Speed Control of DC Motor using PSO based Fuzzy Logic Controller

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Abstract:- **DC motors are widely used in instrumentation applications, particularly in robotics and computer peripherals. The speed of the DC motor can be adjusted to a to a great extent so as to provide easy control and high performance. For any industrial or domestic application it is necessary to control the speed of a motor. Simulation results demonstrate that in comparison with the FLC and the designed FLC-PSO speed controller obtains better dynamic behavior and superior performance of the DC motor as well as perfect speed tracking with no overshoot. The simulation of speed control of DC motor has been done using he software package MATLAB/SIMULINK and coding in MATLAB/m-file.**

Keywords: - PID controller, Particle Swarm Optimization, DC motor, Fuzzy logic controller

1. INTRODUCTION:

AC and DC motors are used in many applications. Particularly , DC motors are used in computer peripherals and robot manipulators and are characterized by its ability to produce full continuous torque: controlled braking is relatively simple and low cost as compared with similar AC drives at high powers. DC motors can be controlled by many controllers which may include the conventional PID controllers and various other techniques. PID controllers have been widely applied in industrial control process for about half century because of their simple structure and convenience of implementation.

However, it is hard to obtain optimal tuning for PID controller. Besides a conventional PID controller may have poor control performance for nonlinear or complex systems for which there are no precise mathematical models. This motivates the interest in using Fuzzy logic controller (FLC) which is based on fuzzy logic theory. Fuzzy logic has gradually adopted as one of major approaches for control design. The conceptual framework of fuzzy logic is much closer to human thinking than the traditional logic systems. Fuzzy controllers are successfully applied to non-linear system because of their knowledge based nonlinear structural characteristics. Fuzzy logic controller is chosen for this paper because it consists of several advantages compared to the other classic controller. It is suitable for applications such as the speed control of DC motor which has nonlinearities.

For the tuning of the parameters of the membership functions of a fuzzy controller, a PSO algorithm has been developed. The plant used in an armature controlled DC motor. Conventional controllers like PI and PID controllers fail in case of nonlinearities and may generate steady state error. In such a case the fuzzy controller is used which is basically a non-linear element whose parameters are tuned using Particle Swarm Optimization Technique (PSO)subject to the condition that steady state error is to be minimized. The quantity to be controlled is the speed of the DC motor. Therefore error in speed is to be minimized.

2. DC MOTOR:

A DC motor is used in a control system where an appreciable amount of shaft power is required. The DC motor are neither field controlled with fixed armature current nor armature controlled with fixed field. A DC motor has six basic parts- axle, rotor, staor, commutator, field magnets and brushes. In most common DC motors, the external magnetic field produced by high strength of permanent magnets. Stator is the stationary part of motor. The rotor rotates with respect to the stator.

Mathematical modeling of DC motor:

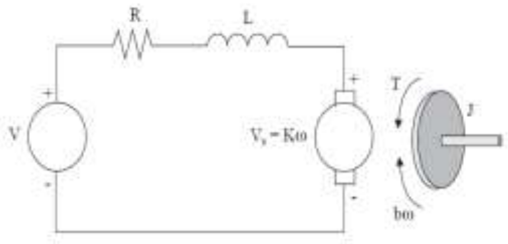

Fig 1: Schematic Diagram of DC motor

The torque T generated on the motor shaft is linearly proportional to armature current,

$$T \propto i_a$$

$$T = k_T i_a$$

The back emf developed is proportional to angular velocity,

$$V_b \propto \omega$$

$$V_b = k_E \omega$$

Take the Kirchhoff's voltage law of the given circuit,

$$R_a i_a + L_a \frac{di_a}{dt} + V_b = V_a \qquad (1)$$

We assumed no saturation occurs in the magnetic circuit of the machine provided the magnitude of the input signal is kept smaller than the rated voltage of the machine. The output of the motor is mechanical; armature current produces the torque in the mechanical port

