Tuning of Fuzzy Logic Controller for a DC Motor Based on Particle Swarm Optimization

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Abstract-This paper presents an active method to determine the parameters of the membership functions of a F.L. Controller. To provide an optimum performance of the system, the parameters of the membership functions of a fuzzy logic system can be tuned through particle swarm optimization (PSO), so the shape of these functions will vary according to the variables, then the fuzzy control output changes and the performance of the system will be changed.

In this model the PSO optimization will consider only certain points of the membership functions. It is used to optimize the triangular membership functions of the fuzzy model to the nonlinear problems. The fuzzy control structure consist of five membership functions and 25 rules and with the PSO optimization becomes enough for driving a DC motors of a six degree of freedom for Robot control with six motors to compensate for uncertainty. The results of the Matlab simulation applied to the DC motor shows the validity of the new presented method.

Keywords-Fuzzy logic (F.L.), Membership functions (M.Fs), Particle swarm optimization PSO

1 INTRODUCTION

THE fuzzy logic is a strong candidate, because of its simplicity and speed of implementation for many control systems. We know that fuzzy logic deals with uncertainty in many engineering applications, and commercially it has been verified the greet successes to control machines because it can be understood and implemented with non specialists [1].

In recent years, some people have been presented new methods to generate fuzzy rules and memberships functions, Kurniawan and Siti [2] presented a method to generate a membership function automatically and used the particle swarm optimization for membership functions automatic adjustment.

Mohammed and Davood [2] have been presented a complete model of the glucose-insulin regulation system, which is a non-linear delay differential model by using a swarm optimization Mamdani fuzzy controller.

In this project a new method for constructing membership functions for five fuzzy levels is shown, and based automatically on particle swarm optimization with the ability of changing particles for best position so as to obtain membership functions that gives a zero detected error value.

This paper is organized as follows-section 2 presents an overview about the fuzzy logic control systems, section 3 presents the particle swarm optimization theory, section 4 shows the design of the fuzzy logic controller, section 5 shows the method used to construct the whole new membership functions, the tests performed and figures, ands section 6 presents the conclusion.

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2 FUZZY LOGIC CONTROLLER SYSTEMS

Systems that use if – then type to characterize the behavior of a system operation are called fuzzy logic systems. These rules are usually based on expert practical knowledge about any system.

FLS is an analytical way used to represent the human way of thought process and imprecise, inexact phenomena. The membership function is a relation that provides for every element of the set a particular membership value.

The fuzzy set is a set where every element associates itself with the set with a membership value; its range is between 0 and 1. If we represent the relation as:

μ

A (x): X → [0, 1]

X is the universe of discourse
A is a fuzzy set with every number of A associated with a membership value.
x is a crisp value in X[3].

The components of the fuzzy logic controller are as shown in figure 1.

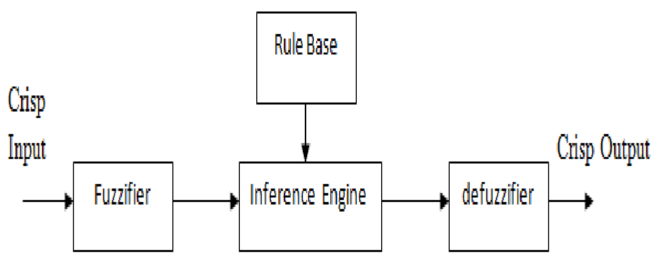

Fig.1. Fuzzy Logic Controller Components

The Fuzzifier transforms the crisp input into fuzzy sets (fuzzification), the inference engine performs all the of the logic operations in a fuzzy controller, the rule base contains the M.Fs and the control ler rules, then the fuzzy sets output is transformed into numeric value by the Defuzzifier component (defuzzification) [4].

3 PARTICLE SWARM OPTIMIZATION (PSO)

The PSO is a very easy algorithm to understand and implement; It requires less computational memory and fewer lines of code in comparison to genetic algorithm (GA) and evolutionary algorithm.

The PSO is a high performance based optimizer with several highly desirable attributes. It is a basically based on the simulation of the social behavior of birds, bees and also of fish swarm theory.

