AC MOTOR POSITION CONTROL USING FUZZY LOGIC CONTROLLER

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ABSTRACT

Motor position control is very important in rotating machinery applications. There are many applications that have been developed based on motor position control theory, such as crane controller, lift and conveyor. The position control of an ac motor is very difficult to be implemented by using traditional control techniques, as it requires a very complex mathematical model. The purpose for this project is to describe the research on fuzzy logic controller (FLC) design based on programmable logic controller (PLC) in order to control the position of an ac motor of University Malaysia Pahang (UMP) mini conveyor. By using FLC, the conveyor will stop at the desired point set by the user with minimum error. The model of the PLC that has been used in this project is OMRON CQM1H-CPU51.Before the controller was developed, numbers of simulations were done using MATLAB Fuzzy Logic Toolbox and SIMULINK. There are three rules that have been implemented in this project, which used three membership functions. Based on the simulation, it can be concluded that the system which has many rules in the fuzzy logic controller produced better response compared to the system using a few rules.

ABSTRAK

Sistem kawalan motor adalah sangat penting dalam aplikasi-aplikasi yang menggunakan motor sebagai keperluan utama dalam sesuatu proses.Terdapat banyak aplikasi yang telah dijalankan berdasarkan teori sistem kawalan motor.Antaranya ialah system kawalan kren, lif dan konveyor.Dalam proses mengawal pergerakan motor, kajian telah menunjukkan bahawa motor arus ulang alik adalah susah untuk dikawal jika dibandingkan dengan motor arus terus. Dengan menggunakan teknik kawalan tradisional, proses kawalan akan menjadi lebih sukar kerana ia memerlukan model matematik yang kompleks. Oleh sebab itu, pelbagai cara dan teknik telah dijalankan untuk mengatasi masalah ini. Tujuan projek ini dijalankan adalah untuk mengkaji salah satu antara langkah untuk mengatasi masalah yang dinyatakan,iaitu sistem kawalan logik dengan menggunakan PLC dan diaplikasikan dengan menggunakan konveyor mini UMP. Dengan menggunakan sistem kawalan logik, konveyor akan berhenti pada tempat atau sudut yang telah ditentukan oleh pengguna pada sedikit ralat. Model PLC yang telah digunakan dalam projek ini OMRON CQM1H-CPU51. Sebelum sistem logik ini dibentuk, simulasi telah dilakukan terlebih dahulu dengan meggunakan MATLAB Fuzzy Logic Toolbox dan MATLAB Simulink. Terdapat tiga arahan yang digunakan dalam projek ini. Ketiga-tiga arahan ini menggunakan tiga fungsi hubungan. Berdasarkan simulasi yang telah dijalankan, ianya membuktikan bahawa sistem kawalan logik yang menggunakan lebih banyak arahan akan menghasilkan respons yang lebih baik dan lebih tepat berbanding dengan sistem yang menggunakan bilangan arahan yang sedikit.

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CHAPTER 1

INTRODUCTION

1.1 Overview

Any controller design for any system commonly needs some knowledge about the system before it will be developed. This involves a mathematical description of the relation among inputs to the process, its variables and its output, that is called the model of the system. The model can be represented as a set of transfer functions, which is usually called mathematical modeling. Modeling for the complex systems can be a very difficult task. For example, in a complex system such as a multiple inputs and multiple outputs system, the inaccurate models will cause the systems is unstable or has a bad system performance.

Fuzzy logic control is an effective alternative approach for systems which are difficult to model. It is a digital control methodology that allows the human description of the physical system, which required control strategy to be simulated in a reasonably natural way [2]. Using fuzzy logic has avoided the need for a precise mathematical model of the control system. It uses membership functions to define the degree to which crisp physical values belong to a set of terms in a linguistic variable set. That is the reason on why fuzzy logic control is widely used in engineering field especially in control, modeling, image/signal processing and expert systems.

1.2 Objective

The main aspect of intelligent control addressed in this thesis is the design of a controller for controlling the position of ac motor by using PLC. The position of single phase ac motor of UMP mini conveyor will be controlled by using FLC. The FLC will act to minimize the error and make the motor stop at the required position.

1.3 Scope

The scope of this project is to build a FLC system with the main contribution is fuzzy algorithm. Secondly is to demonstrate using PLC and single phase ac motor. The third scope focused to control the motor rotating based on the desired set point by the user with minimum error.

