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Application of intelligent control theory in AC servo system

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Abstract: An AC servo system based on neuron control theory is presented. Experimental results show that the neural control mode doesn't need the precise model of the system, therefore, it has many advantages, such as simple design and high response performance. The simulation research of the AC servo system which is non-linear, time-varied, based on neuro-fuzzy controller is done. The results of the simulation show that the performances of the system are considerably improved and it is one of the novel pathways to realize intelligent control of servo system.

Key words: servo system, fuzzy control, neural networks, neuro-fuzzy networks

The PID (Proportional, Integral, Differential) control method is mainly applied to the traditional AC system whose speed and precision are not strictly demanded. The conventional PID control method is difficult to be used in the complex servo system such as robots, digital-control lathes, especially to meet the demand of precise position and tracking during the period of high speed on account of the variation of load model parameter in a wide range and the influence of nonlinear factor. Therefore, it is necessary to apply intelligent control theory to this kind of system in order to resolve the above problems and enhance the robustness of the system[1]. In this paper we mainly investigate the application of the self-adaptive neuron controller and neuro-fuzzy controller, and discuss the validity of the above two methods through the experiment and simulation research of the system[2].

1 AC Servo System Based on Neuron Control

The conventional PID control is incompetent compared with neuron controller in that neuron controller has the characteristics such as simple structure, high ability of self-learning, self-organizing, reconciling the discrepancy of static and dynamic performance, low demand of model parameter. and high resistance to disturbance. The AC servo system based on neuron control whose controlling objective is a permanent magnet servo motor adapts current-loop control strategy.

In order to improve the system's speed and meet the demand of current limit, the current loop adapts vector control theory based on delay-loop control. The set points of three phases are as follows:

$$\begin{pmatrix} i_a^* \\ i_b^* \\ i_c^* \end{pmatrix} = \left(\frac{2}{3}\right)^{0.5} \begin{pmatrix} \cos\theta_r & \sin\theta_r \\ \cos(\theta_r - \frac{2}{3}\pi) & \sin(\theta_r - \frac{2}{3}\pi) \\ \cos(\theta_r + \frac{2}{3}\pi) & \sin(\theta_r + \frac{2}{3}\pi) \end{pmatrix} \begin{pmatrix} 0 \\ i_q^* \end{pmatrix} = I_m^* \begin{pmatrix} \sin\theta_r \\ \sin(\theta_r - \frac{2}{3}\pi) \\ \sin(\theta_r + \frac{2}{3}\pi) \end{pmatrix} \quad (1)$$

In the equation (1), $I_m^* = (2/3)^{0.5} i_q^* \cdot \theta_r$, it is magnetic position pole angle.

Because the speed loop adapts neuron control theory, the relationship between inputs and outputs is as follows:

$$u = \sum_{i=1}^{3} W_i X_i \quad (2)$$

in the equation (2), $X_i (i = 1, 2, 3)$ is respectively three speed errors of three continuos sampling time, $e(k)$, $e(k-1)$ and $e(k-2)$, W_i is the input weight value of neuron. The learning calculation method is as follows:

$$W_i(K+1) = W_i(k) + \eta a_i e(k) x_i(k) \quad (3)$$

In the equation (3), η is learning rate; $e(k)$ is speed error, $e(k)=n^* - n(k)$; $X_i(k)$ is the ith input of neuron; $W_i(k)$ is the weigh value of the ith input; and a_i is constant coefficient.

Combining equation (2) with (3), the calculation method of self-adaptive neuron controller is built up.

DSP (Digit Signal Processor, which is manufactured in Texas Instrument) is selected as the controller whose main task is the calculation of vector model and neuron model. The position signal is input via PA15 port. A phase-current and B phase-current setpoints are output via PA8 and PA9 ports. C phase-current setpoint is as follows:

$$i_c^* = i_a^* + i_b^* \tag{4}$$

On account of the small time constant coefficient of the current loop, the neuron control is realized by means of interrupt program.

