POSITION CONTROL FOR INTELLIGENT PNEUMATIC ACTUATOR USING GENERALIZED MINIMUM VARIANCE CONTROL

ZALINA BINTI KAMIS

A project report submitted in partial fulfilment of the

requirements for the award of the degree of

Master of Engineering (Electrical-Mechatronics and Automatic Control)

Faculty of Electrical Engineering

Universiti Teknologi Malaysia

JANUARY 2014

Specially dedicated to *my family*.

ACKNOWLEDGEMENT

I would like to express my gratitude to Universiti Teknologi Malaysia (UTM) for giving me the opportunities to pursue my Master in Electrical Engineering.

I would like to express my profound gratitude to Ir. Dr. Ahmad ‘Athif bin Mohd Faudzi for his supervision, encouragement, suggestions and trusted throughout the duration of this research. A special thanks to Mr. Khairuddin for his guidance in my project.

Also I would like to express my big thanks to all my colleagues for their support and time during my project.

Last but not least, I would like to thank my mother, my husband and my family for giving me their full support, understanding and patience. Without their support, I would not have been able to finish my project.

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ABSTRACT

Pneumatic actuators are finding increasing acceptance these days due to their low cost, ease of maintenance and moderately high power to weight ratio. A position model for IPA has been proposed by using system identification techniques resulted in a transfer function model. Generalized minimum variance control (GMVC) is one of the commonly control algorithms that used in the pneumatic actuators area. The performance of an algorithm is obtained by combining a generalized minimum variance control with a recursive estimator for the controller parameters. In this project, an indirect self-tuning generalized minimum variance control is used to assure the system output response can track any changes in the reference set point. This project aims to design generalized minimum variance controller to control the position of the IPA. The controller will be designed using MATLAB/SIMULINK based on the proposed models. The simulations results will be compared with the other types of controller (fuzzy logic controller) simulation results in order to see the performance of the GMVC.

ABSTRAK

Penggerak pneumatik semakin diterima hari ini kerana kosnya yang rendah, mudah diselenggara dan kuasa sederhana tinggi kepada nisbah berat. Model bagi kedudukan untuk penggerak pneumatik telah dicadangkan dengan menggunakan teknik pengenalpastian sistem untuk mendapatkan fungsi bagi model tersebut. Kaedah Kawalan Perbezaan Minimum Umum (GMVC) adalah salah satu algoritma kawalan yang digunakan untuk penggerak pneumatik. Prestasi algoritma diperoleh dengan menggabungkan kawalan perbezaan minimum umum dengan penganggar rekursif untuk parameter pengawal. Dalam projek ini, penalaan-teritlak kawalan perbezaan minimum tidak langsung digunakan untuk memberi jaminan kepada isyarat keluaran sistem dapat mengesan apa-apa perubahan dalam titik set rujukan.Projek ini bertujuan untuk merekabentuk kaedah kawalan perbezaan minimum umum untuk mengawal kedudukan penggerak pneumatik. Kaedah kawalan perbezaan minimum umum direka dengan menggunakan MATLAB/ SIMULINK berdasarkan model yang dicadangkan. Keputusan simulasi akan dibandingkan dengan keputusan simulasi pengawal lain iaitu pengawal logic kabur untuk melihat prestasi GMVC

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATION

GMVC	-	Generalized Minimum Variance Control
IPA	-	Intelligent Pneumatic Actuator
GA	-	Genetic Algorithm
SI	-	System Identification
ARX	-	Autoregressive with exogenous terms
PI	-	Proportional Integral controller
PDFLC	-	PD-Fuzzy Logic Controller
GPC	-	Generalized Predictive Control
PSoC	-	Programmable System on Chip
PID	-	Proportional Integral Derivative controller
NGMVC	-	Non-linear Generalized Minimum Variance Control
FLC	-	Fuzzy Logic Control
NL	-	Non-linear
NFGMVC	-	Neuro-fuzzy Generalized Minimum Variance Control

CHAPTER 1

INTRODUCTION

1.1 Introduction

Pneumatic actuator is a device that coverts energy (compressed air) into mechanical motion. It is basically consists of a piston, a cylinder and valves. In cylinder or chamber, it contained regular air, a pressurized gas or a mixture of the two and allowed to expand. Once the gas expands pressure in the natural atmospheric and pressures inside the chamber are different. Due to this pressure difference, it causes the gas to build up energy. After that, the gas leaves the chamber so that it is directed toward a piston, gear or some other in a controlled manner. In order to perform the actual work to be done, the piston is used. The piston can be driven either in a straight line or in a circle depending on how the actuator is designed and how the gas is directed toward the piston.

