Temperature Control of Constant-Temperature Workshop Based on NARX Neural Network

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Abstract: The workshop air-conditioning system is a very complex nonlinear system. It is almost unable to obtain the precise analysis mathematical model. This article builds constant temperature workshop air-conditioning system model by using NARX dynamic neural network, and adopts the non-linearity adaptive inverse control method, finally, designs one kind of constant temperature workshop control system based on the dynamic neural network.

Keywords: NARX neural network; temperature control; constant temperature workshop; modelling

1 Introduction

The great combined workshop is a big-piece precise Production workshop of one Kunming machine Limited company. Machine's working precision is between 0.001mm~0.002mm. Because of the material different between the detecting elements which include coordinate ruler and the grating ruler and the machine bed. When the ambient temperature changes, each material's coefficient expansion will be dissimilar, and machine bed's working precision will be changed. With the different coefficient expansion, when the ambient temperature elevates, the length of expansion of coordinate ruler, grating ruler and machine will be different. Then the machine's working precision cannot meet the requirements the working precision value.

In order to meet the working precision, it has the high standard to the workshop ambient temperature. The great union constant temperature workshop is a big system with temperature affect mutually (that is, coupling). When air-condition equipment works, the balance of equipments' temperature cannot be achieved very quickly. Therefore, when air-condition's system of the depth coupling and the big inertia adopts the traditional PID adjustment, it cannot achieve good results. The neural network is an effective tool to identify complex non-linearity object or to build model. Theoretically, it's already proved that the neural network can approach any non-linearity function. Moreover, compared with other non-linearity object model tool, the neural network has learning capability.

This article uses dynamic neural network to establish the air-condition's system modeling, and it uses the non-linearity adaptive inverse control method to design the control system of constant temperature workshop.

2 Based on Narx Neural Network Object Modeling

The air-condition system is a complex dynamics system which is a kind of the closed coupling and delay time. For the air-condition system modeling, it is obvious a dynamic system modeling. That means the neural network system is a dynamics system. That is to say, it needs dynamics neural network to be the object's modeling tool. There are two kinds of dynamics neural network to be realized. One kind is when the time signal is spread to space expressing, it will be sent to the static forward feed neural network. For example the delay time neural network. The other kind is using the feedback structure, such as the entire regression nerves network and the non-linearity self-regression nerves network with the external input. When using the non-linearity object model, it usually uses the second kind dynamic neural network with the feedback structure. For the NARX neural network, literature [3] has proved that it has an implicit strata neuron which transfers function of unilateral saturation function with border. NARX neural network, whose output layer is linear output unit , is equal with the Turing machine. Although NARX neural net-

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work and FRNN neural network's structure are quiet different, their computing power is equal. The literature [4] has proved that these two kinds of neural network can transform mutually, and proposed, when neural network's output dimension is bigger than the number of implicit strata neuron, it will be easy to train FRNN, or, the NARX neural network's training is easier. The neural network nonlinear system identification usually belongs to the latter. That means the output dimension is smaller than the number of implicit strata neuron. Obviously, the list output system is the same. What's more, the NARX neural network has widespread application in the non-linear adaptive inverse control and the adaptive signal processing. Therefore this article will use the NARX neural network .NARX neural network structure is shown in Figure 1.

In the chart, $\boldsymbol{W}^1$ express the power matrix from input level to the implicit strata, and $\boldsymbol{W}^2$ express the power matrix from implicit strata to the output level. The implicit strata neural neuron uses the Sigmoid function (for example the tahn function), and output level is linear output unit. Neural network's input is:

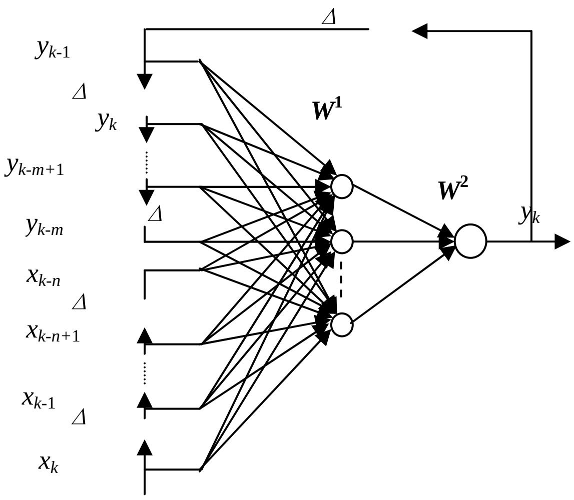

Figure 1 NARX Neural Network

$$\boldsymbol{U} = (x_k, x_{k-1}, \cdots, x_{k-n}, y_{k-1}, y_{k-2}, \cdots, y_{k-m})^T$$