1.4 Problem Statement

The position control of ac motor is very difficult when it is done by using traditional control techniques, as it requires a very complex mathematical model. By using fuzzy logic, we can eliminate the need for the mathematical modeling and allows easy realization as a solution. In this project, the fuzzy logic is implemented into PLC because it offers the easier way to troubleshoot a system compared to the system using microprocessor, microcontroller or other controllers. With this advantage, the men in charge do not have to troubleshoot the system from a scratch when there is system problems happen. Besides that, PLC uses ladder diagram, which is easier to handle and manage by most people.

1.5 Thesis Organization

This thesis consists of five chapters including this chapter. The contents of each chapter are outlined as follows;

Chapter 2 contains a detailed description on the FLC. It will explain about the process in fuzzy logic control, which is fuzzification, fuzzy inference system and defuzzification.

Chapter 3 includes the project methodology. This will explain how the project is organized and the flow of the process in completing this project.

Chapter 4 presents the result of simulation runs using Fuzzy Logic Toolbox and MATLAB SIMULINK.

Finally the conclusions for this project are presented in Chapter 5.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The first FLC was invented by Professor E.H. Mamdani at the University of London in 1974.The controller was designed for a plant which comprised a steam engine and boiler combination. The model of the plant had two inputs: the heat input to the boiler and the throttle opening at the input of the engine cylinder, and two outputs: the steam pressure in the boiler and the speed of the engine. The problem in classical control was that the plant model was highly nonlinear with both magnitude and polarity of the input variables [15]. This is the reason behind the fuzzy logic found.

However, the concept and theoretical foundation of fuzzy control and systems had been developed by Professor Lotfi Zadeh a few years earlier, which is in 1965. There are a few steps that must be followed in order to develop a FLC. First, the actual inputs and output and their universe of discourse range is defined. Next, the scale factors are set for input and output variable. The next step is to define the fuzzy membership functions to be used in setting up the fuzzy sets for each input and output variables. Then, the fuzzy control rule base or fuzzy inference mechanism is created for the system and the last one is determine the defuzzification methods to be applied. Figure 2.1 shows the basic structure of FLC.

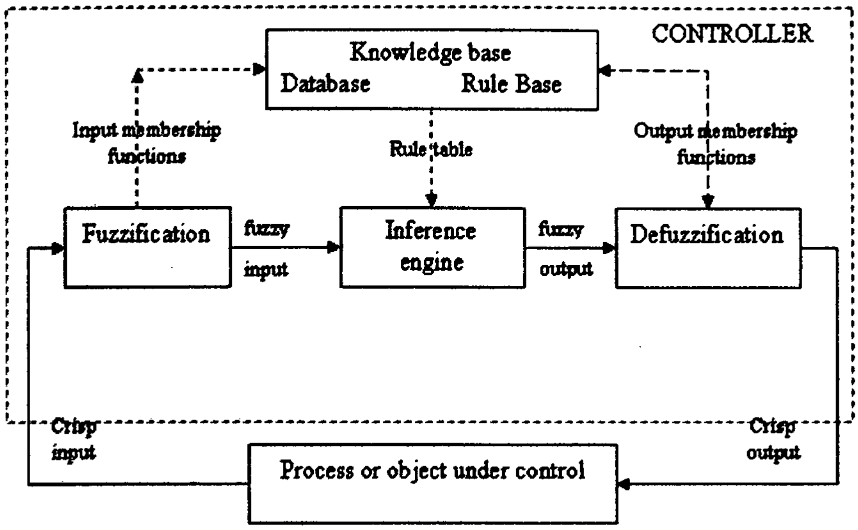

Figure 2.1: Basic Structure of FLC [15]

It has been implemented in the development of improved motor control because fuzzy logic is able to overcome the mathematical difficulties of modeling highly non-linear system [3].A fuzzy system can be created to match any set of input-output data. This process is made particularly easy adaptive techniques. Fuzzy systems are the knowledge-based systems that use a set of fuzzy rules of the IF-THEN form to determine the output of the controller from a given set of inputs. Besides, it is also responds in a more stable function to imprecise readings of the feedback control parameters and controls mathematic [3].

Everything is imprecise if we look closely enough but more than that, most things are imprecise even on careful inspection. Fuzzy reasoning builds this understanding into the process rather than tracking it onto the end. In addition, fuzzy logic is able to manage mathematics and the software are simple to develop and flexible for each modification. With any given system, it is easy to massage it or layer more functionality on top of it without starting again from scratch. The fuzzy logic control approach was chosen to achieve a very short implementation time, high robustness towards the effects of temperature and saturation and good lead and disturbance behavior [3]. In addition, fuzzy logic is based on the natural language. The basis for fuzzy logic is the basis for human communication. This observation includes in many of the other statements about fuzzy logic.