There are several types of actuators; manual, hydraulic, electric and pneumatic. Pneumatic compared with other types of actuators is more simplistic so it easier to produced and control. Other than that, pneumatic is safer on producing motion since it only use air (compressed gas). Pneumatic actuator is highly durable. Since it only contain compressed gases, even though there is no electricity supplied to the actuator the gas still can be stored. Due to this property, pneumatic actuator can remain operational for a very long time.

The intelligent pneumatic actuator is expected to be an independent actuator that can be driven depending on the input given and can control the data equivalently to execute certain output action (valve). The term 'intelligent' is being used because the actuator has the ability to process data locally and give output based on the input response. To control the data for input and output processing the control algorithms and communication protocol are set in PSoC. Force is controlled by manipulating the difference of pressures in the two chambers.

IPA is a linear double acting cylinder [2,3,4,5] which is consists of two inlets and one exhaust outlet. There are five components in IPA plant and IPA schematic operation is as shown in Figure 1.1 and Figure 1.2 below. Table 1.1 below shows the components in IPA model and its function. For driving the cylinder, two ON/OFF valves (two ports two positions) is applied at the cylinder. PSoC is fixed at the top of the actuator and at the end of the cylinder, valves are attached to it. Force for this actuator is up to 100N and has 200mm stroke.

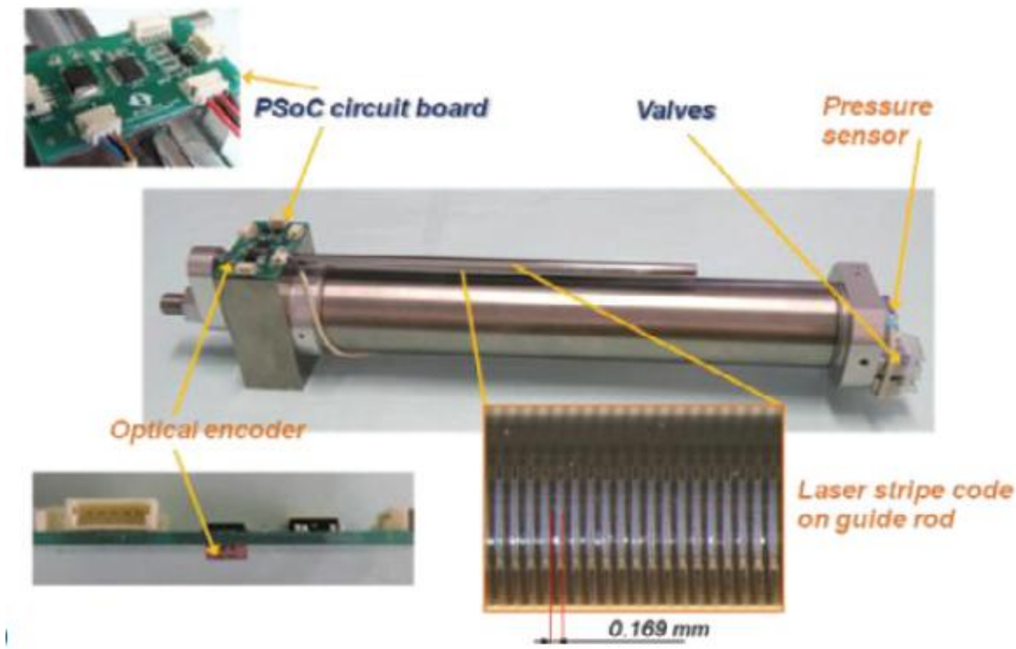

Figure 1.1 IPA and its components [2]

