

APPLICATION OF HARMONY SEARCH ALGORITHM AND  
PARTICLE SWARM OPTIMIZATION FOR TUNING PROPORTIONAL -  
DIFFERENTIAL FUZZY CONTROLLER FOR POSITION CONTROL IN  
PNEUMATIC ACTUATOR

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This thesis is dedicated to my beloved parent, Mohd Ishak Bin Zakaria and Rohana Bt Mohamad, my wife, Wan Nurul Hani Bt Wan Hasan and not forgotten to all my friend, thank you for the sacrifice and support.

May Allah bless all of you. Amin!

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## **ABSTRACT**

Pneumatic actuator system is highly nonlinear and time varying due to many factors such as friction, load variations, air compressibility, dead-time and leakage. Therefore handling and controlling the pneumatic actuator required a specific knowledge and suitable control strategy. In this project, the optimization of pneumatic actuator system which primarily consists of proportional valve and double acting cylinder are presented. The optimization methods that are chose is Harmony Search Algorithm (HSA) which recently introduced and developed and the other one is Particle Swarm Optimization (PSO); population based stochastic optimization technique that inspired by social behaviour of bird flocking or fish schooling. The optimization techniques will be tested by simulation using MATLAB Simulink and then validated by real time experiment. The tracking performances of both techniques are compared and the results show that the HSA provides a better tracking performance compared to the PSO.

## ABSTRAK

Sistem penggerak pneumatik adalah tersangat kompleks disebabkan oleh beberapa faktor seperti geseran, perubahan beban, kemampatan cecair, kebocoran dan lain-lain. Oleh itu mengendalikan dan mengawal penggerak pneumatik yang diperlukan pengetahuan tertentu dan strategi kawalan yang sesuai. Projek ini bertujuan mengoptimumkan sistem penggerak pneumatik yang terdiri daripada injap berkadar dan silinder dua tindakan. Kaedah-kaedah pengoptimuman yang dipilih adalah *Harmony Search Algorithm* (HSA) yang baru dibangun dan diperkenalkan dan yang lain adalah *Particle Swarm Optimization* (PSO); populasi berdasarkan teknik pengoptimuman stokastik yang diilhamkan oleh tingkah laku sosial burung atau ikan. Teknik-teknik pengoptimuman akan diuji oleh simulasi menggunakan MATLAB Simulink dan kemudian disahkan oleh eksperimen. Prestasi penjejak kedua-dua teknik dibandingkan dan keputusan menunjukkan bahawa HSA menunjukkan prestasi penjejak yang lebih baik berbanding dengan PSO.

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**LIST OF ABBREVIATIONS**

DAQ – Data Acquisition  
DP - Dynamic Programming  
FLC - Fuzzy Logic Control  
GA - Genetic Algorithms  
HS - Harmony Search  
HSA – Harmony Search Algorithm  
LED - Light-Emitting Diode  
LP - Linear Programming  
NLP - Non-Linear Programming  
PA - Pneumatic Actuator  
PD - Proportional Differentiator  
PDF – Proportional Derivative Fuzzy  
PI - Proportional Integral  
PID - Proportional Integral Differentiator  
PSO - Particle Swarm Optimization  
PSoC - Programmable System on a Chip  
SMC - Sliding Mode Controller

# CHAPTER 1

## INTRODUCTION

### 1.1 Introduction

Intelligent linear motion is one of the applications that have high demand in industry. A smooth motion, higher linear force densities and good position accuracy are required in most of the applications. Pneumatic actuator (PA) is a system for application that requires better control and accuracy. Due to pneumatic actuators special attribute, they have become alternate actuator in automated material handling.

Fuzzy logic provides a certain level of artificial intelligence to the conventional PID controllers. PID Fuzzy controllers have self-tuning ability and on-line adaptation to nonlinear, time varying, and uncertain systems. PID Fuzzy controllers provide a promising option for industrial applications with many desirable features. Hence, this study will focus on the PD Fuzzy (PDF) controller for position control of the pneumatic actuator.