As mentioned before, fuzzy logic operations can be divided into three steps. The first one is fuzzification, whereby the actual inputs are fuzzified and fuzzy inputs are obtained. Secondly, fuzzy processing, which process the fuzzy inputs according to the rules set and produce fuzzy outputs and the last step is defuzzification, which produce a crisp real value for a fuzzy output.

2.2 Fuzzy Inference System

The inference engine is the heart of a FLC. The fuzzy inference systems are the knowledge-based systems that use a set of fuzzy rules of the IF-THEN form to determine the output of the controller from a given set of inputs [3].

It is the actual process of mapping from a given input to an output using fuzzy logic. The mapping then provides a basis from which decisions can be made. It can contain the elements with only a partial degree of membership. In this project, Fuzzy Logic Toolbox in MATLAB and SIMULINK has been used to build the initial experimental of fuzzy inference system. In general, there are five parts of the fuzzy inference process. The fuzzy inference process consists of fuzzy set definition, fuzzification, rule base, fuzzy operators, implication, aggregation and defuzzification.

2.2.1 Fuzzy Set Definition

Before developing FLC, the universe of discourse must be identified and fuzzy sets also must be defined. The definition of these sets requires expert knowledge of the control system. The shape of the membership function is also determined at this step. The most common shape of membership function is triangular. In this project, triangular shape of membership function is used. Figure 2.2 shows an example of triangular shape for the membership function MIN, MED and MAX.

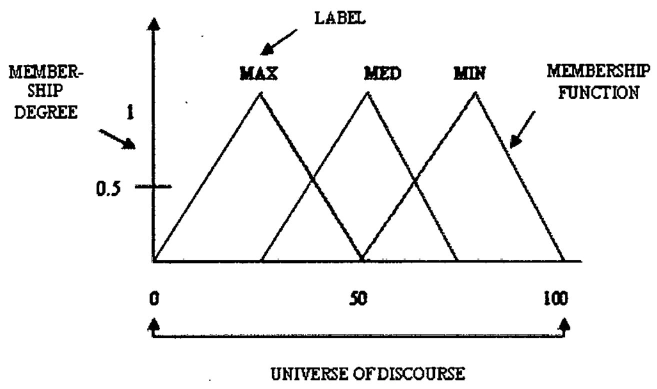

Figure 2.2: Triangular Shape of Membership Function

2.2.2 Input fuzzy sets

These inputs are resolved into a number of different fuzzy linguistic sets. For example, in Figure 2.3, there are 5 fuzzy set inputs, which are Very Small, Small, Big, Very Big and Zero.

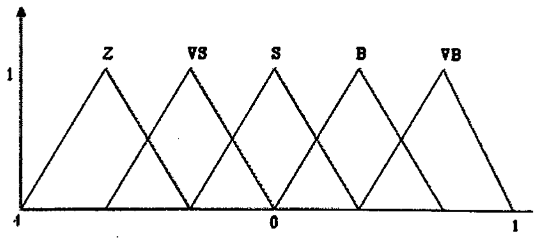

Figure 2.3: Five Membership Functions for Input

2.2.3 Output fuzzy sets

Figure 2.4 shows the output fuzzy sets. There are also five fuzzy sets.

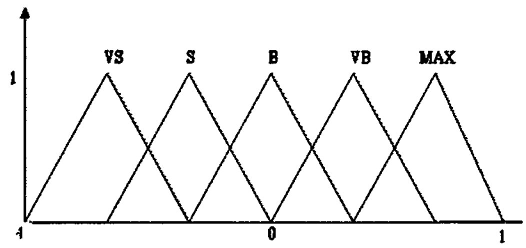

Figure 2.4: Five Membership Functions for Output

2.2.4 Fuzzification

The input data (crisp data) is fuzzified according to the membership functions. The fuzzified input is the degree to which each part of the antecedent has been satisfied for each rule.

2.2.5 Rule Base

There are three methods to determine of control rules, which are the method based on a fuzzy model of the process, method based on the operator's experience and/or the control engineer's knowledge and method based on learning.

2.2.6 Fuzzy Operators

The fuzzy operator is applied to the fuzzified input and results in a single number that represents the result of the antecedent for that rule. This number can be then applied to the output membership function. The inputs to the fuzzy operator are two or more membership values from the fuzzified input variables. In this project, AND operator is used.