The speed response curve shown in Fig. 1 is acquired through the experimental research into the AC servo system. The speed response curve of PI (Proportional, Integral) controller and neuron controller are shown

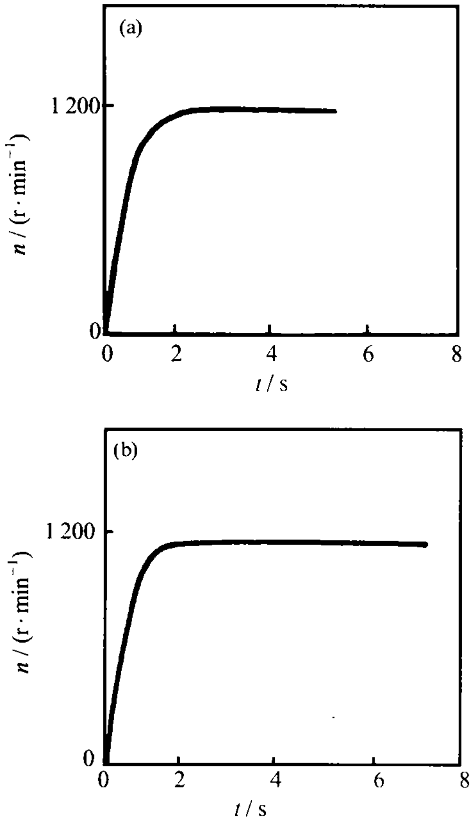

Fig.1 Speed response curve when the speed setpoint is 1 200 r/min
(a) PI controller, (b) neuro-fuzzy controller

respectively in Fig. 1.

From Fig. 1 we can get a conclusion that the response time of the system is reduced by means of the neuron control, but the static performance of the neuron control is a little worse than that of the PI control with great respect to the selection of the learning rate (η). If the learning rate is high, the response time is short and the system can't keep stable easily; otherwise the system can keep stable easily and the response time is long. In order to resolve the problem, we can select big learning rate value during the starting period and select small learning rate value during the period of approaching to static state[2].

2 AC Servo System Based on Neuro-fuzzy Control

According to the existed fuzzy models, we build up the neural network shown in Fig. 2 which consists of two kinds of neurons: one is shown as ● indicating that its relationship between input and output is sigmoid function, the other is shown as ○ indicating that its relationship between input and output is linear function. In Fig. 2, the precise quantum is changed into fuzzy quantum in the first 3 layers of the neural network (the realization of premised membership function) and the neurons' weight value can be adjusted via BP (back propagation) learning algorithm. We choose endowment table of the premised membership as the learning sample. The training program diagram of the system is shown in Fig. 3. The fuzzy rules are realized in 4th and 5th layer of the neural network. For example:

IF e is NM and $\dot{e}$ is ZO THEN u is NM

The premised conditions' verdicts are realized in the 4th layer of neural network, the verdict results are realized in the 5th layer, the fuzzy decision is realized in

