UNIVERSITI PUTRA MALAYSIA

AN IMPROVED FUZZY PARALLEL DISTRIBUTED –LIKE CONTROLLER FOR MULTI-INPUT MULTI-OUTPUT TWIN ROTOR SYSTEM

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An Improved Fuzzy Parallel Distributed –Like Controller for Multi-Input Multi-Output Twin Rotor System

By

Thair Sh. Mahmoud

Thesis Submitted to the School of Graduate Studies, Univeristi Putra Malaysia, in Fulfillment of the Requirements of the Degree of Master of Science

May 2009

DEDICATION

To my Parents,

To my Brother and Sisters,

To my Grandmothers

Thair

Abstract of thesis presented to the Senate of University Putra Malaysia in fulfillment of the requirement of the degree of the Master of Science

An Improved Fuzzy Parallel Distributed –Like Controller for Multi-Input Multi-Output Twin Rotor System

By

Thair Sh. Mahmoud

December 2008

Chairman : Assoc. Prof. Tang Sai Hong, PhD

Faculty : Engineering

Twin Rotor Multi Input Multi Output (MIMO) System (TRMS) is a laboratory set-up design for which it has been used for control experiments, control theories developments, and applications of the autonomous helicopter. Fuzzy Logic Control (FLC) has been widely used with different control schemes to cope with control objectives of TRMS. In this work, Self Tuning Fuzzy PD-like Controller (STFPDC) is proposed to make the response of FLC more robust to the interactions and the non-linearity of the process in terms of less rising time, settling time and overshoot. Adaptive Neuro Fuzzy Inference System (ANFIS) based Fuzzy Subtractive Clustering Method (FSCM) was used to remodel the proposed STFPDC to achieve the control objectives on TRMS with less number of rules. MATLAB/SIMULINK was involved to achieve the simulations in this work. The results showed the

proposed controller could simplify the STFPDC to reduce the number of rules from 392 to 73, which is even less than the original FLC that has 196 rules.

The conclusion of this work is improving FLC response by using STFPDC and reducing the number of rules used to achieve this improvement by using ANFIS based on FSCM modeling. For future works, it is recommended to develop an optimization algorithm which achieves best selection for the range of influence which gives best response with less number of rules.

Abstrakt tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

Kawalan Bagai Agihan Selari Kabur Yang Diperbaharui Bagi Sistem Putaran Kembar Pelbagai Input Pelbagai Output

Oleh

Thair Sh. Mahmoud

Disember 2008

Pengerusi : Prof. Madya Tang Sai Hong, PhD

Fakulti : Kejuruteraan

Sistem Rotor Kembar Pelbagai Input Pelbagai Output (MIMO) (TRMS) adalah satu reka cipta makmal yang sebelum ini digunakan untuk uji kaji kawalan, pembangunan teori kawalan dan aplikasi helikopter autonom. Kawalan logik kabur (FLC) telah banyak digunakan dengan skim kawalan yang berbeza bagi menampung tujuan kawalan TRMS. Dalam tugas ini, pengawal kabur putaran sendirian bagai PD (STFPDC) dicadangkan untuk menjadikan gerak balas lebih tegap daripada FLC biasa bagi interaksi dan proses yang taksekata dari segi pengurangan masa bangkit, masa tinggal dan keterlanjuran. Cara gugusan penolakan kabur yang berdasarkan sistem kesimpulan kabur penyesuaian saraf (ANFIS) telah digunakan untuk mengubah bentuk cadangan STFPDC untuk mencapai tujuan kawalan TRMS dengan bilangan peraturan yang kurang. MATLAB/SIMULINK telah dilibatkan untuk mencapai simulasi dalam tugas ini. Keputusan ini mununjukkan sistem kawalan yang dicadangkan boleh memudahkan STFPDC dengan mengurangkan bilangan

peraturan daripada 392 peraturan kepada 73 peraturan, malah kurang daripada FLC tulen yang mempunyai 196 peraturan.

Kesimpulan tugas ini ialah memperbaiki gerak balas FLC dengan menggunakan STFPDC dan mengurangkan bilangan peraturan yang digunakan untuk mencapai perbaikian dengan penggunaan pemodelan FSCM berdasarkan ANFIS. Bagi tugas yang akan datang, ia dipertimbangkan untuk memajukan satu algoritme optimasi di mana ia mencapai pilihan terbaik bagi banjaran pengaruh yang memberi gerak balas terbaik dengan bilangan peraturan yang kurang.

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I take this opportunity to formally thank my fellow house mates, for their help and support throughout the whole project.

I would also especially like to thank my family who has always believed in me.

Thair Sh. Mahmoud

May 2009

I certify that an Examination Committee has met on 11 May 2009 to conduct the final examination of Thair Sh. Mahmoud on his thesis entitled “An Improved Fuzzy Parallel Distributed–Like Controller for Multi-Input Multi-Output Twin Rotor System" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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This thesis submitted to the Senate of University Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory are as follow:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Putra Malaysia or other institutions.