T expresses the transposition

The *jth* neuron's input of implicit strata is:

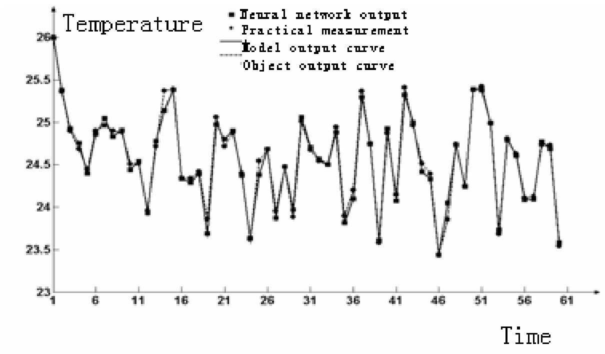

Figure2 Air-condition system NARX neural network model curve

$$v_{j,k} = \sum_{i=1}^{n+m+1} w^1_{i,j,k} \cdot U_i$$

The *jth* neuron's input of implicit strata is:

$$s_{j,k} = f(v_{j,k}); \quad f(x) = (e^x - e^{-x}) / (e^x + e^{-x})$$

The neural network's output is:

$$y_k = \sum_{j=1}^{h} w^2_{j,k} \cdot s_{j,k};$$

h is the implicit strata neuron number

The NARX neural network's learning algorithm is:

$$J_i = \frac{1}{2}\mathbf{e}_i^T \cdot \mathbf{e}_i; \quad \mathbf{e}_i = \mathbf{d}_i - \mathbf{y}_i$$

$$\frac{dJ}{d\mathbf{w}} = -e_i^T \cdot \frac{dy_i}{d\mathbf{w}}; \quad \frac{dy_i}{d\mathbf{w}} = \frac{\partial y_i}{\partial \mathbf{w}} + \sum_{k=0}^{m} \frac{\partial y_i}{\partial y_{i-k}} \cdot \frac{dy_{i-k}}{d\mathbf{w}}$$

$$\mathbf{w}_{k+1} = \mathbf{w}_k - \eta \cdot \frac{dJ}{d\mathbf{w}_k}$$

J is the objective function, d is the object output, y is the NARX neural network output, W is the NARX neural network joint power,$\eta$is study speed.In order to stimulate air-conditioning system's dynamic characteristic fully, this article joins the perturbation artificially, when air-conditioning system operate normally, and record corresponding input and output data as the NARX neural network's training regulations.The concrete procedure is, first set the air-conditioning system to the normal work temperature (25 degrees), then to set the operating temperature willfully in certain scope wife, and each time when set it, record the indoor temperature. Finally, take the set temperature each time as the NARX neural network's input, and the indoor temperature obtained at the

