SYSTEM IDENTIFICATION AND CONTROL OF THE HORIZONTAL MOTION OF A TWIN ROTOR MULTI-INPUT MULTI-OUTPUT SYSTEM (TRMS)

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To my beloved mother and father

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ABSTRACT

Rescue helicopters are often required to hover in certain motion, and most likely to maintain in still-air position for lifting purposes. The vibration produced by a helicopter during still-air hovering creates complexity in the physical control by the pilot, especially in the horizontal motion. 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 Twin Rotor Multi-Input-Multi-Output System (TRMS), similar to a helicopter system needs to be developed before designing a controller to control this vibration. The objectives of this project are to identify the model and develop the controller for the horizontal motion of a TRMS. Previous studies has shown that parametric modelling involving Auto Regressive with Exogenous Input model using Recursive Least Squares algorithm, and non-parametric modelling involving Nonlinear Autoregressive with Exogenous Input model using Multilayer Perceptron Neural Network modelling are suitable to model the TRMS system, with acceptably low Mean Square Error. The project is done by reviewing the TRMS dynamic modelling and control methodology. The collection of data from the TRMS system will be simulated and identified as the dynamic TRMS. A Proportional-Integral-Derivative controller is developed based on the system identification model, using heuristic and automatic tuning techniques within Matlab environment. 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 with significant reduction of vibration in the horizontal motion.

ABSTRAK

Helikopter penyelamat sering diperlukan untuk berlegar dalam pergerakan tertentu, dan kadangkala perlu mengekalkan kedudukan di udara untuk tujuan mengangkat objek dari tanah. Getaran yang dihasilkan oleh helikopter semasa berlegar di udara mewujudkan kerumitan dalam pengawalan fizikal oleh juruterbang, terutama sekali dalam gerakan mendatar. Sistem operasi helikopter mestilah dikenalpasti untuk membina sistem kawalan optimum bagi gerakan mendatar tersebut. Model sistem ujian pelantar ujikaji mewakili Twin Rotor Multi-Input Multi-Output System (TRMS), yang memiliki persamaan seperti sistem helikopter perlu dibina sebelum merekabentuk sistem pengawal untuk mengawal getaran ini. Objektif projek ini adalah untuk mengenalpasti model dan membina pengawal untuk gerakan mendatar TRMS. Kajian-kajian terdahulu telah menunjukkan bahawa model parametrik melibatkan model Autoregressive with Exogenous Input dengan penggunaan algoritma Recursive Least Squares, dan model bukan parametrik melibatkan Nonlinear Autoregressive with Exogenous Input dengan Multilayer Perceptron Neural Network adalah sesuai untuk memodelkan sistem TRMS, dengan nilai Mean Square Error yang rendah. Projek ini mengkaji semula model dinamik TRMS dan metodologi kawalan. Pengumpulan data daripada sistem TRMS disimulasikan dan dikenalpasti sebagai TRMS dinamik. Pengawal Proportional-Integral-Derivative dibina berdasarkan model pengenalan sistem, dengan menggunakan teknik tuning heuristik dan automatik dalam persekitaran Matlab. Prestasi pengawal yang dibina disahkan oleh simulasi Matlab SIMULINK. Objektif tercapai apabila pengawal terbukti stabil dengan pengurangan getaran dalam gerakan mendatar yang signifikan.

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Over the decades, helicopters have been used for loading and unloading goods, transferring people from disastrous area, and also for military purposes (U.S. Department of Transportation, 2012). Since the beginning of modern helicopter development in mid 20^{th} century, various engineering problems have been listed down, placing the problem of balancing the rotor torque and problem of producing smooth and positive, quick acting rotor controller, on top of the list (Piasecki, F.N., 1946). This has triggered various studies to model and develop a control system of automated helicopters with optimized stability (Sanchez, E. N. *et al*., 2006; Marconi, et. al, 2008; Cai, et. al, 2009; Bisgaard, M. *et al*., 2010; Bristeau, P. J. *et al*., 2010; Nonami, K., *et al*., 2010, Wu, W., 2014). To understand the system and apply implemented new control systems, the Twin Rotor Multi-Input Multi-Output System (TRMS) is developed and used to represent the helicopter system, which was built with some simplifications (Manual Twin Rotor, 2006).

1.2 Research Objectives

The main objectives of this project are to identify the model, and develop the controller for the horizontal motion of the TRMS.

1.3 Problem Statements

The behaviour of the TRMS 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.

1.4 Scope of Research

The scope of this research project is listed as follows:

(i) Literature review of TRMS dynamic modelling and control methodology.
(ii) Data collection of the TRMS system, specifically the sine input and sine output data of the system in horizontal hovering position.
(iii) Parametric identification and simulation of the dynamic TRMS using Autoregressive with Exogenous Input model with Recursive Least Squares algorithm.
(iv) Non-parametric identification and simulation of the dynamic TRMS using Nonlinear Autoregressive with Exogenous Input model and Nonlinear Autoregressive model with Multilayer Perceptron Neural Network.
(v) Development of PID controller using heuristic and auto tuning techniques within Matlab environment.
(vi) Analysis, verification and validation of the performance of the controllers thus developed via simulation environment.