$$J\frac{d^2\theta}{dt^2} + B\frac{d\theta}{dt} + T_L = T$$

here, θ = angular displacement

So above equation becomes,

$$J\frac{d\omega}{dt} + B\omega + T_L = T$$

Torque can be written as, $T = k_T\, i_a$

ie,

$$J\frac{d\omega}{dt} + B\omega + T_L = k_T\, i_a \qquad (2)$$

take Laplace transform of (1) equation,

$$R_a I_a(S) + L_a S I_a(S) + V_b = V_a$$

$$I_a(S)[L_a S + R_a] = V_a - V_b$$

$$I_a = \frac{V_a - V_b}{L_a S + R_a}$$

Then take Laplace transform of (2) equation,

$$JS\omega(S) + B\omega(S) + T_L = k_T\, i_a$$

$$\omega(S)\,[JS + B] = k_T I_a - T_L$$

$$\omega(S) = \frac{k_T I_a - T_L}{JS + B}$$

After simplification, we get the transfer function as,

For loaded condition,

$$\frac{\omega}{V_a} = \frac{k_T - \frac{T_L(L_a S + R_a)}{V_a}}{k_T\, k_E + (JS + B)(L_a S + R_a)}$$

For no loaded condition,

$$\frac{\omega}{V_a} = \frac{k_T}{k_T\, k_E + (JS + B)(L_a S + R_a)}$$

3 FUZZY LOGIC CONTROLLER:

Fuzzy logic controller (FLC) is based on a controller and constitutes a way of converting linguistic control strategy into an automatic by generating a rule base which controls the behavior of the system. Fuzzy control is a control method based on fuzzy logic. It provides a simple way to draw definite conclusions from vague ambiguous or imprecise information. It is suitable for applications such as the speed control of DC motor which has nonlinearities. FLC have some advantages compared to other classical controller such as simplicity of control, low cost and possibility to design without knowing the exact mathematical model of the process. (Rahul Malhotra, Tejbeer Kaur)

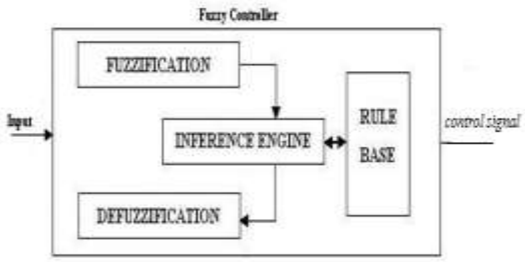

Fig 2: Block diagram of FLC

Here the inputs are error 'e' and change in error 'de' and the three outputs have been classified as NB, NS, ZO, PS, PB. The linguistic labels used to describe the fuzzy sets were, Negative Big (NB), negative Small (NS), Zero (ZO), Positive Small (PS), Positive Big (PB). The fuzzy rules are extracted from fundamental knowledge and human experience about the process. These rules contain the input/output relationship that defines the control strategy. Each control input have five fuzzy sets so that there are at most 25 fuzzy rules. Each rule uses an If-Then logic.

3.1. Particle Swarm Optimization (PSO):

PSO is a population based optimization method first proposed by Eberhart and Colleagues. Attractive features of PSO include the ease of implementation and the fact that the no gradient information is required and it can be used to solve a wide array of different optimization problems. PSO technique conducts search using population particles corresponding to individuals. Each particle represents a candidate solution to the problem. In PSO system, particles change their positions by flying around in a multidimensional search space until computational limitations are exceeded.

The PSO algorithm is an evolutionary computation algorithm, it differs from other well-known computation algorithms such as genetic algorithm (GA). In PSO, a population is used for searching the search space but there are no operators inspired by the human DNA procedures applied on the population. Here each companion called particle in the population, which is called swarm, is assumed to 'fly' over the search space in order to find promising regions of the landscape.