In 1995, Kennedy and Ebarhart gave us the design and introduce the particle swarm optimization. The principle of this optimization is by using its particles with best known positions to converge the swarm population to a single optimum in the solution space. The velocity is changed iteratively for each particle by its personal best position, which is found by the particle, and also the best position found by the particles in its neighborhood.

At each step a new velocity and position is updated for each particle:

$$Vi\,(t+1) = \Phi\, Vi\,(t) + c1r1\,(Pbest\,(t) - Xi\,(t)) + c2r2\,(Gbest\,(t) - Xi\,(t)) \quad (1)$$

$$Xi\,(t+1) = Xi\,(t) + Vi\,(t+1) \quad (2)$$

Where:

Xi = Position of the ith position

c1and c2 = positive constants

Φ = inertia weight

r1and r2 = Random numbers between 0 and 1

Pbest = local best for previous position; (position of the best fitness value) of the ith particle.

Gbest = position of the best particle among particles in the population.

Vi = Change of velocity for particle i [3].

The optimization method starts by setting the initial set of parameters then gets the fitness function to obtain clearly a new values which is the set values of M.Fs. The new values will be used as an optimal requirement. Each particle will be formed according to the membership functions parameters of the fuzzy controller error input variable.

3.1 IMPLEMENTATION PROCEDURE OF THE PSO OPTIMIZATION

The PSO algorithm shown in figure 2 illustrates the

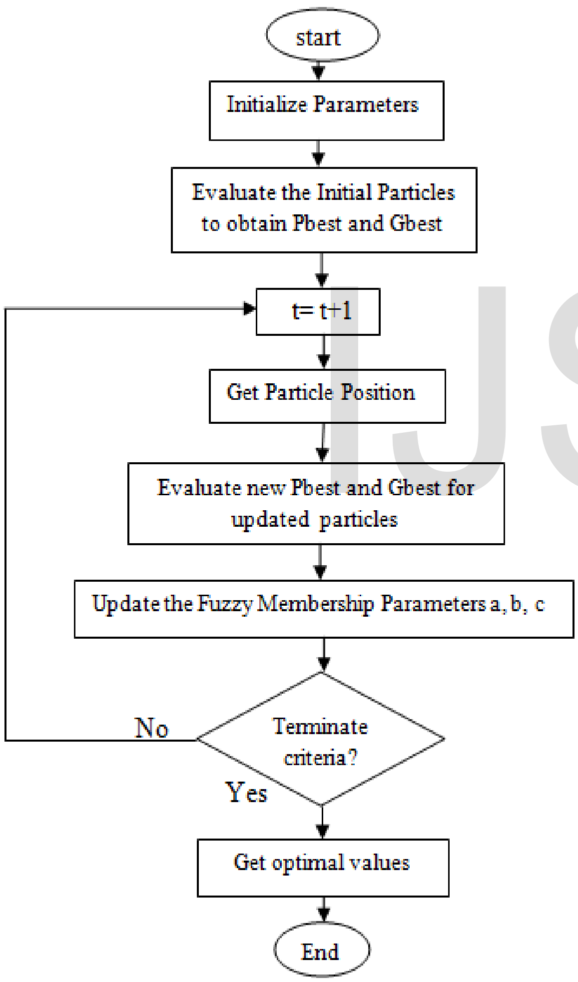

Fig. 2. Flowchart of PSO algorithm to adjust fuzzy membership functions of error input variable

procedure of finding the solution space for particles, and develops a collaborative good search of the Pbest and Gbest for the determination of optimal values.

The algorithm starts by initialization of parameters, they are the centers, lefts, and rights of each M.Fs, They will acts as the particles and also looking for finding the global best of fitness, then these parameters will be used to check the performance of the F.L. Controller, the process is repeated until the parameters optimization is achieved or the method reached the global best.

4 DESIGN OF THE F.L. CONTROLLER

The fuzzy controller has been developed with the Matlab code program, the PSO code used to achieve this work with a maximum number of iteration of 30 and time steps of 50. The error signal and responses of the plant with PSO are shown in figure 3 and figure 4 respectively with bests of 179.0092 and 417.0092. All measured curves are chosen to be the most fitted to obtain minimum overshoot and rise time.

