Faculty of Information and Communication Technology

GENETIC ALGORITHMS IN OPTIMIZING MEMBERSHIP FUNCTION FOR FUZZY LOGIC CONTROLLER

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ABSTRACT

This study investigates the use of Genetic Algorithms (GA) to design and implement of Fuzzy Logic Controllers (FLC). A fuzzy logic is fully defined by its membership function. What is the best to determine the membership function is the first question that has be tackled. Thus it is important to select the accurate membership functions but these methods possess one common weakness where conventional FLC use membership function and control rules generated by human operator. The membership function selection process is done with trial and error and it runs step by step which is too long in solving the underlined the problem. GA have been successfully applied to solve many optimization problems. This research proposes a method that may help users to determine the membership function of FLC using the technique of GA optimization for the fastest processing in solving the problems. The performance of GA can be further improved by using different combinations of selection strategies, crossover and mutation methods, and other genetic parameters such as population size, probability of crossover and mutation rate. The data collection is based on the simulation results and the results refer to the transient response specification is maximum overshoot. From the results presented, the method which proposed is very helpful to determine membership function and it is clear that the GA are very promising in improving the performance of the FLC to find the optimum result.

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ABSTRAK

Penelitian ini mengkaji kegunaan Algoritme Genetik (GA) dalam mereka dan melaksanakan pengontrol berasaskan logic kabur (FLC). Logik kabur ditakrifkan sepenuhnya oleh fungsi keanggotaanya. Apa yang terbaik dalam menentukan fungsi keanggotaan adalah isu/soal pertama yang ditemui. Disebabkan itu adalah sesuatu perkara yang sangat penting dalam menentukan ketepatan fungsi keanggotaan tetapi kaedah ini mempunyai satu kelemahan di mana kaedah FLC lama menggunakan fungsi keanggotaan dikawal oleh manusia. Proses penentuan fungsi keanggotaan dilakukan dengan "kaedah cuba jaya" dan ianya dijalankan langkah demi langkah di mana mengambil masa yang panjang untuk menyelesaikan masalah. GA dengan jayanya telah diaplikasikan untuk menyelesaikan banyak masalah pengoptimuman. Penyelidikan ini mencadangkan sebuah kaedah yang boleh membantu pengguna dalam menentukan fungsi ahli FLC dengan meggunakan teknik pengoptimuman GA untuk proses yang lebih cepat dalam menyelesaikan masalah. Prestasi GA boleh dilaksanakan lebih baik dengan menggunakan kombinasi yang berbeza dari segi penentuan strategi, persilangan dan kaedah mutasi, serta lain-lain genetik parameter seperti saiz populasi, kebarangkalian persilangan dan kadar mutasi. Data yang didapati adalah berdasarkan keputusan simulasi dan keputusan merujuk kepada spesifikasi tindakbalas sementara iaitu *maximum overshoot*. Dari keputusan yang dipaparkan, sistem yang dibangunkan ini adalah sangat membantu dalam menentukan fungsi keanggotaan dan amat jelas GA menjanjikan pembaikan dalam meningkatkan prestasi FLC untuk mendapatkan perintah/arahan bagi mencapai keputusan yang optimum.

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DEDICATION

To my beloved :

My mother and my father, Hj. Siti Rahmah and Drs H. Muh Yusuf

My wife, Rohana bte Abd Hakim

My son, A. Hisham

My daughters, A. Almeira Zocha and A. Regina Acacia

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DECLARATION

I declare that this thesis entitle "Genetic Algorithms in Optimizing Membership Function for Fuzzy Logic Controller" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : Ismail

Date : March 5th, 2010

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LIST OF SYMBOLS

$\tilde{A}_i^j$	-	linguistic value
b	-	parameter determining the degree of non-uniformity
$c(t)$	-	time response of a control system
$c_{tr}(t)$	-	transient response
$c_{ss}(t)$	-	steady – state response
$eval(v_{Ch})$	-	fitness value for each v_{Ch}
F	-	total fitness for the population
M_p	-	maximum overshoot
p_c	-	the probability of crossover rate
p_m	-	the probability of mutation rate
p_{Ch}	-	selection probability
pop_size	-	size of population
q_{Ch}	-	cumulative probability
r	-	is a random number from [0, 1]
$r(t)$	-	reference input
t	-	maximal generation number
t_d	-	delay time
t_p	-	peak time
t_r	-	rise time
t_s	-	settling time
$u(t)$	-	plant input
$\tilde{u}_i$	-	linguistic variables