In PSO algorithm, instead of using evolutionary operators such as mutation and crossover, to manipulate algorithms, for a variable optimization problem, a flock of particles are put into a d-dimensional search space with randomly chosen velocities and positions knowing their best values so far (Pbest) and the position in d-dimensional search space. The velocity of particle, adjusted according to their own flying experience and the other particles flying experience. In PSO i-th particle is represented as (X_i=$X_{i,1}$,$X_{i,2}$,…….$X_{i,d}$) in the d-dimensional space. The best previous value of the i-th particle is recorded and represented as:

$Pbest_i$=($Pbest_{i,1}$,$Pbest_{i,2}$,…………$Pbest_{i,d}$)

The index of best particle among all of the particles in the group is $gbest_d$. the velocity for i-th particleis represented as, $V_i=(V_{i,1},V_{i,2},\ldots\ldots V_{i,d})$. (S.J Bassi,2011)the modified position and velocity of each particle can be calculated using current velocity and distance from $Pbest_{i,d}$ to $gbest_d$ shown in the following formulas:

$$V_{i,m}^{(t+1)}=W.V_{i,m}^{t}+C_1*rand()*(Pbest_{i,m}-x_{i,m}^{(t)}) + C_2* rand()*(gbest_m-x_{i.m}^{(t)})$$

$$X_{i,m}^{(t+1)} = X_{i,m}^{t} + V_{i,m}^{(t+1)} \quad i=1,2,\ldots.n \;;\; m=1,2,\ldots d$$

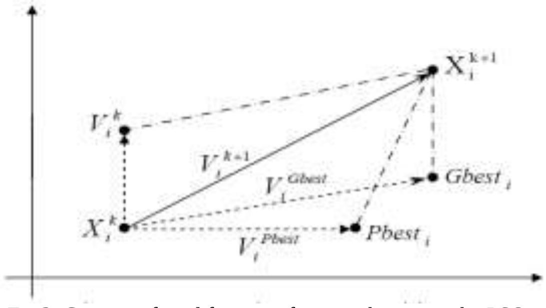

Fig 3: Concept of modification of a seacrching point by PSO

Each particles Pbest value only indicates the closest the data has ever come to the target since the algorithm started. The gbest value changes only when any particle's Pbest value comes closer to target than gbest. Through each iteration of algorithm, gbest value moves closer to the target until one of the particle reaches the target.

4. OPTIMIZATION OF FUZZY LOGIC CONTROLLER USING PSO ALGORITHM

PSO is population based optimization method first proposed by Eberhart and Colleagues. Attractive features of PSO include ease of implementation and the fact that no gradient information required. It can be used to solve wide array of different optimization problems. The main advantage of PSO over other optimization techniques like GA is that there is less complexity in it. There is no crossover or mutation unlike in genetic algorithm to deal with.

4.1 steps for PSO:

Step1: Initialization for each particle in the Population, initialize X(i) and V(i) randomly
Step2: evaluate the objective function of X(i) and assigned the value to fitness(i)
Step3: initialize Pbest(i) with acopy of X(i)
Step4: from the values of fitness(i) select best One and set it as the new fbest
Step5: choose the particle with the best fitness value from all the particles as the gbest
Step6: for each particle calculate particle Velocity and update particle position
Step7: Then check selected gbest value is correct Or not
Step8: While maximum iterations is not attained Repeat from step2.

5. RESULTS AND DISCUSSIONS:

This section presents the results and discussion of PSO-FLC controller for DC motor and its comparison with other conventional tuned PID controllers, Fuzzy and Fuzzy PID controllers. Conventional tuning of PID controller is done using Zeigler Nichols method and fuzzy designed using fuzzy rules. Variations of output for different load disturbances are discussed here. Open loop response for DC motor is shown in figure.