2.2.7 Implication

The implication method is defined as shaping of the consequent (a fuzzy set) based on the antecedent (a single number). The input for the implication process is a single number given by the antecedent, and the output is a fuzzy set.

2.2.8 Aggregation

Aggregation is the method for unifying the outputs of each rule by joining the parallel threads. In this process all the output fuzzy sets from each rule are united into one fuzzy set.

2.2.9 Defuzzification

The input for defuzzification is the fuzzy set and the output is a crisp value. This process can be obtained using six known ways, which are mean of maxima, first-of-maxima, center-of-gravity/area, center-of-largest area, middle-of-maxima and height defuzzification. Centroidal defuzzification method (center of gravity method) is perhaps the most popular method is used for defuzzification. The equation for calculating the output using this method is;

$$U_o = \frac{\Sigma U (U_j) U_j}{\Sigma U (U_j)}$$

Where U_0 is determined by means of gravity center of the area under the membership function curve of the fuzzy output and $U (U_j)$ is a membership grade of U_j.

2.3 PLC

PLC is used primarily to replace relays, timers and counters. The updating process for these facilities for the yearly model change-over were very time consuming and expensive, as the relay systems needed to be rewired by skilled electricians. In 1968, the automatic transmission division of General Motors, which is known as GM Hydramatic issued a request for proposal for an electronic replacement for hard-wired relay systems [13]. The successes proposal came from Bedford Associates of Boston, Massachusetts. Then, the first PLC is designed and named as 084 because it was Bedford Associates eighty-fourth project. Bedford Associates started a new company dedicated in developing, manufacturing, selling, and servicing a new product called Modicon, which is stand for Modular Digital Controller. One of the people who worked on that project was Dick Morley, who is considered to be the "father" of the PLC. The Modicon brand was sold in 1977 to Gould Electronics, and later acquired by German Company AEG and then by Schneider Electric, the current owner [13].

Nowadays, electricity has been used for control and early electrical control was based on relays. These relays allow the power to be switched on and off without a mechanical switch. It is common to use relays to make simple logical control decisions. The development of low cost computer has brought PLCs revolution as mentioned before and now, it has become the most common choice for manufacturing controls and motor controls. They have gained popularity in engineering field because of the advantages they offers.

One of the advantages is an effective cost for controlling complex systems. Secondly, it is flexible and can be reapplied to control other systems quickly and easily. Besides, its computational abilities and trouble shooting aids allow more sophisticated control and make programming easier while reduce downtime.

2.4 Single Phase Ac Motor

Various market analyses shows that 90% of all industrial motor applications use induction type motors [6]. There are many reasons for this analysis includes reliability, cheaper, more rugged, maintenance free, high efficiency, which is up to 80% higher and are most common in-medium-to high power applications involving fairly constant speed operation.

Of late, much effort has been invested in developing improved control methods for ac motors, and significant progress is seen in this area. Today's ac motors and their advanced drive systems with frequency control and field feedback compensation. However, the used of induction motors has several disadvantages which is difficult controllability due to the complex mathematical model of the motors, their nonlinear behavior during saturation and oscillations of the electrical parameters due to the physical influence of the temperature. That is the reason on why fuzzy logic approach is the most preferable solution in motor controls.

In this project, a single-phase ac motor will be used because of its advantages of simplicity and low cost. The stator of a single-phase motor has only one set of drive windings (with two or more stator poles) excited by a single-phase ac supply. If the rotor is running close to the frequency of the line ac, this single phase can maintain the motor torque, operating as an induction motor.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter presents the methodology of this project. It describes on how the project is organized and the flow of the steps in order to complete this project. The methodology is diverged in two parts, which is simulations using Fuzzy Logic Toolbox and MATLAB SIMULINK. The other is developing the real project by implementing the fuzzy logic into PLC.

3.2 Methodology

There are three mains method in order to develop this project. Before the real project is developing using PLC, it is need to be simulated using Fuzzy Logic Toolbox and MATLAB SIMULINK. The flowchart in Figure 3.1 illustrated the sequence of steps for this project.

