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# 뉴럴 네트워크를 이용한 DC 모터의 지능제어기법

# Artificial Intelligent Control for DC Motor via Neural Network

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**Abstract** Artificial intelligence control has recently been applied to various fields such as railway, traffic, and electric device. In this paper, we propose a DC motor speed control method with the identified system model using artificial neural networks. The closed-loop system controlled by the proposed method follows the reference model, only by system identification using a neural network without direct calculation or estimation of DC motor parameters. The procedure and effectiveness of the proposed method were verified by simulations.

***Keywords*** : AI, Artificial Neural Network, Model-based Control, DC Motor Control, ANN Identification

## 1. Introduction

Recently, the understanding and implementation of artificial intelligence (AI) technology are actively being promoted as the basis of the fourth industrial revolution. In industry of railway, AI technology has been being researched for various applications such as intelligent railway system, fault diagnosis, energy management system, and automatic train operation (ATO/ATC), and so on [1].

In this paper, we propose an artificial intelligence control method for speed control of DC motors using artificial neural network (ANN). The structure of the proposed controller for DC Motors consists of reference model and identified plant [2].

The closed loop transfer function follows the reference model by the proposed structure including the plant model predicted by dynamic neural networks, which include tapped delay lines of states and output for nonlinear filtering and prediction.

The effectiveness of the control method is verified by simulation results.

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## 2. System Dynamics and Proposed Method

### 2.1 Mathematical Model of DC Motor

The general mathematical model of a separately excited DC motor is considered in this paper. The voltage and torque dynamics are given in Eq. (1) and (2) respectively [2].

$$L\frac{di(t)}{dt} = -Ri(t) - K_b\omega(t) + V(t) \qquad (1)$$

$$J\frac{d\omega(t)}{dt} = K_m i(t) - K_f\omega(t) - T_L \qquad (2)$$

The terminal voltage, $V(t)$, is assumed to feed directly into the plant in order to simplify the dynamics of the power converters in the simulation.

### 2.2 Proposed ANN Control Method

The closed-loop transfer function of unit feedback control loop is known as Eq. (3). We propose the controller $C(s)$ including the system plant $G(s)$ and the reference model $G_m(s)$ in order to follow the desired reference model as shown in Eq. (4).

$$\frac{y(s)}{r(s)} = \frac{C(s)G(s)}{1 + C(s)G(s)} = G_m(s) \qquad (3)$$

$$C(s) = \frac{G_m(s)}{G(s) - G(s)G_m(s)} \qquad (4)$$

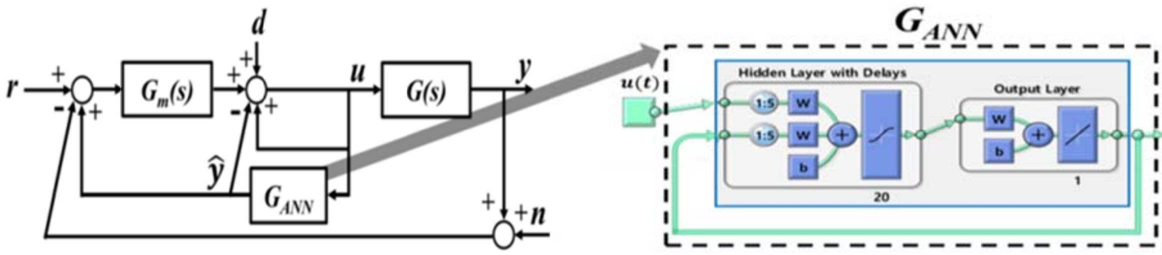


**Fig. 1** Structure of the proposed controller with ANN identification plant

Fig. 1 shows the structure of the proposed systems, in which the controller includes the identified plant $G_{ANN}$ in the loop instead of the real plant $G(s)$. In the controller, the algebraic loop error to solve the differential equation can be addressed by using unit delay or appropriate filter. The system is identified by dynamic neural networks which include tapped delay lines. The nonlinear autoregressive network with exogenous inputs (NARX) is applied to predict the output values from a recurrent dynamic network with feedback connections and several hidden and output layers of the network [3].

In this paper, parallel architecture of NARX neural network is applied, given in Eq. (5).

$$\hat{y}(t+1) = F\begin{pmatrix} \hat{y}(t), \hat{y}(t-1), \cdots, \hat{y}(t-n_y), \\ x(t), \hat{x}(t-1), \cdots, \hat{x}(t-n_y) \end{pmatrix} \quad (5)$$

where $n_y = 5$ and hidden layers are 20.

### 2.3 Simulation

The specifications of DC motors for the simulation are presented in Table 1. The model reference is selected as 1st order low pass filter type $G_m = 1/(\alpha s + 1)$ in order to reject the sensor noise. In the simulation results shown in Fig. 2, the performance of the proposed control method is relatively satisfactory with good command following and noise rejection. The system identification obtained by neural networks shows that the mean square error is less than $10^{-6}$.

**Table 1** Specifications of DC motor.

| Parameters | Values and units | |
|---|---|---|
| $L$ | *Armature inductance [H]* | 0.5 |
| $R$ | *Armature resistance [Ω]* | 2 |
| $K_b$ | *Back-emf constant [N·m·A$^{-1}$]* | 0.1 |
| $J$ | *Rotor inertia [kg·m$^2$·s$^{-2}$]* | 0.02 |
| $K_m$ | *Torque constant [N·m·A$^{-1}$]* | 0.1 |
| $K_f$ | *Damping constant [N·m·s]* | 0.2 |
| $T_L$ | *Load torque [N·m]* | 5 |

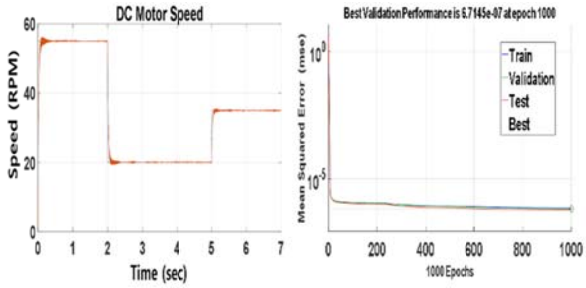


**Fig. 2** Output speed and identification error by ANN

## 3. Conclusions

In this paper, we propose the model-based feedback control method for DC motor control based on ANN identification using input and delayed output. The proposed design method has an advantage that it can be applied directly through ANN without information about the system plant.

## Acknowledgments

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