Intelligent Speed Control of DC Servo Motor

Sudarshan L. Chavan

JSPMs Rajarshi Shahu College of Engineering, Pune, India
*Corresponding author: chavan_sl@rediffmail.com

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Abstract: DC servomotors are conventionally controlled using P, PI, PD, and PID controllers. The controller design for such scheme requires exact mathematical model of the plant. On the other hand the controller is designed for only fixed loads. If load is changed, the controller has to be redesigned for other values of K_p, K_i and K_d constants of PID controller. In the presented work the comparative study of the controller designed with conventional PD controller, PD like fuzzy controller, Neural network controller and Neuro-fuzzy controller is done. The simulations are carried out in MATLAB SIMULINK. The improvements as expected form these state of art techniques is clearly seen form presented results. The overall design scheme using neuro-fuzzy controller is robust and results in improved dynamic and steady state response. The novelty of the presented research is that the fuzzy controller can cope up with the uncertainty and nonlinearity of the plant model and the neural network controller reduces the noise as well as imparts system robustness.

Keywords: DC Servomotor; PID Controller; Fuzzy Logic Controller; Neural Network Controller; Combined Neuro-fuzzy Controller.

Introduction

A control system, which is having excellent performance and good efficiency plays very important role in robot technology. Research and development in control techniques increases day to day to strengthen the robot technology. Robot technology has excellent future in industrial manufacturing and health care sectors. This technology works in any condition of atmosphere, which is notable advantage of this technology. The most important component of robot technology system is a DC servomotor. Various control techniques are developed to effectively use this motor in robot technology systems but due to non linear behavior it directly or indirectly affects overall efficiency of the system. A more efficient intelligent system is required to be develop to compensate its non linear behavior, control it effectively and improve overall efficiency of the system. The speed-torque characteristic of DC servomotor is mostly suitable for industrial loads and therefore it is widely used in industries as a drive. Conventionally PID controllers were used for controlling its speed. PID controller incorporates the proportional, integral and derivative control action to improve the transient and steady state response. Frequently for DC servomotors PD type controller is used because it improves the dynamic response. The DC servomotor differs from dc motors by constructional features such as increased axial length of rotor and reduced diameter. This improve the dynamic response which is required in most of the control applications like in robotics for sudden acceleration, sudden reversal etc.

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For design of conventional PD control there is a need of exact system model. In fact there is lot of dissimilarity in the mathematical model and actual system [1][2]. In addition, the practical systems have inherent nonlinearity. The fuzzy logic has immerged as a powerful mathematical tool to cope up with the nonlinearity and uncertainty of the plant model [3]. Generally, the conventional PD is designed for fixed loads i.e. the performance criterion is very narrow as compared to fuzzy logic controllers. The neural network on the other hand has the capability of approximating any linear and nonlinear systems by adjusting it weights. The main ability of neural networks is in its learning capability. The neural networks has lack of decision making ability while the fuzzy controller has lacks of learning capability [4-6]. Neural networks and Fuzzy logic can be combined together to construct a neuro-fuzzy controller which have the advantages of both these methods. In the presented paper, intelligent controller for speed control of DC servomotor is designed using PD like Fuzzy Logic controller, Neural network controller and Combined Neuro-fuzzy controller. The novelty of the presented research is that the fuzzy controller can cope up with the uncertainty and nonlinearity of the plant model and the neural network controller reduces the noise as well as imparts system robustness. The advantage of fuzzy logic (FL) which is decision making ability and the advantage of neural network (NN) which is the learning capability, both these advantages of NN and FL are incorporated in Neuro-Fuzzy controller for effective speed control of DC Servo motor.

Materials and Methods

For the proportional plus integral controller, the control action is given by,

$$u(t) = K_p e(t) + K_d \frac{de(t)}{dt} \qquad (1)$$

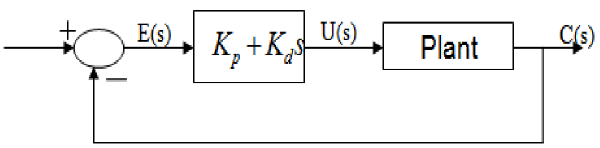

Figure 1. PD controller block diagram

Figure 1 shows block diagram for PD controller. From the block diagram of proportion plus derivative controller, the Transfer Function (TF) can be written as,

$$\frac{U(s)}{E(s)} = K_p + K_d s \qquad (2)$$

In derivative control action, the magnitude of specified controller response is directly depends on the rate of change of actuating error signal. Derivative control increases system stability by taking fast corrective action with respect to actuating error [7-9]. There is very less effect of derivative control on steady state error but it will improve steady state error by embedding damping in system itself. The frequency domain characteristics of PD controller is represented in Figure 2.