In this paper two crisp inputs (e and ce) are fuzzified in the fuzzy controller with 5 membership functions and also the same for the output to drive the DC motor, they are chosen to be triangular in shape.

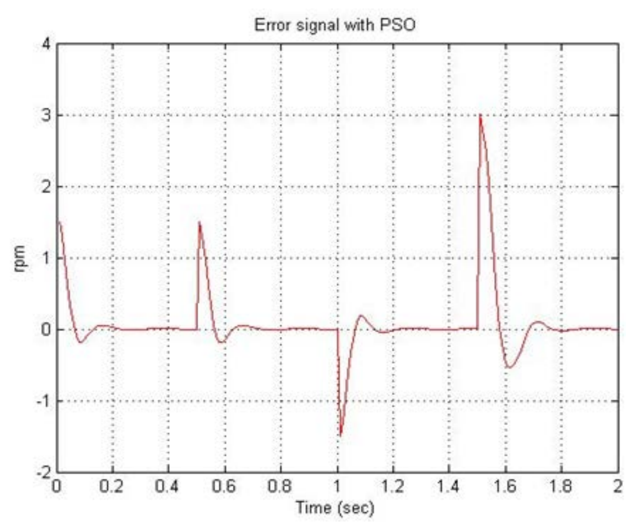

Fig. 3. The error signal with PSO

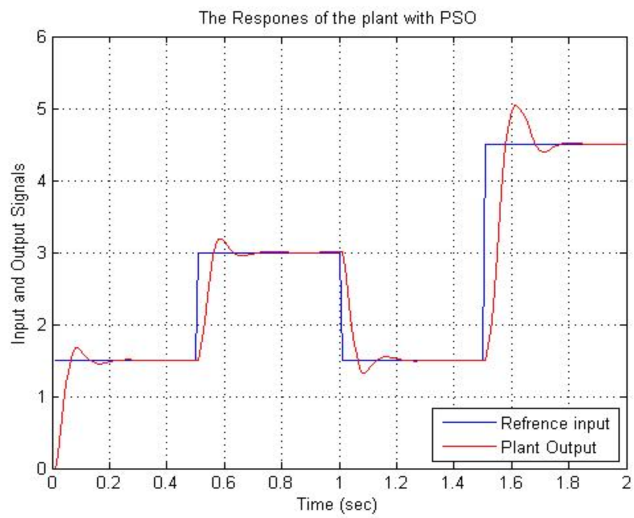

Fig. 4. the responses of the plant with optimization

The fuzzy controller was applied to the position control of DC motor. The block diagram of the system in figure (5) shows the use of PSO algorithm to tune the membership functions for the input error variable of the controller.

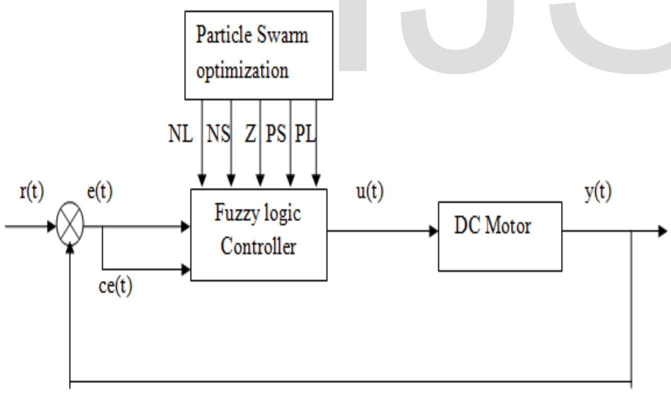

Fig.5. Block diagram of the system

4.1 Error input variable (e)

This input quantized into five fuzzy sets; negative large NL, negative small NS, zero Z, positive small PS, and positive large PL as shown in figure 6.

