

NEURAL NETWORK ADAPTIVE CONTROL FOR DARMA SYSTEM

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Abstract.

A neural network controller which is used to control unknown discrete-time DARMA system is described. A two-layered neural network is used to estimate the unknown plant dynamics. The well known Widrow-Hoff delta rule is used as the learning algorithm for this network to minimize the difference between the plant actual response and that predicted by the neural network. The control law is generated online using a second two-layered neural network, so that the plant output is brought to a desired reference signal. It is proved that the control objective is achieved by the closed-loop system and that the system remains closed-loop stable.

Key words: Neural network, Learning rule, Adaptive control, DARMA systems, Widrow-Hoff rule

Introduction

Network theory has been a great field of research over the last years. Researchers pay particular attention to the application of neural network to adaptive control system design. In this paper we will use the adaptive learning approach and the control input is determined online as the output of neural network, this is a direct learning approach.

We use a two-layered neural network as a model for the unknown plant. The network online learns the regular dynamics of the system. This learning is used to adjust the connection weights of a second two layered neural network which is used as controller.

The control objective is to bring the plant output y to a desired reference signal y^* .

Plant model

We shall deal with a linear DARMA plant [1] described by :

$$\begin{aligned} A(q^{-1})y(k) &= B(q^{-1})u(k) \\ A(q^{-1}) &= 1 + a_1q^{-1} + \dots + a_nq^{-n} \quad (1) \\ B(q^{-1}) &= b_1q^{-1} + \dots + b_mq^{-m} \end{aligned}$$

Where q^{-1} is the backward shift operator. $u(k), y(k)$ is the plant input and output respectively.

Neural model of the plant

Next we shall use a linear two-layered neural network as a model of the plant. The network learns the plant dynamics using the Widrow-Hoff delta rule[2]. The input layer consists of $n+m$ elements. These $n+m$ inputs are the input-output signals measured at previous instants in the plant. The output layer has only one element whose output is the predicted output of the plant. This neural model of the plant estimates its regular dynamics

The weight vector at time k , defines by $w(k) = [w_1(k), \dots, w_n(k), w_{n+1}(k), w_{n+m}(k)]^T$ (2)

Widrow-Hoff rule :

$$w(k+1) = w(k) + \frac{\alpha e(k+1)x(k)}{\varepsilon + x^T(k)x(k)} \quad (3)$$

Where $x(k)$ is the network input vector $x(k) = [x_1(k), \dots, x_n(k), x_{n+1}(k), \dots, x_{n+m}(k)]^T$
 $= [-y(k), \dots, -y(k-n+1), u(k),$

$$\dots, u(k-m+1)]^T \quad (4)$$

and α is the reduction factor. The constant ε is chosen to be close to zero and is only included to avoid division by zero in (3) if $x^T(k)x(k) = 0$

The error signal $e(k)$ is the difference between the real plant response $y(k)$ and the response $\hat{y}(k)$ predicted by the neural model. This predicted output is linearly calculated as follows:

$$\hat{y}(k) = \sum_{i=1}^{n+m} w_i(k-1)x_i(k-1) \quad (5)$$

Neural controller

The learning of the plant dynamics by the neural estimator present above is used to adjust the connection weights of a neural controller which generates the control signal $u(k)$. This control signal, when applied to the plant input, is intended to bring the plant output $y(k)$ to a desired reference signal $y^*(k)$. The closed-loop control system is shown in Fig 1.

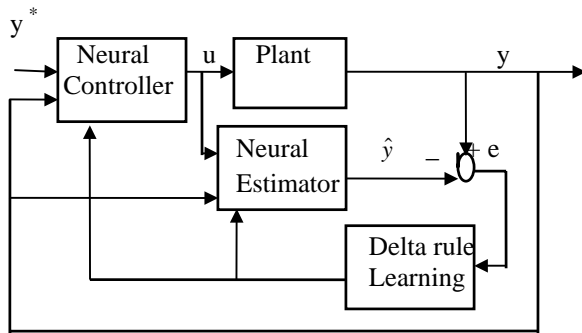


Fig.1

The neural controller consists of a second two-layered neural network with $n+m$ elements in the input layer and one element in the output layer. The input vector at instant k is defined by:

$$z(k) = [y^*(k+1), -x_1(k), -x_2(k), \dots, -x_n(k), -x_{n+2}(k), \dots, -x_{n+m}(k)]^T \quad (6)$$

and the connection weights vector $w'(k)$ is defined as a function of adjustable weights of the neural model of the plant as follows:

$$w'(k) = \frac{1}{w_{n+1}(k)} [1, w_1(k), w_2(k), \dots, w_n(k), w_{n+2}(k), \dots, w_{n+m}(k)]^T \quad (7)$$

The control signal is generated as a linear combination of element of the input vector $z(k)$, using the new weights $w'_i(k)$

$$u(k) = \sum_{i=1}^{n+m} w'_i(k)z_i(k) \quad (8)$$

In the end, the sequence of action in the control loop at instant k is as the follows:

- (a) Measure $y^*(k+1), y(k)$;
- (b) Use the neural model of the plant (Equ.5) to compute the predicted output $\hat{y}(k)$ using the old weights $w_i(k-1)$;
- (c) Compute the error $e(k) = y(k) - \hat{y}(k)$, and use the delta rule to calculate the new weight $w'_i(k)$;
- (d) Update the neural controller weights $w'_i(k)$;
- (e) Use the neural controller to generate the control signal $u(k)$.

Conclusion

A simple adaptive control scheme for discrete-time systems based on neural networks has been described. The design is based on two simple linear two-layered neural network. The first learns the unknown plant dynamics using the Widrow-Hoff delta rule. The second uses this knowledge to adjust its connection weights to generate the control signal online.

Reference

- [1]GOODWIN. G.C, and SIN.K. Adaptive filtering, prediction and control. Prentice-Hall, Englewood Cliffs 1984
- [2]Wang Junpu, Intelligent Control, USTC Publishing House. 1996