MATLAB SIMULINK is used to develop models for fuzzy logic controller and PD control for DC motor. The sub-system for PD controller is shown in Figure 3.

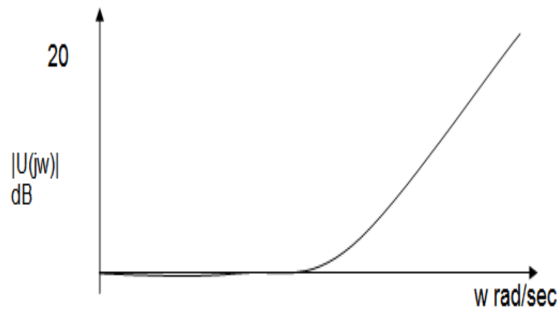

Figure 2. (a) PD controller magnitude variation with frequency

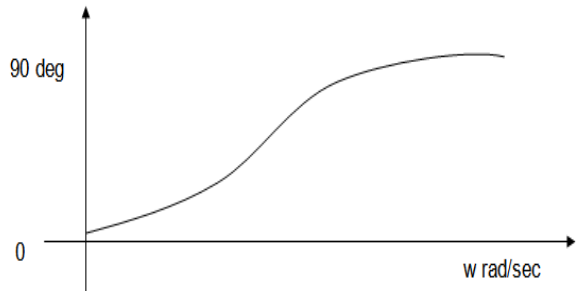

Figure 2. (b) PD controller phase variation with frequency

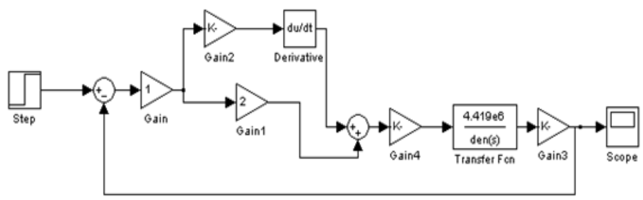

Figure 3. Sub-system for PD controller

The Fuzzy Logic Toolbox allows us to do several things, but the most important thing is that it helps to

create and edit fuzzy inference systems. These systems can be created using graphical tools or command-line functions, or they can be generated automatically using either clustering or adaptive neuro-fuzzy techniques. If access to Simulink is provided, easily the fuzzy system can be tested in a block diagram simulation environment.
The representation of rule base for Fuzzy Logic Controller (FLC) is presented here. The fuzzy rule base consists of 25 rules which are given in Table 1.

The rule for proportional plus derivative (PD) like fuzzy knowledge based controllers can be expressed as [10].

If e is <property symbol > and de is <property symbol > then u is <property symbol >.

The surface plot for rule 25 is shown in Figure 4.

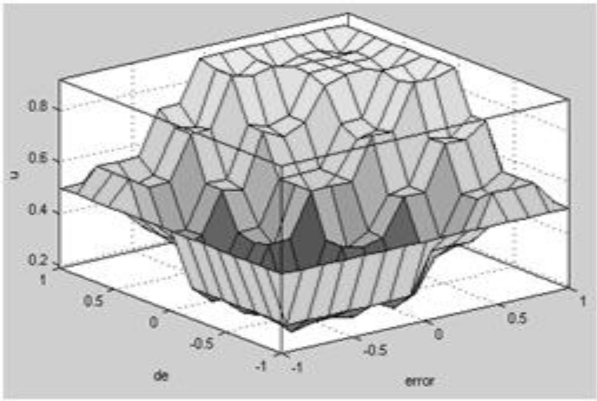

Figure 4. Surface plot for rule 25

Table 1. The Fuzzy Rule Base

Error De	Negative Medium	Negative Small	Zero	Positive Small	Positive Large
Negative Medium	Negative Medium	Negative Medium	Negative Medium	Negative Small	Zero
Negative Small	Negative Medium	Negative Medium	Negative Small	Zero	Positive Small
Zero	Negative Medium	Negative Small	Zero	Positive Small	Positive Large

The FLC system is designed to control the response of power electronics based buck converter with the help of mamdani-style fuzzy inference system [11][12]. The input and outputs in FLC system are as follows,
Input 1: Error signal (e)
Input 2: Change of error signal (de).
Output: Duty cycle of PWM signal.