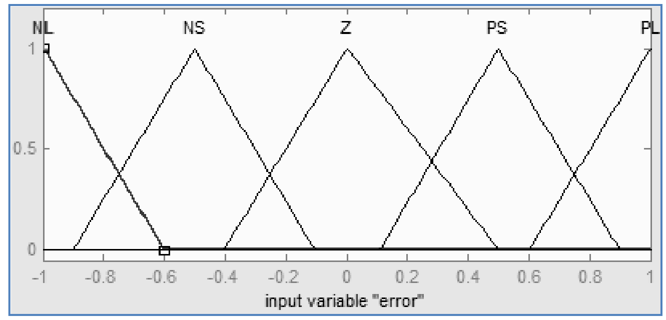

Fig. 6. Error Input (e)

4. 2 Change of error input variable (ce)

This input quantized into five fuzzy sets; Negative large NL, Negative small NS, zero Z, Positive small PS, and positive large PL as shown in figure 7.

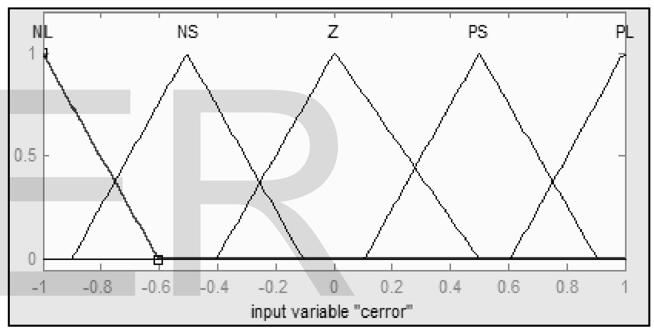

Fig. 7. change of error input (ce)

4. 3 Output

It is five fuzzy sets; Negative large NL, Negative small NS, zero Z, positive small PS, and positive large PL as shown in figure 8.

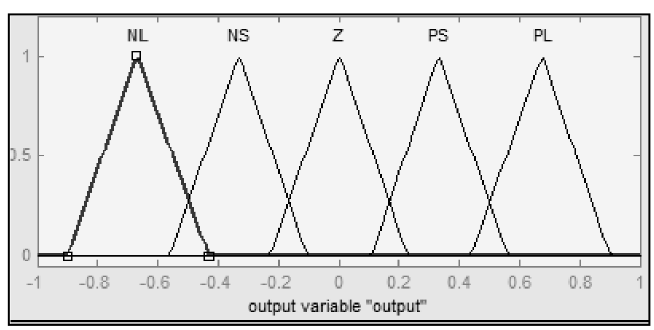

Fig. 8. output u(t)

5 MEMBERSHIPS CONSTRUCTION USING PARTICLE SWARM OPTIMIZATION

The two inputs and output of the F.L. Controller are correlated by Membership Functions; in this case the five membership functions of the error input variable is sufficient to be optimized because the fuzzy controller deals with the quantity which must be controlled to get the motor position required. Since there are five Membership Functions there are a total of 15 parameters to be tuned in this optimization as shown in figure 9.

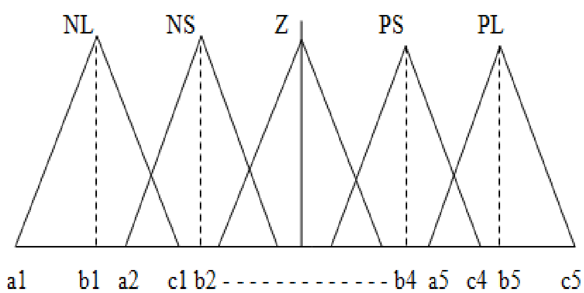

Fig. 9 Membership Functions and their Parameters

A new membership function successfully adjusted from the standard fuzzy membership function. In each iteration of optimization method, the particles will be changed to reach the optimal value and minimize error.

