CONTROLLER DESIGN FOR INDUSTRIAL HYDRAULIC ACTUATOR USING ARTIFICIAL NEURAL NETWORK

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To my beloved father, mother, father in law, mother in law, my wife, my daugther and all of my family member

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ABSTRACT

Electro-hydraulic actuators are widely used in motion control application. Its valve needs to be controlled to determine direction of the actuator. Mathematical modeling is a description of a system in terms of equations. It can be divided into two parts, which is physical modeling and system identification. The objective of this study was to determine the mathematical modeling of Industrial Hydraulic Actuator by using System Identification technique by estimating model using System Identification Toolbox in MATLAB. Then, an ANN controller is designed in order to control the displacement of the hydraulic actuator. Finally the controller is validated by implementing in the real time experiments. Experimental works were done to collect input and output data for model estimation and ARX model was chosen as model structure of the system. The best model was accepted based on the best fit criterion and residuals analysis of autocorrelation and cross correlation of the system input and output. Then, PIDNN controller was designed for the model through simulation in SIMULINK. The neural network weights and controller's parameters is tuning by The Particles Swarm Optimization (PSO) method. The simulation work was verified by applying the controller to the real system to achieve the best performance of the system. The result showed that the output of the system with PIDNN controller in simulation mode and experimental works was improved and almost similar. The designed PIDNN with PSO tuning method controller can be applied to the electro-hydraulic system either in simulation or real-time mode. The others automatic tuning method controller could be developed in future work to increase the reliability of the PIDNN controller. Besides, the hydraulic actuator system with non linear model could be modeled.

ABSTRAK

Penggerak elektro hidraulik digunakan dengan meluas dalam applikasi kawalan pergerakan. Injapnya perlu dikawal bagi menentukan haluan penggerak. Permodelan matematik adalah perihal suatu sistem dalam terma persamaan. Ia boleh dibahagikan kepada dua bahagian, iaitu permodelan fizikal dan sistem pengecaman. Objektif kajian adalah untuk mengenalpasti pemodelan matematik bagi penggerak hidraulik industri dengan cara menggunakan teknik sistem pengecaman, iaitu dengan mengangar model dengan menggunakan kotak alatan Sistem Pengecaman di dalam Matlab. Selepas itu, Pengawalan ANN direka bentuk bagi tujuan mengawal pergerakkan penggerak hidraulik. Akhir sekali, pengawal yang direka bentuk disahkan dengan melaksanakan pada ekperimen masa sebenar. Eksperimen dilakukan untuk mengumpul data masukan dan keluaran bagi anggaran model dan model ARX dipilih sebagai struktur model bagi sistem. Model terbaik adalah diterima bepandukan kreteria padanan terbaik dan analisis baki pada hubungkait automatik dan hubungkait silang untuk sistem masukan dan keluaran. Pengawal PIDNN direkabentuk untuk model melaui simulasi di dalam SIMULINK. Pemberat rangkaian saraf dan parameter penggawal adalah ditala dengan kaedah Pengoptimuman Kerumunan Zarah (PSO) dengan mengaplikasikan pengawal pada sistem sebenar bagi mencapai prestasi terbaik sistem. Keputusan menunjukkan keluaran daripada sistem bersama pengawal PIDNN dalam mod simulasi dan eksperimen adalah bertambah baik berserta hampir sama. Pengawal PIDNN yang direkabentuk bersama kaedah larasan pengawal PSO boleh diaplikasikan pada sistem penggerak elektro hidraulik, sama ada dalam mod simulasi ataupun pada masa sebenar. Lain-lain kaedah pelaras automatik bagi pengawal boleh dibangunkan pada masa akan datang untuk meningkatkan kebolehpercayaan bagi pengawal PIDNN. Disamping itu, sistem penggerak hidraulik juga boleh dimodelkan dengan model tidak linear.

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LIST OF ABBREVIATIONS

ANN	-	Artificial Neural Network
PSO	-	Particle Swarm Optimization
PID	-	Proportional Derivative Integral Controller
N-Z	-	Zeigler-Nichols tuning method
SI	-	System Identification
PRBS	-	Pseudorandom Binary Sequences
ARX	-	Auto-regressive with Exogenous Input
ARMAX	-	Auto-regressive Moving Average with Exogenous Input
AR	-	Auto-regressive
OE	-	Output Error
BJ	-	Box-Jenkins
DAQ	-	Data Acquisition Systems
LS	-	Least Square Method
IV	-	Instrumental Variables Method
FPE	-	Final Prediction Error
MSE	-	Mean Square Error
ISE	-	Integral Square Error
RMS	-	Root Mean Square
GA	-	Genetic Algorithm
PIDNN	-	Proportional-Integral-Derivative-Neural-Network
NN	-	Neural Network
FPE	-	Final Prediction Error
NI	-	National Instrument
PCI	-	Peripheral Component Interconnect
IV	-	Instrumental Variable method
LC	-	Least Squares method