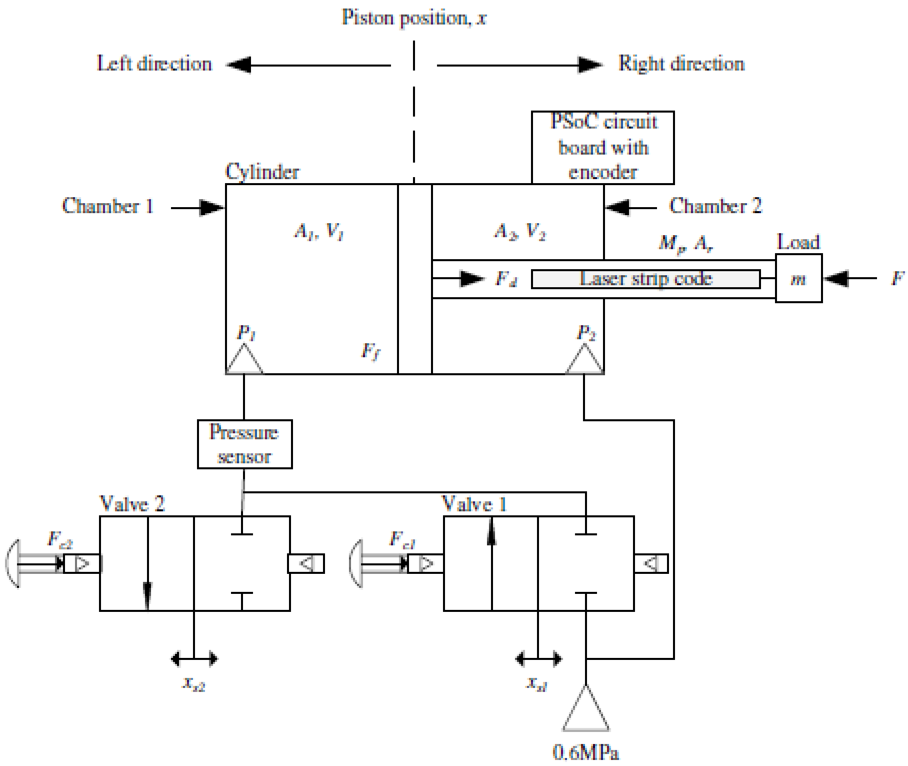

Figure 1.2 IPA schematic operation [2]

Table 1.1: IPA components and its function

Components	Function
PSoC	As a controller
Laser strip code	Has two types: 1.0 0.169 mm 2.0 0.01 mm For position feedback
Optical encoder for 0.169 mm and laser sensor for 0.01 mm	Reading the laser strip code
Valve	Controlling the injection of air into the chamber
Pressure sensor	Check chamber pressure to control cylinder (applies two ON/OFF valves)

1.2 Overview of Generalized Minimum Variance Control

Controller as in Oxford Dictionary can be defining as a person or thing that directs or regulates something. In Oxford Advanced Learner's Dictionary, controller can be defined as a device that controls or regulates a machine or part of a machine. Controller can be divided into two parts. There are model based and non-model based controller. Figure 1.3 below shows an overview of control structure.

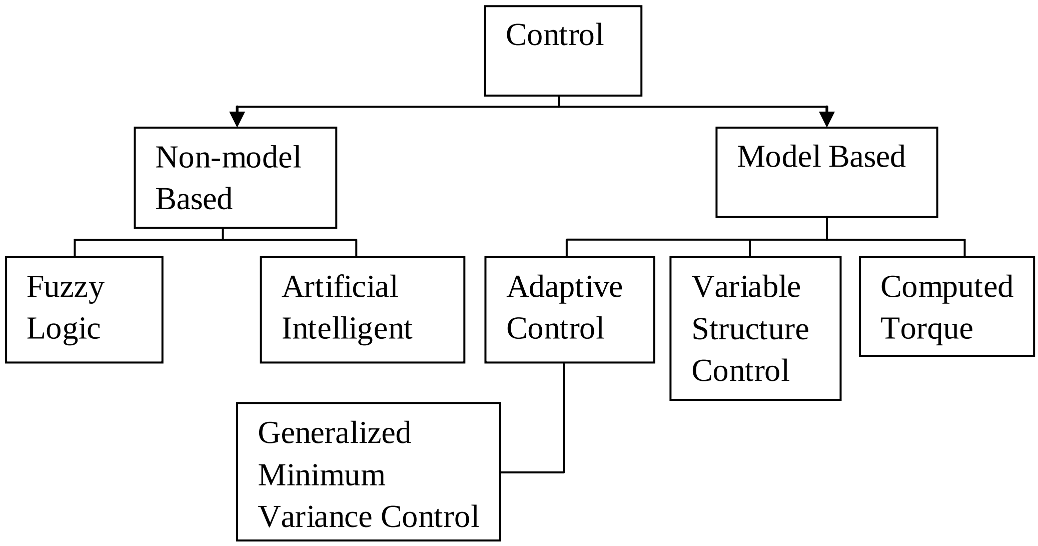

Figure 1.3 Overview of control structure

GMVC is one type of adaptive predictive control methods [1] that consist of a tracking error cost function and a control input. The GMVC is an extended modification from MVC. This controller is obtained by minimizing the cost function of linear input-output model. There are several ways in designing GMVC and as for this project indirect self-tuning GMVC is used. One advantage of indirect self-tuning GMVC is that the computation design is eliminate since the controller parameter are estimated directly.