Once the controller have been chosen, the optimization of the controller need to be develop. Many problems in various fields have been solved using diverse optimization algorithms. Traditional optimization techniques such as linear programming (LP), non-linear programming (NLP), and dynamic programming (DP) have had major roles in solving these problems. However, their drawbacks generate demand for other types of algorithms, such as

heuristic optimization approaches (simulated annealing, tabu search, and evolutionary algorithms).

Particle Swarm Optimization (PSO) was first introduced in 1995 by Dr. Russell C. Eberhart and Dr. James Kennedy. The PSO algorithm is an adaptive algorithm based on a social-psychological metaphor; a population of individuals (referred to as particles) adapts by returning stochastically toward previously successful regions. Particle Swarm has two primary operators: Velocity update and Position update. During each generation each particle is accelerated toward the particles previous best position and the global best position. At each iteration a new velocity value for each particle is calculated based on its current velocity, the distance from its previous best position, and the distance from the global best position. The new velocity value is then used to calculate the next position of the particle in the search space. This process is then iterated a set number of times or until a minimum error is achieved.

A new heuristic algorithm, mimicking the improvisation of music players, has been developed and named Harmony Search (HS). Advantageous features of Harmony Search that are different from other methods are HS makes a new vector after considering all existing vector and HS does not require the setting of initial values of decision variables. These features help HS in increasing flexibility and in finding better solutions (1).

## **1.2 Problem Statement**

The highly nonlinear characteristics and uncertainties make pneumatic actuators difficult to achieve high performances. The compressibility of air and friction in the pneumatic actuators are the main factors to the nonlinearities in

the system that makes the pneumatic actuators difficult to control. A high number of unknown parameters need to be identified in order to achieve a dynamical response closed to real systems.

In order to overcome difficulties in pneumatic actuators, many approaches have been investigated and developed. The classical control was investigated such as Proportional-Integral-Derivative (PID) controller by (1). Besides, there are also some reports on the advanced control such as sliding mode controller (SMC), adaptive controller and a combination of controller.

### **1.3 Objectives**

The objectives of this study are:-

- i. To apply Harmony Search Algorithm (HSA) techniques in tuning Proportional Derivative Fuzzy (PDF) Controller for position control for Pneumatic Actuator (PA) system.
- ii. To apply Particle Swarm Optimization (PSO) techniques in tuning Proportional Derivative Fuzzy (PDF) Controller for position control for Pneumatic Actuator (PA) system.
- iii. To validate the simulation result with the real time experiment.

## **1.4 Scope and limitation**

The scope and limitation of this project are as follows:-

- i. The application of HSA and PSO will be implemented in both: simulation & real time application
- ii. Simulation will be done using MATLAB software while the real-time application is using actual pneumatic actuator system.
- iii. The study consists of the effectiveness of HSA and PSO in tuning PDF's parameters for PA and limited to position control of pneumatic actuator.

In this project, the application of HSA and PSO will be implemented in both: simulation and real time application.

## **1.5 Report Outline**

Chapter 1 introduces the overall project and explains the objectives as well as the scope of the project in order to give an insight and the sense of direction of the project.

Chapter 2 describes the pneumatic actuator system in general terms. Proportional derivative fuzzy controller and optimizations method problem and constraints are discussed. In addition, the recent literature on the approach is reviewed.

Chapter 3 discusses about the pneumatic actuator plant which will be optimized. The second part focuses on the discussion of development of the proposed Particle Swam Optimization and Harmony Search Algorithm and its application to the problems in details.

Chapter 4 discusses and analyzed the results obtain from simulation for Harmony Search Algorithm and Particle Swam Optimization. Then the result from both simulations will be validating in real time experiment.

Chapter 5 concludes and summarizes the result obtain. The suggestion for future work for this study has been proposed.

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