LIST OF SYMBOLS

v_p	-	Piston velocity
P_L	-	Hydraulic pressure
F_L	-	External load disturbance
x_v	-	Spool value diplacement
A	-	Piston surface area
m	-	Mass of the load
β	-	Effective bulk mod ulus
b	-	Viscous damping coefficient
V	-	Total volume of hydraulic oil in the piston chamber & connection line
T_s	-	Sampling Time
k	-	Number of Sample
K_p	-	Proportional Gain
K_I	-	Integral Gain
K_D	-	Derivative Gain
$u(t)$	-	Perturbation in controller output signal from the bias or base value corresponding to the normal operating condition
$e(t)$	-	Error between the reference input and the process output
φ_i^k	-	Current velocity of agent I at iteration k
φ_i^{k+1}	-	New velocity of agent i at iteration k
η_1	-	Adjustable cognitive acceleration constants (self confidence)
η_2	-	Adjustable social acceleration constant (swarm confidence)
$\Gamma_{1,2}$	-	Random number between 0 and 1
Ω_i^k	-	Current position of agent i at iteration k
$pbest_i$	-	Personal best of agent i
$gbes$	-	Global best of the population

LIST OF APPENDICES

CHAPTER 1

PROJECT INTRODUCTION

1.1 Project background

Hydraulic Actuators are crucial in engineering field as used in industrial process control. With capability to provide very high forces, high control accuracies, high power to weight ratio, good positioning capability and also have a compact structure to employ hydraulic pressure to drive an output member (Ljung, L., 1987). The fluid used in hydraulic actuator is highly incompressible and so that pressure applied can be transmitted instantaneously to the member attached to it. Due to that reason, research for the control of force and position of electro-hydraulic system attract a great interest to both the researchers and engineers.

An important step in designing a control strategy is to having a proper model for the plant system. An exact system model should produce output responses similar to the actual system. The complexity of most physical systems, however, meets any difficulties in developing the exact models. In case the model and parameters are unknown, appropriate techniques that called System Identification can be applied to overcome all those limitations.

Currently, a number of techniques of system identification have been applied to estimate the hydraulic actuator model in form linear models, non-linear models and intelligent models. Linear model such as Auto-regressive Exogenous (ARX) model with PRBS signal as input signal (Huang, S.H. and Chen, Y.H.C., 2006) and ARX model with multi sine signal with three different frequencies is chosen as the input to the system (Rahmat, M.F. *et al*, 2010). Nonlinear model has proposed in observer canonical form using a modified Recursive Instrument Variable (Jelali, M. and Schwarz, H., 2005), and Hammerstein model which makes the assumption that the nonlinearities of the systems can be separated from the system dynamics (Kwak, B.-J. *et al*., 1998). Since neural networks have been successfully used in various fields, back-propagation neural networks were applied in identification of electro-hydraulic actuator model (Anyi, H. *et al*., 1997). In the last few years, neural networks have been developed in form online identification using Recurrent High Order Neural Networks (RHONN) method (Lizarde, C. *et al*., 2005). Another online identification of the systems parameters is based on recursive least square algorithm, with constant trace (Kaddissi, C. *et al*., 2007). In this Project, the linear model such as Auto-regressive Exogenous (ARX) model with multi sine with different input frequencies is used.

Regarding on the controller propose for the industrial hydraulic actuator, there are several type of controller has been designed before starting with linear control, which applied a simple poles placement to a linearized model of an electro-hydraulic system (Lim,T.J.,1997) and following by classic cascaded loops and proportional-integral-derivative (PID) controllers were employed respectively for the position control of a hydraulic actuator (Plahuta, M.J. *et al*., 1997), (Zeng, W. and Hu, J.,1999). The next control design is an indirect adaptive controller, based on pole placement for the speed and position feedback of electro-hydraulic systems (Yu, W.S. and Kuo, T.S., 1996). However, the controllers which are based on a linear model of the plant, imposes certain limitations on the efficiency and robustness of the controller. With dynamic characteristics of fluid power leads to uncertain dynamic modeling and thus robust control strategies can increase safety, reliability and availability of hydraulic actuators. As a controller designing stage for the industrial hydraulic actuator, the Proportional Integral Derivative Neural Network (PIDNN) controller is implemented. PID neural network which is proposed by Huaillin *et al*. (2000) is a new kind of networks and its hidden layer neurons simply work as PID controller terms through their activation functions thus it simultaneously utilizes advantages of both PID controller and neural structure.