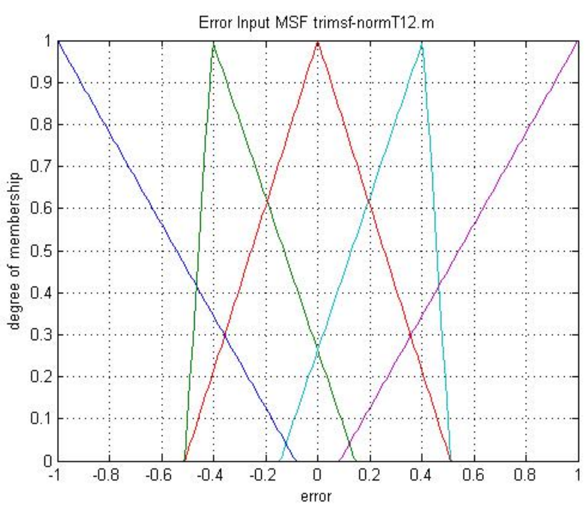

Fig. 10. Optimized Error Input

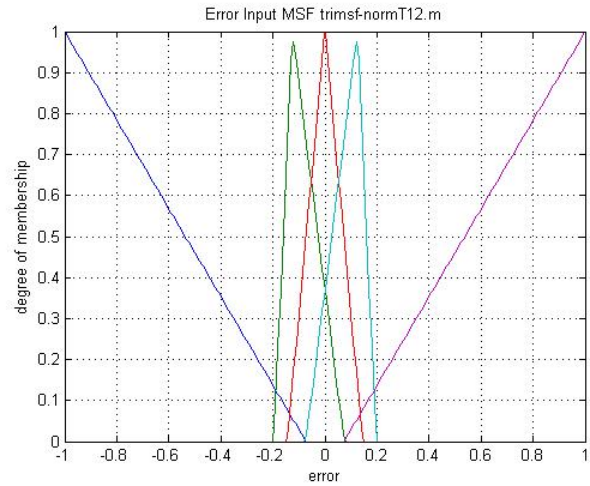

Fig. 11. Good optimized Error Input

6 Conclusions

This paper shows a search method with good and stable convergence characteristics based on particle swarm optimization (PSO). Figure 4 shows the best response with very little overshoot. Tuning the membership function of the error input variable of a fuzzy logic controller is an objective function to minimize overshoot, give better performance and also to obtain an optimal position control to the DC motor; Figures 10 and 11 .Steady error has been made zero and response is oscillatory because of the inductance which is present in the armature circuit.The experimental results show that fuzzy logic controller based on PSO is superior to the classical fuzzy logic and linear control methods since it is easy and don't need to solve complex mathematical equations.

REFERENCE

[1] S. Bouallègue , J. Haggège and M. Benrejeb, "Fuzzy Controllers – Recent Advances in Theory and Applications", chapter 6, INTECH 2012

[2] E.P. Kurniawan and Z. M. H. Siti, "Fuzzy Membership Function Generation using Particle Swarm Optimization", Int. J. Open Problems Compt. Math., Vol. 3, No. 1, March 2010

[3] H. K. Mohammad, N. M. A. Davood, A. Alireza, and S. Mehdi, "Swarm optimization tuned Mamdani fuzzy controller for diabetes delayed model", Turkish Journal of Electrical Engineering & Computer Sciences, 2013

[4] V. James, " Fuzzy Logic Systems", control-systems-

principles.co.uk

[5]. M. Settles,“An Introduction to Particle Swarm Optimization ”, Department of Computer Science, University of Idaho,PP.1-8, Nov 7, 2005

[6] H. Chao-Ming**, C.** Shin-Ju and C. Huang-Chi , “An On-line Implementation of Particle Swarm Optimization-Based Fuzzy Controllers for Magnetic Levitation Systems”, International Conference on Artificial Intelligence and Soft Computing Lecture Notes in Information Technology, Vol.12, 2012

[7] B. Brian, “A Particle Swarm Optimization (PSO) Primer With Applications”, 2004

[8] D. Debasmit, G. Arka, “Algorithm for a PSO Tuned Fuzzy Controller of a DC Motor”, International Journal of Computer Applications (0975 – 8887) Volume 73– No.4, July 2013

[9] H. Jorge, M. Anthony and G. Alfonso, “ Tuning a Fuzzy Controller by Particle Swarm Optimization for an Active Suspension System”, IEEE 2012

[10] D. Trung-Kien and C. Chih-Keng, “Fuzzy Logic – Controls, Concepts, Theories and Applications”, Capter 17, INTECH 2012

[11] C.D. Sree Bash, C.S. Pintu and M. Kazuyuki, “Particle Swarm Optimization Based Adaptive Strategy for Tuning of Fuzzy Logic Controller”, International Journal of Artificial Intelligence Applications (IJAIA). January 2013; Vol. 4.