The inputs for fuzzy interface can be represented as [13-14],

$$e(t) = y_{rb} - y(t) \quad (3)$$

$$de(t) = e(t) - e(t-1) \quad (4)$$

Where,

e(t):Process error at any time t,
y_{rb}: Voltage signal as a reference,
y(t): Voltage signal,
de(t):Change in error signal att^{th} instant,
u(k): Response signal.

The input and output variables has five logistic values according to rule 25 of fuzzy rule base. All input variables are defined in domain of [-1 1] and the output variable is defined in domain of [0 1]. The simulation diagram for proposed PD control for DC motor is shown in Figure 5 below.

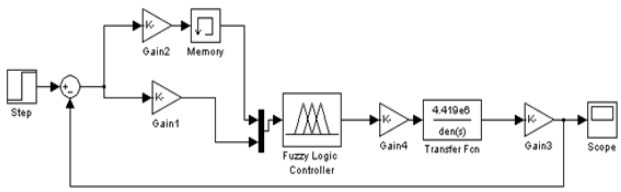

Figure 5. System for PD control for DC motor

Model and Code for Neural Network Controller

The Simulink model for the proposed Neural Network Controller scheme is shown in Figure 6. A simplified code for Neural Network Controller is written below,

```
inpt1=e;
inpt2=de;
```

```
output=re;
x=[inpt1 inpt2];
y=output;
x1=minmax('inpt1');
x2=minmax('inpt2');
x3=[x1 x2];

net=newff([x1;x2],[4 1],{'tansig','purelin'});
net=init(net);
net.trainParam.epochs=300;
net.trainParam.show=50;
net.trainParam.lr=0.1;
[net,tr]=train(net,x3,y);
gensim(net);
net.trainParam.goal=0.00001;
```

Structure of Adaptive Neuro Fuzzy Inference System (ANFIS)

The ANFIS is trained with the above fuzzy controller and the surface plot for the Sugeno type of inference is given in Figure 7.

Result and Discussion

The simulation of the proposed system is done in MATLAB SIMULINK. The responses of DC servomotor motor with open loop step, closed loop with unit feedback, Step response from PD controller and Step response of Fuzzy PD and with ANFIS are shown in Figure 8 to 11. From the figures 8 to 11 it is clear that there is improvements as expected form these state of art techniques i.e. from PD to ANFIS.