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$\tilde{u}_1$	-	linguistic variables for input-1, ℓ
$\tilde{u}_2$	-	linguistic variables for input-2, ℓ'
U_i	-	universe of discourse for u_i
v_{Ch}	-	value of chromosome Ch^{th}
v_1	-	parents 1^{st}
v_2	-	parents 2^{nd}
v'	-	offspring 1^{st}
v''	-	offspring 2^{nd}
x_k	-	element of it is selected for mutation
x_k'	-	is randomly selected from mutation
x_k^U	-	upper bounds for x_k
x_k^L	-	lower bounds for x_k
$y(t)$	-	output data
$\tilde{y}_1$	-	linguistic variables for output-1
Y_i	-	universe of discourse for y_i
$[\alpha, \beta]$	-	α and β are the points at which the outermost membership functions saturate for universe of discourse
ℓ	-	error
ℓ'	-	change in error
μ	-	quantifies the certainty (degree of truth)

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CHAPTER 1

INTRODUCTION

1.1 Introduction

This research investigates the use of genetic algorithms (GA) to design and implement of fuzzy logic controllers (FLC). As described earlier, a fuzzy logic is fully defined by it is membership function (Passino & Yurkovich, 1998). What is the best to determine the membership function is the first question that has been tackled (Filipe, 1998; Torres et al, 2000; Casillas et al, 2007).

In our daily life from the production lines in manufacturing plants, medical equipment, and agriculture to the consumer products such as washing machine and air-conditioner, FLC can be applied. The important part in FLC is during the process in selecting the membership function. The membership function of a fuzzy set is a generalization of the indicator function in classical sets. In fuzzy logic, it represents the degree of truth as an extension of valuation.

As for an example, the controller temperature sets for plastic extruders by FLC. When extruding certain materials, the temperatures along the extruder must be accurately controlled in accordance with properties of the particular polymer and of the extruder. If the temperatures are not accurately controlled, the molten polymer will not be uniform and may decompose as a result of excessive temperatures.

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One of the problems associated with the prior art extruder control systems occurs in the design of the barrel zone temperature controllers (Tsai & Lu, 1998; Lu & Tsai, 2001). Preferably, these controllers are designed with a high sensitivity to disturbance signals. However, when a change in a temperature set point occurs, there is a danger in saturating the zone temperature controllers as the magnitude of the temperature set point changes are generally greater than the magnitude of disturbances. Hence, the sensitivity of the controller to disturbance signals must be reduced to prevent saturation of the controllers to set point changes (Tsai & Lu, 1998; Lu & Tsai, 2001; Altinten, et al., 2006).

Thus it is important to select the accurate membership functions for temperature setting an extruder control systems. However, conventional FLC uses membership function generated by human operator, where the membership function selection process is done with trial and error and it is runs step by step, which is too long in solving the problem (Torres, 2000; Altinten et al, 2006). For a new approach for optimum coding of fuzzy controllers via Genetic Algorithms (GA), GA are used to determine membership function specially designed in situations as above.

1.2 Statement of the Problem

The reason why we propose this research is to get the best solution for the membership function of FLC by using the GA application to find exact result. The controller must operate in two modes (Bela, 2006; Hung & Sheng, 2006).

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1. In automatic mode, it increases from a fixed initial point to a fixed set point at a fixed rate. Designing a conventional controller for these operational specifications is routine.

2. In autonomous mode, however, the control system must cope with abnormal situations that can shut down plant operation. Recovery from such conditions involves reheating from arbitrary initial points at different rates and possibly to different set points. A conventional controller cannot handle all these situations efficiently.

According to the situations, this is why this research proposed to use control system based on FLC, but manually designing the membership function of FLC to satisfy such requirements is to possess one common weakness where conventional FLC use membership function generated by human operator (Torres, 2000; Altinten et al, 2006). Thus, GA used to design FLC. GA are a rule of the resolution that is carried out at the same time to several solutions and they are done randomly to increase the efficiency as well as taking the fastest processes in solving the problems (Torres, 2000; Galantucci et al, 2004; Altinten et al, 2006; and Gen et al, 2008).

1.3 Research Objectives

Research objectives consist of understanding the performance of GA as a membership function for FLC, building and adapting the method as well to further tests in applications.

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The main objective of this research is to propose a method which may help the users to determine the membership function of FLC for the fastest processing in solving the problems and the most accurate in order to find the optimum result. This research uses real numbers code for representing a chromosome.

1.4 Expected Results

A system enables users to determine the membership function of FLC using the technique of GA optimization.

The technique using real numbers code can be used as references for the researchers in representing chromosomes as a new choice besides binary code.

The performances of GA (combination parameters) can be used as a reference for the researchers in selecting the membership function for FLC machines and other application.

1.5 Scope and Limitation of the Research

The research is focused on the development of a system which enables users to determine the membership functions. This can be achieved through the following scope:

1. To apply the GA to tune the membership function in the FLC.
2. The test will be done through a simulation on FLC and then will be made to analyze the performance.

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