# Design of Neuro-Fuzzy Controllers for DC Motor Systems with Friction

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**Abstract** : Recently, a neuro-fuzzy approach, a combination of neural networks and fuzzy reasoning, has been playing an important role in the motor control. In this paper, a novel method of friction compensation using neuro-fuzzy architecture has been shown to significantly improve the performance of a DC motor system with nonlinear friction characteristics. The structure of the controller is the neuro-fuzzy network with the TS(Takagi-Sugeno) model. A back-propagation neural network based on a gradient descent algorithm is employed, and all of its parameters can be on-line trained. The performance of the proposed controller is compared with both a conventional neuro-controller and a PI controller.

**Keywords** : Neuro-fuzzy networks, DC motor system, Nonlinear friction

## I. INTRODUCTION

The compensation of friction nonlinearities for servo motor control has received much attention due to undesirable and disturbing effects the friction often has on conventional control systems. Therefore, we consider a problem of this type, namely, a servo with nonlinear friction.

Friction compensation has been considered before. Canudas *et al.*[1] proposed a control scheme where nonlinear frictional effects are compensated adaptively by estimating the parameters of a nonlinear friction model. Friedland and Park[2] presented another adaptive friction compensation scheme which was based upon a Lyapunov-like argument involving the position error. Many other studies on Friction compensation techniques are reported in survey paper[3]. Most of them are model based feedforward compensation methods. It is difficult, however, to make a perfect friction model because of the complexity of static and dynamic characteristics of the friction such as the Stribeck effect, the Dahl effect, stick-slip motion, and so on.

Recently, a neuro-fuzzy approach, a combination of neural networks and fuzzy reasoning, has been playing an important role in the control system. Applying the neuro-fuzzy approach, learning/adaptation ability and human knowledge can be incorporated into a motor control system.

In this paper, a novel method of friction compensation using neuro-fuzzy architecture has been introduced to significantly improve the performance of a DC motor system with nonlinear friction characteristics. The structure of the controller is the neuro-fuzzy network with the TS(Takagi-Sugeno) model. A back-propagation neural network based on a gradient descent algorithm is employed, and all of its parameters can be on-line trained.

## II. MATHEMATICAL MODEL OF A DC MOTOR SYSTEM

The motor plant with dynamic friction in Fig. 1 can be described by the following model :

$$J\frac{d\omega}{dt} = -B\omega + u(t) - T_f(t) - T_d(t) \tag{1}$$

where $\omega$ is the angular velocity of the motor shaft, $J$ is the total moment of inertia reflected to the motor axis, $B$ is the viscous friction, $u$ is the control input torque, $T_f$ is the nonlinear friction torque, and $T_d$ is the load disturbance.

The control force $u$ which is given by the PI controller

$$u = K_p(x - x_d) + K_i\int(x - x_d)\ dx \tag{2}$$

In the classical Coulomb friction model there is a constant friction torque opposing the motion when $\omega$ =0. This model is represented in Fig.2(a). The mathematical models of the friction-velocity curve in Fig.2(b) often represents the transition from static to kinetic friction by an exponential term in velocity.