To obtain the optimal parameter tuning for the controller, it is highly desirable to increase the capabilities of PIDNN controllers by adding new features. Most in common, artificial intelligence (AI) techniques have been employed to improve the controller performances for a wide range of plants while retaining the basic characteristics. Artificial Intelligent techniques such as artificial neural network, fuzzy system and neural-fuzzy logic have been widely applied in order to get proper tuning of PID controller parameters. In this project is focuses on utilizing a soft computing strategy, namely the particle swarm optimization (PSO) technique that was first proposed by Kennedy, J. and Eberhart, R. (1995), as an optimization strategy to tuning of PID neural network weights adjustment and fine tuning the controller's parameters. Below Figure 1.1 is shown the general idea on this project.

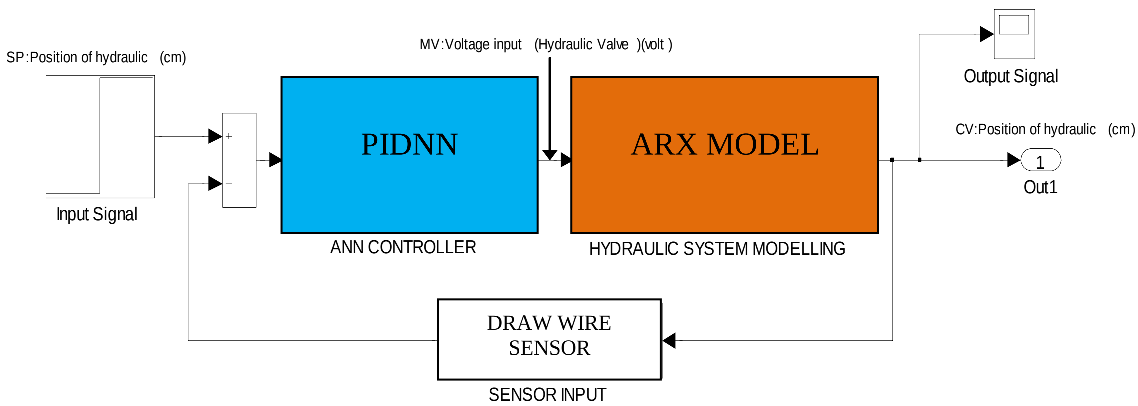

Figure 1.1: General idea for this project

1.2 Objectives

In carrying out of this project, the objectives are as follows in order to fulfill the requirement of system identification and controller design for industrial hydarulic actuator:

i. First objective of this project is determining the mathematical modeling of Industrial Hydraulic Actuator by using System identification technique utilizing real experiment data.

ii. Second objective is design a controller for an industrial hydraulic actuator's position control or displacement control.

iii. Third objective is to validate the controller design obtained via simulation through experimental procedure.

1.3 Project Scopes

This project is t intends to concentrate on the scopes as follows:

i. Familiarize with the Hydraulic Industrial Actuator system. In order to ensure the data are taken in the right manner, the study of the system is must be made. The integration connection between the hydraulic systems with the MATLAB is performing with the DAQ card.

ii. Experimental data collection with Real Time Workshop. The input-Output for Hydraulic System Actuator are being collected trough the real time Workshop. The multi Sine input are used as a input to the system. Then, the movement of the cylinder that varies with the input is recorded in term of voltage.

iii. The model is for the industrial hydraulic actuator system performed in linear discrete model to obtain a discrete transfer function for the system. Model estimation and validation procedures are done by using System Identification Toolbox in MATLAB. Data for model estimation is taken from an experimental works.

iv. Design the artificial neural network (ANN) controller and implement at modeling of industrial hydraulic actuator.

1.4 Project report overview

This document is arranged as follows:

i- Chapter one gives an introduction and general overview of the study. It focuses on the research problem and motivation for the study.

ii- Chapter two provides a brief outline on Electro hydraulic actuator system, system identification, artificial neural network controller and some background for Particles Swarm Optimization (PSO).

iii- Chapter three highlights the methodology of the project. Which is includes the experimental setup, modeling by using Matlab, PID neural network controller design and discusses on the PSO tuning approach.

iv- Chapter four discusses about the result of simulation and real time experimental study that compares the control performance of PIDNN tuning by PSO with the conventional PID controller.

v- Chapter five concludes the findings of the study and provides direction for further research that could be pursued in the field.

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