, menggunakan teknik heuristik dalam persekitaran MATLAB dan ujian keteguhan dijalankan pada magnitud yang berbeza untuk menentukan keteguhan pengawal. Prestasi pengawal dikembangkan disahkan oleh simulasi MATLAB SIMULINK. Objektif tercapai apabila pengawal terbukti stabil dengan berkesan mengawal kedudukan sudut hab dalam gerakan mendatar di dalam air.

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A/D	-	Analog to Digital
AC	-	Alternate Current
AI	-	Analog Input
AO	-	Analog Output
DAQ	-	Data Acquisition System
DC	-	Direct Current
DE	-	Differential Evolution
FEM	-	Finite Element Method
GA	-	Genetic Algorithm
I/O	-	Input to Output
MSE	-	Mean Square Error
PID	-	Proportional Integral Derivative
PZT	-	Piezoelectric
RLS	-	Recursive Least Square
UFSLMS	-	Underwater Flexible Single Link Manipulator System

CHAPTER 1

INTRODUCTION

Flexible structures are being used in nowadays especially the underwater flexible structure in any of the engineering applications. The basic elements for flexible structural analysis are plates, beams, frames and shells. These elements are used in a broad range of engineering applications and particularly in aeronautical, mechanical, marine, aerospace, civil engineering and many more.

This paper presents modelling and control of flexible manipulator with single link in an underwater environment. The underwater environment completely contrasts with ground or space environment. The single link flexible structure in an underwater situation is subjected to various dynamic forces like buoyancy forces, hydrostatic and hydrodynamic forces.

In order to control the physical system or to predict its behaviour under different operating conditions, a model can be created using an approach called system identification. The main objective of system identification is to find an accurate or an approximate model of system dynamics based on the observed inputs and the outputs.

The project is first done by reviewing the UFSLMS dynamic modelling and control methodology. The collection of data from the UFSLMS system will be simulated and identified as the dynamic UFSLMS. A Proportional-Integral-Derivative controller is developed based on the system identification model, using heuristic techniques within MATLAB environment and robustness test is carried out

at different magnitudes to determine the robustness of the controller. The performance of the controllers thus developed is verified and validated by simulation on MATLAB SIMULINK.

1.1 Objective of study

The main objectives of the project are to model dynamically via system identification and develop angular position control for underwater flexible manipulator structure. Hence, four objectives are stated below.

1. Literature review of the UFSLMS dynamic modelling and control methodology.
2. To acquire data from an underwater flexible manipulator experimental rig and model the system using intelligent method by using data collected.
3. Development of angular position controller using self-tuning PID controller for flexible manipulator system.
4. Analysis, verification and validation of the performance of the controllers.

1.2 Scope of study

1. The project involves by using Recursive Least Squares algorithm and Evolution Algorithm to model the UFSLMS system.
2. In this study, the evolutionary algorithms considered to tune PID controller is differential evolution. The performance of the controller in controlling the hub angle is investigated based on the data collected by experiment.
3. The real-time self-tuning control schemes are based on the self-tuning of proportional and PID control using iterative learning algorithm by tuning the PID gain heuristically.
4. The robustness test for the proposed control scheme is limited to variation of disturbance amplitude (velocity).

1.3 Problem Statement

Position control is delicate, such as angular position control of a flexible structure especially underwater condition, but in case of mechanical application, the unwanted position of the structure may cause unrecoverable damages and maneuverability to a system. Flexible structure in an underwater condition often having the problem of the hub angle position as compared to rigid structure which is always leads to vibration at the tip. Hub angle is affected by the inline force of the flexible structure underwater as the vibration is already dampened in the underwater condition. The behaviour of the UFSLMS under different operating conditions is too complex to be identified and requires a model which gives minimum prediction error in order to predict and control the system accurately. Hence, the purpose of carrying out this research is to overcome the angular position of the hub angle of a flexible structure underwater by effectively design a dynamic controller to make the aim come true.

1.4 Research Flowchart

Figure 1.1 shows the research flowchart which describes how this project is carried out.