When using indirect self-tuning GMVC, there are two steps involved. The first step is to estimate the polynomials of the process model. In a second step, to determine the polynomials in the regulator from the estimated parameter (in step 1) a design method is used. Astrom and Wittenmark (1980) present a typical application of an indirect self tuning GMVC as shown in Eq. 1.0 and Eq 1.1.

$$A(z^{-1})y(t) = B(z^{-1})u(t-k) + C(z^{-1})e(t) \tag{1.0}$$

$$AE + z^{-k}G = PC \tag{1.1}$$

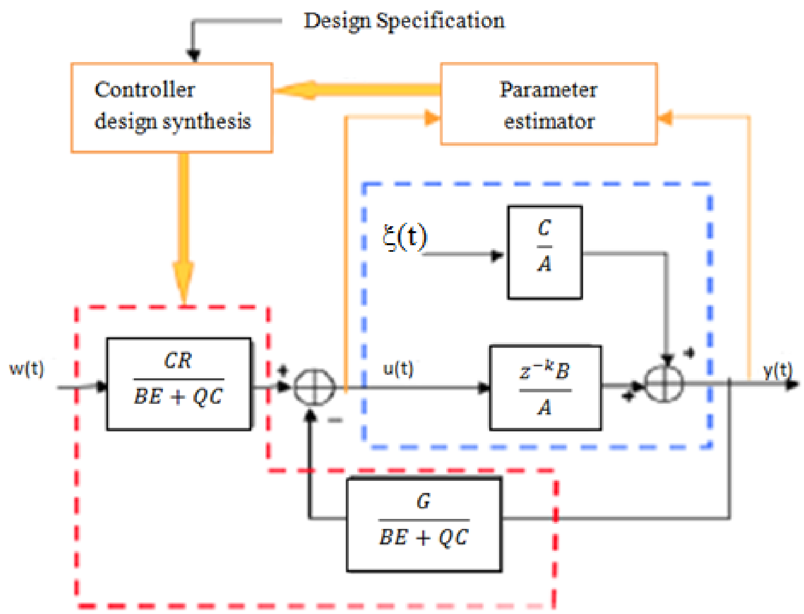

Figure 1.4 The Structure of self tuning GMVC

1.3 Problem Statement

Pneumatic actuator is become more complex and leads to the development of an intelligent pneumatic actuator. Due to this development, controlling design for pneumatic system is more challenging to control the position and force. Furthermore, IPA has many non-linear characteristic such as mass flow rate parameters, dead zone problem and compliance variation that causes it difficult to control. This non linearity and constraint such as friction, the limitation of the valve and the natural weight involved will make the plant unstable. Other than that, pneumatic actuator has many uncertainties and disturbances so that robust controller is suitable as a controller.

1.4 Project Objectives

The objective of this research is mainly focus to develop a generalized minimum variance control as a position control for intelligent pneumatic actuator. Additionally, the design of generalized minimum variance control must be able to adapt to the IPA plant.

1. To design generalised minimum variance control as a controller for position of IPA system.

2. To verify generalized minimum variance control simulation results with other types of controller (fuzzy logic control).

1.5 Project Scope

The scope of this project is limited to the following items so that the research could be focused to achieve the stated objectives. First, the design of generalized minimum variance control is focusing on control position of IPA. Model for IPA system using SI techniques is obtained from previous work done by Ahmad ‘Athif *et al.* Next, GMVC is simulating by using MATLAB/SIMULINK Toolbox. GMVC simulation results for position control are compared to the other simulation results of different types of controller (FLC).

1.6 Thesis Outline

Chapter 1 presents some overview about pneumatic actuator, generalized minimum variance control, problem statement, objectives and scope or limitation of the study.

Chapter 2 describes some relevant literature review on pneumatic actuator system and generalized minimum variance control. Besides that, the pneumatic plant for position is also included.

Chapter 3 discussed methodology or flow process for study area. In this chapter also include design procedure for generalized minimum variance control and fuzzy logic controller.

Chapter 4 discussed and analyzed the results obtain for both controller used; generalized minimum variance control and fuzzy logic controller. The comparison in term of characteristic performance for these two controllers also discussed.

Chapter 5 concluded from the results obtain and suggestion for future work has been proposed.

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