Thair Sh. Mahmoud

Date: 11 May 2009

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LIST OF ABBRIVIATIONS AND NOTATIONS

AI	Artificial Intelligence
ANFIS	Adaptive Neuro Fuzzy Inference System
CGA	Conjugate Gradient Algorithm
CPU	Central Processing Unit
D/A	Digital to Analog converter
DC	Direct Current
DOF	Degree Of Freedom
FIS	Fuzzy Inference System
FSCM	Fuzzy Subtractive Method
GUI	Graphic User Interface
HLA	Hybrid Learning Algorithm
ITSE	Integral of Time Multiplied by Square Error Criterion
LQ	Linear Quadratic
MIMO	Multi Input Multi Output
MLP	Multi Layer Preceptron
MRAN	Minimal Resource Allocating network
NARX	Non-linear Auto Regressive process with eXternal input
NN	Neural Networks
PDC	Parallel Distributed Compensator
PID	Proportional Integral Derivative
PSO	Particle Swarm Optimization
RBF	Radial Basis Function
RGA	Real valued Genetic Algorithms
RLS	Recursive Least Square
STFPDC	Self Tuning Fuzzy PD-like Controller

SISO	Single Input Single Output
SNN	Single Neural Net
TRMS	Twin Rotor MIMO System
TSK	Takagi-Sugeno-Kang
UAV	Unmanned air Vehicle

CHAPTER 1

INTRODUCTION

1.1 Background

In recent years, Unmanned Aerial Vehicles (UAVs) have attracted significant research interests. UAVs can do piloted aerial vehicles jobs in risky places without risking pilot's life. UAVs are very useful in doing missions in hostile environments. Unmanned helicopters have practical interesting dynamic features among autonomous flying systems. The main difficulties in designing controllers for them come from nonlinearities and couplings.

Twin Rotor MIMO System (TRMS) is a laboratory set-up design for which it has been used for control experiments, control theories developments, and applications of the autonomous helicopter. Basically, it resembles in certain aspects the behavior of helicopter. It introduces some of the platforms and control architectures, and exemplifies a high order non-linear system with significant cross-couplings from control engineering point of view. A detailed approach to the control problems connected with the TRMS involves some theoretical knowledge of laws and physics (Feedback Corp. 1998).

Modeling and controlling of TRMS are considered challenging for control community. It has attracted many researchers in the last decade. The researchers have started working of solving TRMS control problems with conventional PID controller. It seems to be inadequate for this complex problem, and resulting to a poor performance with the non-linearity and coupling effects. PID controller performance can be improved by adjusting gains, but this still has its limitation (Juang and Liu, 2006a). Artificial intelligence has also been used to improve control performance and reduce interactions effects.

Artificial Intelligence (AI) is necessary to achieve successful embedded control systems with good control performance. So, computation resources and complexity of the used AI algorithm need to be considered for less computation resources and more flexibility in developing the embedded software's that achieve the control objectives on the systems.

1.2 Problem Statement

TRMS control has been studied in the last few years as it represents a control and modeling challenge for researchers. Fuzzy Logic Control (FLC) has been widely used with different control schemes to cope with control objectives of TRMS. It has been shown that FLC was superior to classical controllers in terms of tracking and transient response of TRMS (Islam *et al.*, 2003; Juang and Liu, 2006a). FLC has been utilized in many different hybrid schemes, and implemented with the use of classical and/or intelligent control like Genetic Algorithms (GA). As mentioned by many researchers (Jang *et al.,* 2005; Adebrez *et al.*, 2006; Rahideh *et al.*, 2006; Jang *et al.*, 2006a, 2006b;

Jang *et al.*, 2008), fuzzy logic has been proposed in different schemes with the use of Genetic Algorithms (GA) and conventional PID controller.

From the literature, it looks that the limitation of FLC is related to the difficulty in predicting changes in the operating conditions of a system and then adjusting for them. Hence, it is desirable to develop a self-tuning fuzzy controller that can improve FLC performance based on its experience, and to adapt its response in relation to variations in TRMS dynamics (Zhang and Liu, 2006).

In this work Self Tuning Fuzzy PD-like Controller (STFPDC) is proposed to make the response more robust to the interactions and non-linearity of the process. For this work, it is obvious that STFPDC scheme is using eight fuzzy reasoning blocks; each with forty-nine rules at least for this system. The eight fuzzy reasoning blocks are needed to achieve control objectives for horizontal, vertical, and the two de-coupling parts; each with two fuzzy reasoning blocks. It is considered complex control scheme with high number of the used fuzzy rules.

1.3 Aims and Objectives of the Research

The aims of this study is to improve FLC trajectory tracking performance and reduce cross coupling of TRMS by adding self tuning fuzzy inference system to the original FLC. Then, ensure achieving same control objectives with simpler control strategy in terms of less number of rules.

To achieve these aims, three specific objectives need to be achieved:

i) Proposing Self Tuning Fuzzy PD-like Controllers to improve FLC response in terms of solving control problems and interactions between each degree of freedom.
ii) Developing an Adaptive Neural Fuzzy Inference System (ANFIS) based on Fuzzy Subtractive Clustering Method (FSCM) from the original proposed Self Tuning Fuzzy PD-like Controllers.
iii) Controlling TRMS with new Adaptive Neuro Fuzzy Inference Systems based Self Tuning Fuzzy PD-Like Controllers.

1.4 Scope of the Work

In this work, ANFIS-STFPDC based Fuzzy Subtractive Clustering Method (FSCM) is proposed to control TRMS. This work will neither cover optimization of achieving best parameters selections of FLC nor any method achieve best selection of range of influence in FSCM. This project will try to solve trajectory and interaction problems between yaw and pitch angles of TRMS with better response than that of FLC using STFPDC. This work will achieve same performance of STFPDC with less number of rules. In this work, all the simulations and designs are made under MATLAB®/SIMULINK®.