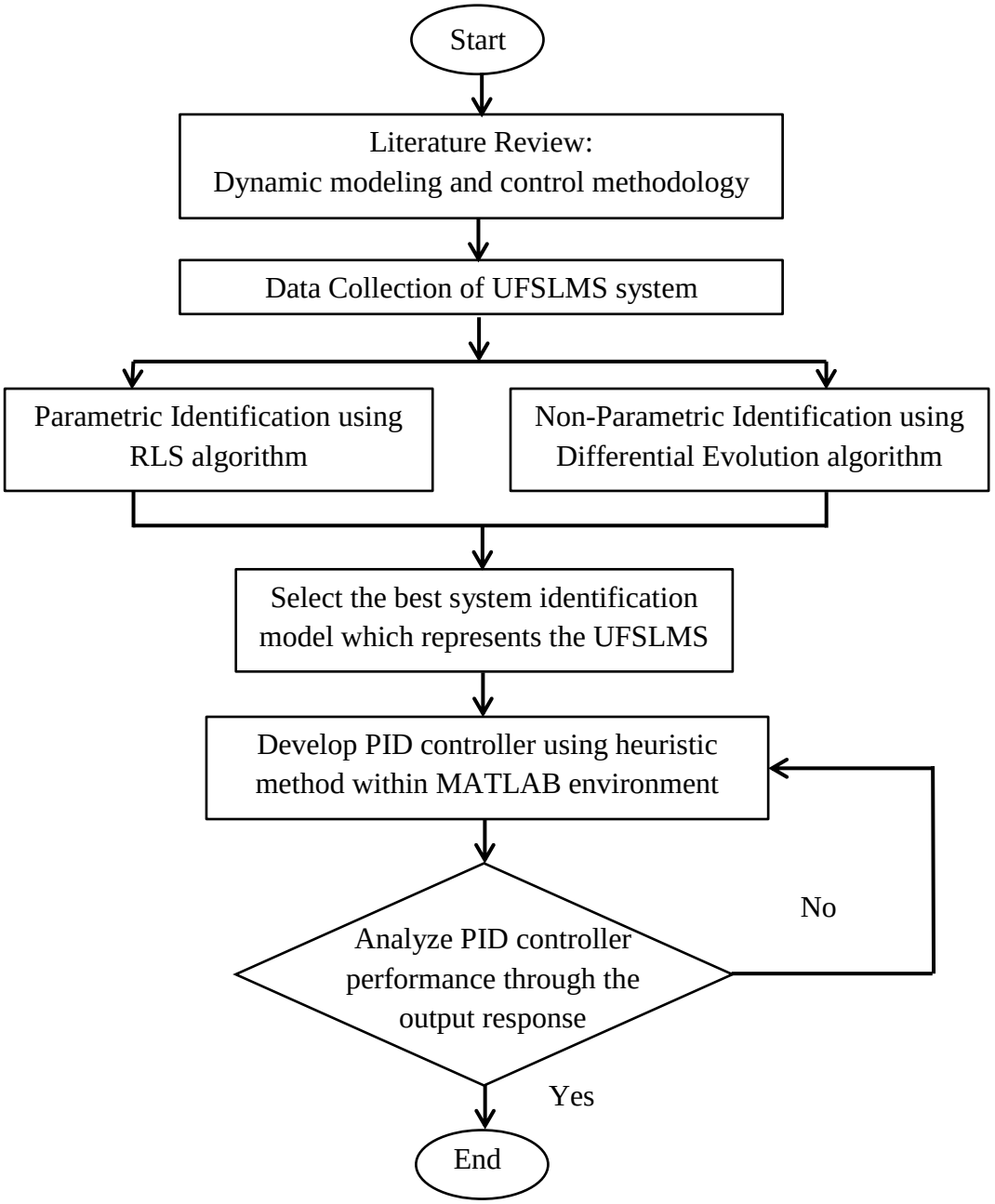

Figure 1.1 Research Flow Chart

This project will be conducted in three phases: (i) literature review of the application of UFSLMS; (ii) system identification of UFSLMS; (iii) development of controller for UFSLMS based on the best system identification model.

1.5 Project Activities

NO	TASK	WEEK (SEMESTER 1)															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	LITERATURE REVIEW Underwater Flexible Single Link Manipulator System UFSLMS UFSLMS Modelling and Identification Parametric Identification RLS Algorithm Control of UFSLMS																
2	PARAMETRIC MODELLING & SYSTEM IDENTIFICATION WITHIN MATLAB ENVIRONMENT RLS Algorithm																
3	ASSESMENT OF PARAMETRIC MODELLING																
4	WRITING REPORT FOR MP PART 1																
5	PRESENTATION WEEK Prepare for presentation																
6	COMPLETE MP PART 1																

Figure 1.2 Gantt chart for Master Project 1

NO	TASK	WEEK (SEMESTER 2)															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	LITERATURE REVIEW Underwater Flexible Single Link Manipulator System UFSLMS UFSLMS Modelling and Identification Non-Parametric Identification Differential Evolution algorithm Control of UFSLMS																
2	NON-PARAMETRIC MODELLING & SYSTEM IDENTIFICATION WITHIN MATLAB ENVIRONMENT Differential Evolution Algorithm																
3	COMPARASIVE ASSESMENT OF SYSTEM IDENTIFICATION METHODS																
4	DEVELOPMENT OF UFSLMS CONTROLLER																
5	ANALYSIS OF CONTROLLER PERFORMANCE																
6	FINAL REPORT AND PRESENTATION Reprort writing Presentation																
7	COMPELTE MASTER PROJECT																

Figure 1.3 Gantt chart for Master Project 2

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