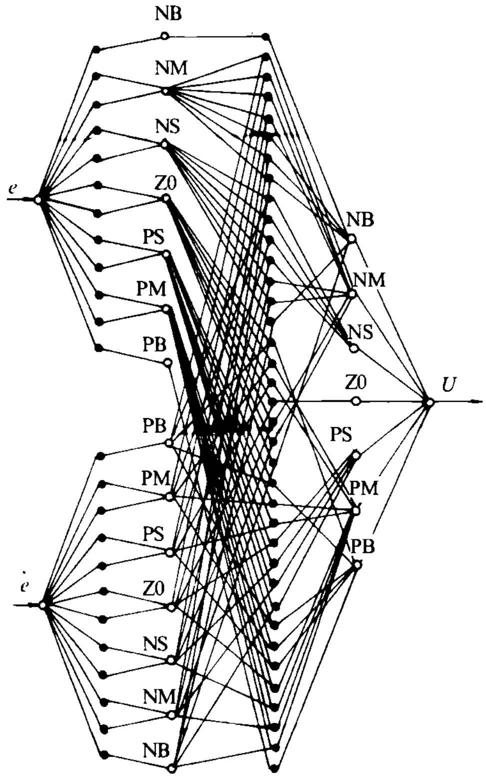

Fig.2 Neural−network based on fuzzy model

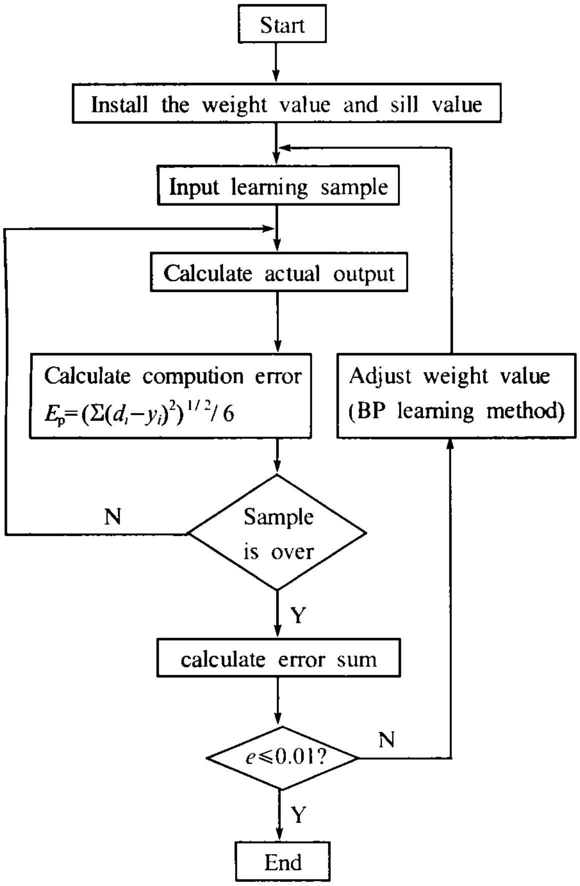

Fig.3 Training program diagram

the 6th layer.

From the above-mentioned neuro-fuzzy network which consists of neuro-fuzzy controller[3] and adapts BP learning algorithm to train the system, we can get more precise control model.

The simulation research into the AC servo system based on neuro-fuzzy control (shown as Fig. 4) is done,

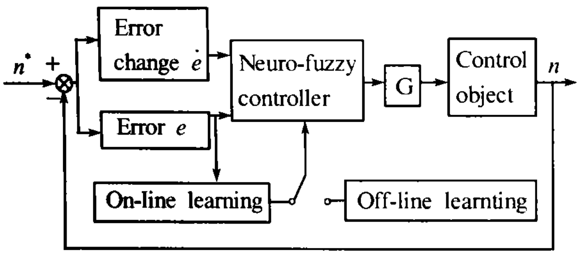

Fig.4 AC servo system based on neuro-fuzzy control

and the result of the system whose speed setpoint is 1200 r/m is also shown in Fig. 5. By comparison, we can see that the neuro-fuzzy control system's overshooting is nearly zero and its starting time is reduced. In addition, the static performance of PI regulator is less than that of neuro-fuzzy controller during the period of variation of the mechanic constant coefficient, while

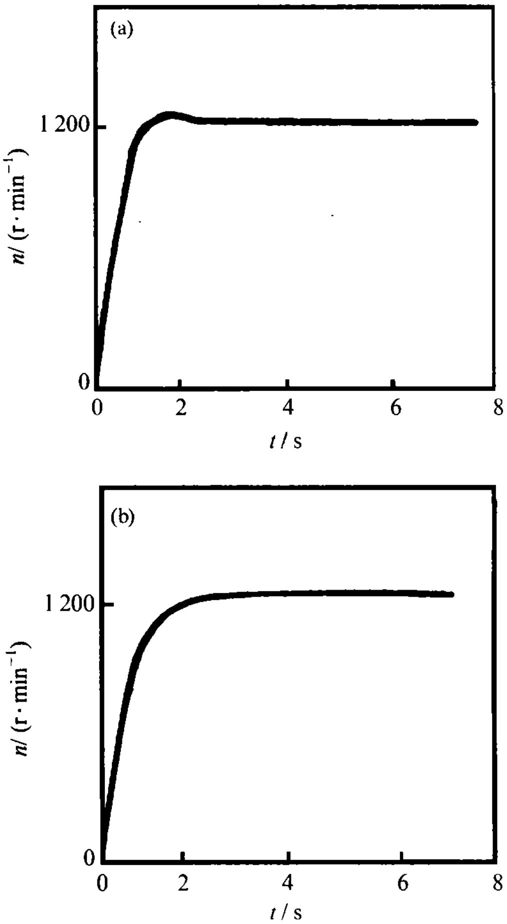

Fig.5 The simulation curve when the speed setpoint is 1 200 r/min

(a) PI controller, (b) neuro-fuzzy controller

the neuro-fuzzy control system isn't influenced by the factor. This proves that the neuro-fuzzy control system has strong robustness.

3 Conclusion

Self-adaptive neuron control method has many advantages, such as simple structure, enhanced response performance and without precise mathematical model, but its vital problem is the decision of the learning rate. The performance of the neuro-fuzzy control method is seemingly better than that of conventional PI regulator.

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