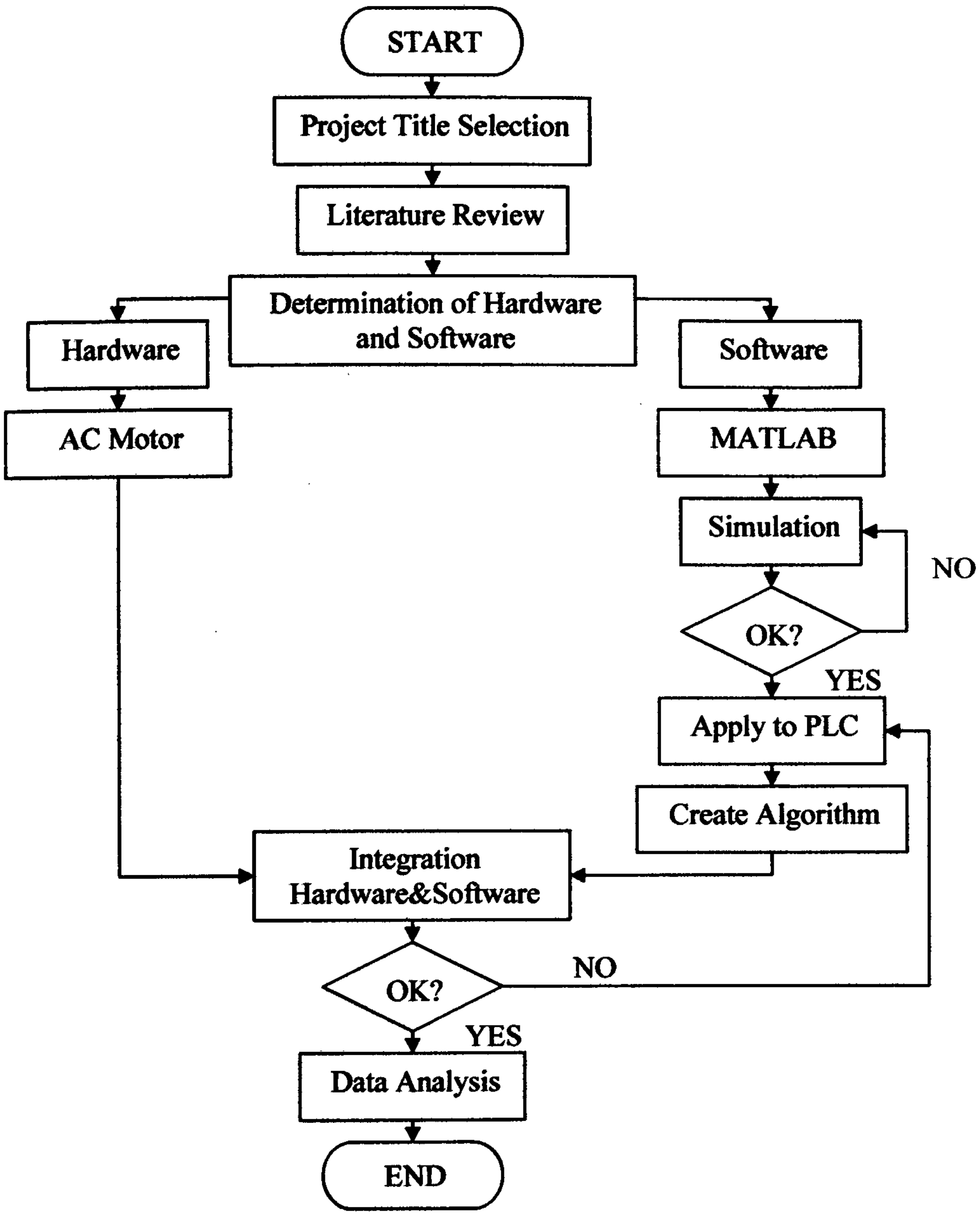

Figure 3.1: Flowchart for Whole Project

3.2.1 Build the system using Fuzzy Logic Toolbox

In order to build up the FLC, it is easier to use Fuzzy Logic Toolbox in MATLAB software. The figures below show the FIS Editor and Membership Function Editor for two systems. Figure 3.2 shows the membership function for the first controller. It uses three membership functions, which are Minimum (MIN), Medium (MED) and Maximum (MAX). The other controller uses five membership functions, which are Zero (Z), Very Small (VS), Small (S), Big (B) and Very Big (VB), as shown in Figure 3.3. By using all these membership functions, the fuzzy inference engine will decide the output based on human thinking or human experience.

Table 3.1: Input and Output Fuzzy Sets for Three Membership Functions

Fuzzy Set	Description
MIN	Minimum
MED	Medium
MAX	Maximum

Table 3.2: Input Fuzzy Sets for Five Membership Functions

Fuzzy Set	Description
Z	Zero
VS	Very Small
VB	Very Big
B	Big
S	Small