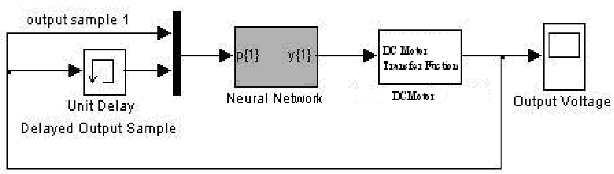

Figure 6. Simulink model of the proposed NN scheme

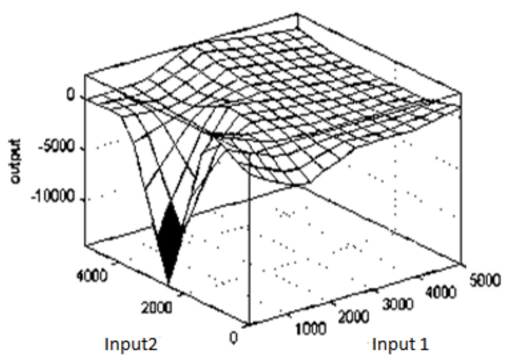

Figure 7. Surface plot for the Sugeno type of inference

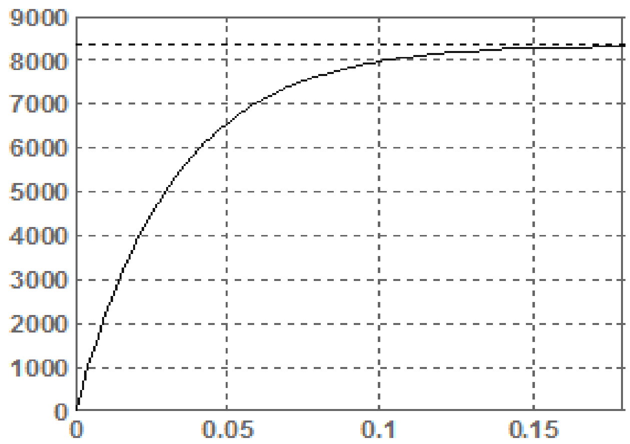

Figure 8. Open loop step response of DC servomotor

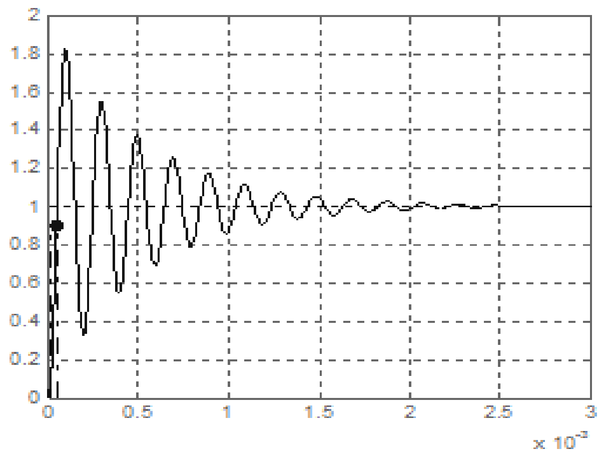

Figure 9. Closed loop step response with Unity feedback

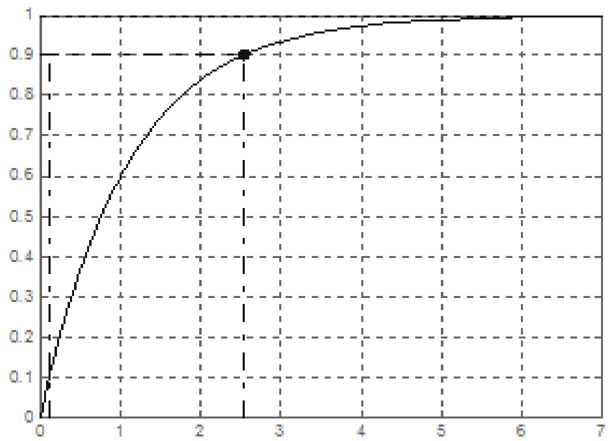

Figure 10. Step response of PD controller

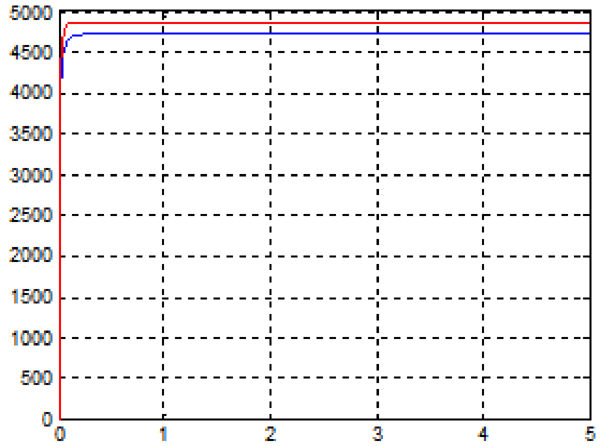

Figure 11. Step response of Fuzzy PD (Blue) and with ANFIS (Red)

Conclusion

In the presented paper, an intelligent controller for speed control of DC servomotor is designed using PD like Fuzzy Logic controller, Neural network controller and Combined Neuro-fuzzy controller. The simulation of the developed model is done in MATLAB SIMULINK. The improvements as expected form these state of art techniques is clearly seen form presented results. The overall design scheme using neuro-fuzzy controller is robust and results in improved dynamic and steady state response.

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