1.5 Research Flowchart

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

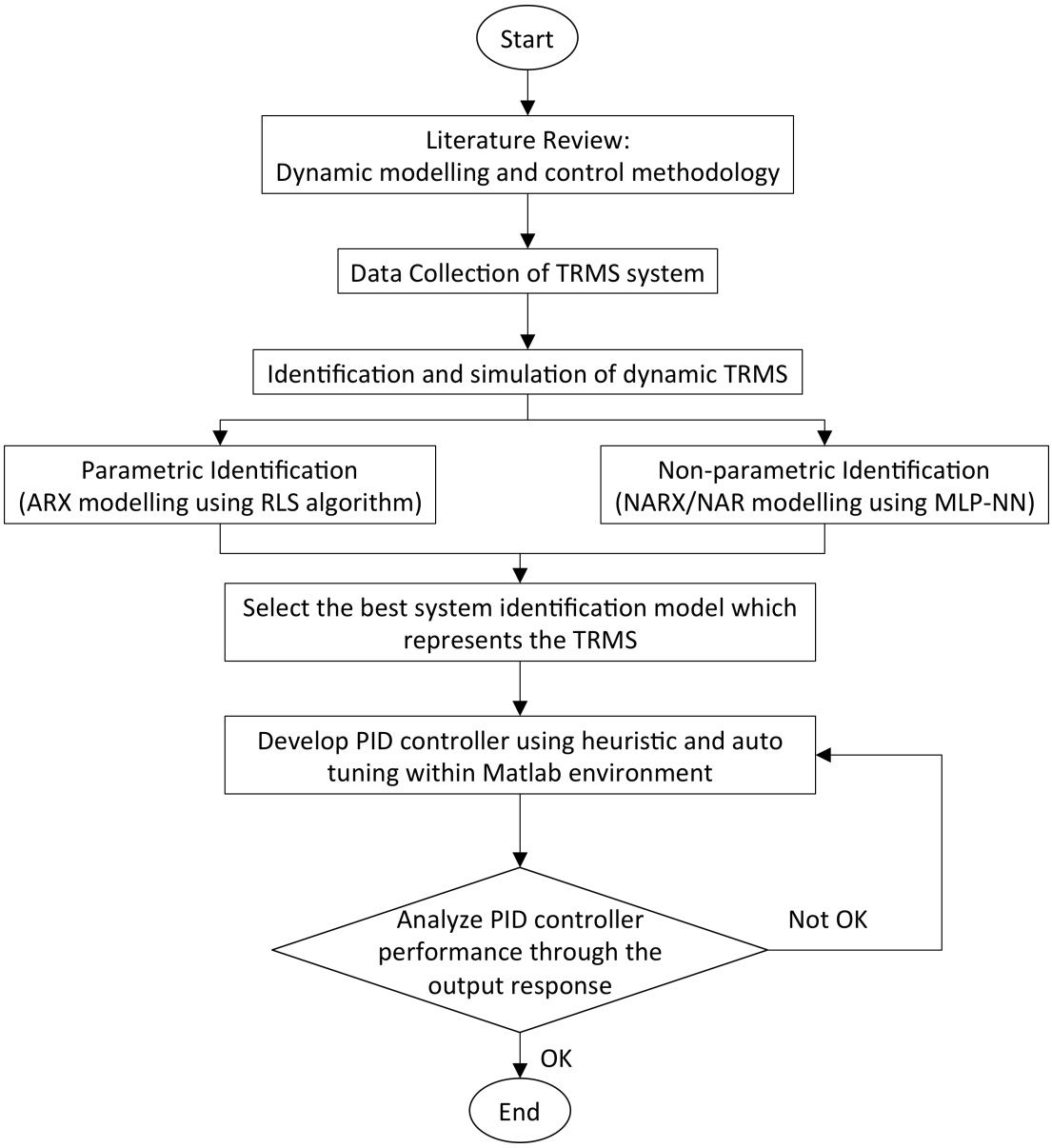

Figure 1.1: Research Flowchart

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

1.6 Gantt Chart

NO.	TASK	WEEK (SEMESTER 1)															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	LITERATURE REVIEW Helicopter and TRMS TRMS Modelling and System Identification Parametric Identification RLS algorithm Control of TRMS			■	■	■	■	■	■	■	■	■		■	■		
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																◆

NO.	TASK	WEEK (SEMESTER 2)															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	LITERATURE REVIEW Helicopter and TRMS TRMS Modelling and System Identification Non-parametric Identification MLP Neural Network Control of TRMS - Adaptive Control																
2	NON-PARAMETRIC MODELLING & SYSTEM IDENTIFICATION WITHIN MATLAB ENVIRONMENT MLP-NN																
3	COMPARASIVE ASSESMENT OF SYSTEM IDENTIFICATION METHODS																
4	DEVELOPMENT OF TRMS CONTROLLER																
5	ANALYSIS OF CONTROLLER PERFORMANCE																
6	FINAL CONSULTATION Final consultation with supervisor Corrections and modifications																
7	FINAL REPORT AND PRESENTATION Report writing Presentation																
8	COMPLETE MASTERS PROJECT																◆

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