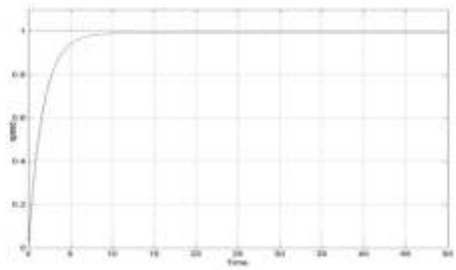

Fig4: Open loop response of DC motor

5.1 Comparison of PSO based FLC controller with other controllers:

Closed loop control for DC motor is done using three controllers, they are PID controller, Fuzzy Logic controller, Fuzzy PID controller and PSO based Fuzzy controller for three load cases. They are no load condition, step load condition and pulsating load condition. Comparison of no load condition for different controllers,

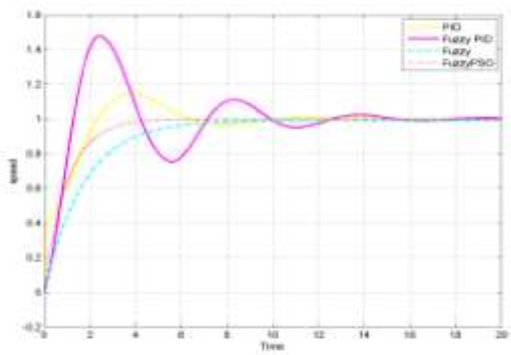

Fig5: Response of DC motor control in no load condition

Comparison of response of no load condition

	PID	Fuzzy PID	Fuzzy	Fuzzy PSO
IAE	0.492	0.1294	1.861	0.02086
Settling time	13.5	15.2	10	7.5
Overshoot	14.5	47.77	0	0

Comparison of pulsating load condition for different controllers,

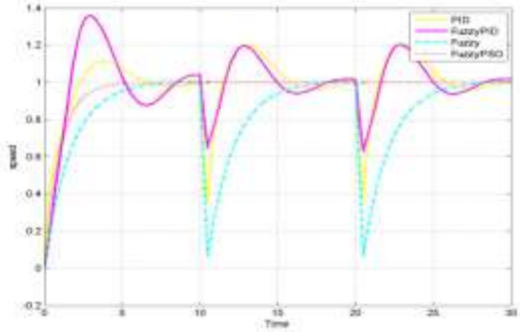

Fig6: Response of DC motor control using pulsating load condition

Comparison of pulsating load condition with different controllers

Comparison of step load condition for different controllers,

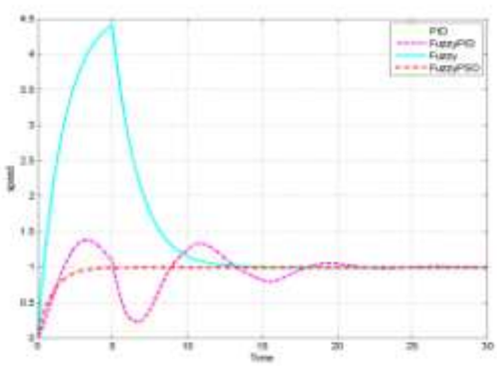

Fig7: Response of DC motor control using step load condition

Comparison of step load condition with different controllers

	PID	Fuzzy PID	Fuzzy	Fuzzy PSO
IAE	2.296	1.572	16.27	0.04409
Settling time	20	24.32	14.14	6.46
Overshoot	21	33.46	34.13	0

The response for different controllers are compared and listed in table. The results shows that PSO-FLC controller offers a better controlling option than other controllers used.

6. CONCLUSION AND FUTURE WORK:

The PSO tuned Fuzzy controller was implemented on the system. The plant was chosen to be a DC motor with speed being the quantity to be controlled. The algorithm for tuning the fuzzy controller has been developed. Steady state error has been minimized and gets best response with zero overshoot. The proposed controller provides robustness improvement and gives very good results in terms of three parameters such as integral absolute error, settling time and overshoot. From this work, by using PSO based Fuzzy Logic controller, settling time, overshoot and IAE was reduced and get good response.

7. REFERENCES:

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