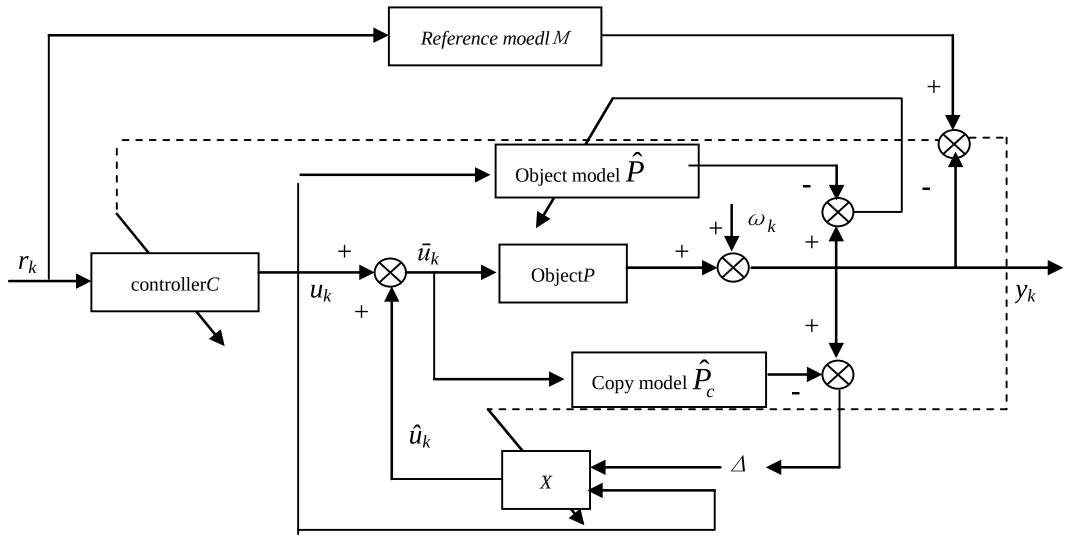

Figure 3. Non-linearity adaptive inverse control system structure chart

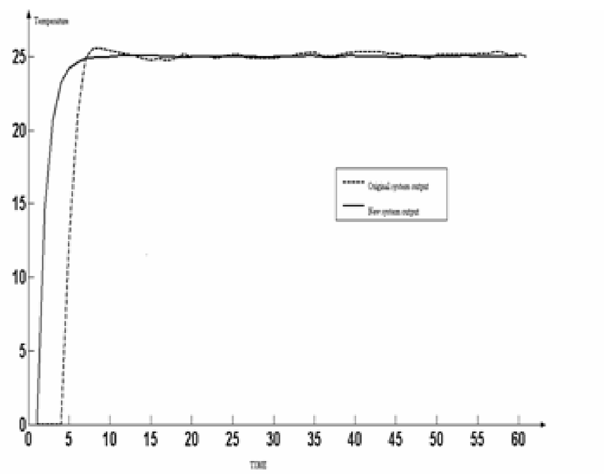

Figure 4 Air-condition system adaptive inverse control adjust curve

corresponding time as the neural network's output, training neural network off-line. This article has selected 60 pairs of data as the NARX neural network's training data set. The NARX neural network implicit strata is 8 neu--rons, whose input time delay exponent number is 4, output feedback timedelay exponent number is 2, study speed is 0.001,trained 3000 times. Figure 2 is the object output and the model output's correlation curve.

3 Based on Narx Neural Network Air-Condition System Non-Linearity Adaptive Inverse Control Method

The adaptive inverse control (AIC) was named for the first time by US Standford University B.Widrow in 1986.It is a new design method of control system and the regulator [5].It is a series of method using the adaptive signal processing and it can touch the adaptive control system's certain questions from another hand, it means how to use the adaptive filtering algorithm to complete the adaptive control of unknown or time-variable system .In the traditional feedback control and the adaptive control, the control of noise and interference is achieved by using negative feedback from the output to the input. But this definitely will change the object dynamics response. Therefore, in the course of the design, it needs to balance between the dynamics response control and noise and interference control. But in the adaptive inverse control, the object dynamic response control and the object noise and the perturbation are divided into the independent adaptive process. It can enable these two aspects of control simultaneously to achieve the most ideal effect, moreover, the corresponding adaptive subsystem is relatively simple and easy to analyze. This article uses Plett' non-linearity adaptive inverse control system structure which proposed in literature [6], its structure schematic drawing is shown in Figure 3.

Controller C and the interference annihilator X use NARX neural network which has the same structure with the object model. Because the goal of control is to make a constant temperature workshop, the transfer function of reference model M is 1.

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Figure 4 is the output compare curve of air-condition system between using the non-linearity adaptive inverse control method and the original system. From the chart we can see, the new system can reduce system's delay time, and does not have the over-modulation. Particularly, when the system is running normally, it is good for interference-free effect.

4. Conclusions

For the difficult problem to model the air-condition system, this article proposes the method which uses the dynamics neural network with NARX to model air-condition system, and the simulation research indicated the NARX neural network can establish the quite ideal air-condition system model.

Based on this, this article adopts the non-linearity adaptive inverse control method to realize the air-condition system's control. Compared to the original system, the new system's delay time is shorten, when the system's response ability is enhanced, it overcome the original over modulation phenomenon, and it can take effective interference-free in the course of the system's normal running , finally, the workshop can maintain effectively constant temperature effect.

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