The Strategy of Construction Equipment Energy-Saving Control

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Abstract

To improve building energy-saving equipment control gets more and more attention. In order to make the room have a good comfort level, this paper designed a system to control temperature and humidity of variable air volume (VAV) air conditioning (AC), by a new control method of VAV air conditioning self-adaption decoupling to decouple temperature and humidity, combining the fuzzy PID control and the RBF neural network decoupling control method, improved the control effect that inhibit the coupling of temperature and humidity. Simulation results show that the neural network decoupling control method has a strong decoupling control capability for the strong coupling lead to control issues like accuracy is not high and the control performance is not good in the multi-variable control system. Stable state and dynamic performance have been improved and the control effect of the air-conditioning systems and indoor air quality has improved.

Keywords: construction equipment, decoupling control, neural network, variable air volume

1. Introduction

With the development of our society, the requirements of the living environment such as indoor comfort are getting more and more attention. At present, most of the domestic central air conditioning systems are for temperature control and are lack of humidity control. so ensure the living environment and comfort are very important. This paper will design the temperature and humidity control of central air conditioning system. It has been the core research object in the field of intelligent building for its high flexibility, high comfort, and strong energy-saving ability. The adjusting of temperature and humidity for VAV air conditioning system is to become the focus of our research.

Because it has strong coupling between the temperature and humidity control, at present usually used PID decoupling control, but this decoupling control effect is not ideal. Therefore, this paper puts forward a method based on genetic algorithm to optimize the fuzzy neural network control, making use of RBF neural network can be a very good approximation of nonlinear characteristics of the system, identified the dynamic characteristics of the system, and combining the fuzzy PID control and RBF neural network decoupling control method, inhibition of temperature and humidity to produce coupling effect, improve the control effect. This control method has strong adaptive ability, high precision of control, can satisfy regulation demand of multivariable temperature and humidity control of the variable air volume air conditioning system.
2. The design of adaptive decoupling control system

Variable air volume air conditioning system is a multivariable, strong coupling and time-varying system, its mathematical model is very difficult to determine, this paper presents a new type of multi-variable air-conditioning decoupling control method, in order to improve the control performance of air-conditioning systems. Control system structure shown in Figure 1. In this paper, the design of air conditioning control system to complete temperature and humidity control of the system. The controller is mainly composed of three parts: The fuzzy PID controller, identification controller and decoupling controller. RBF neural network identification controller to identify the output of the two circuits controlled object, based on future output and combine adjustment of the fuzzy PID controller and RBF neural network decoupling controller to improve the inhibit the control effect of the temperature and humidity coupling.

This paper will design every controller, which focused on the design of the decoupling controller. Because the two loops using the same control method, this paper only take one loop as an example to explain.

![Figure 1. Adaptive neural network decoupling controller](image)

3. The design of fuzzy PID controller

In the field of industrial control, many controlled objects are influenced by many factors like outside interference or load change, the object's structure or parameters will change easily. Adaptive control can realize on-line identification characteristic parameter of the object, ensure that the system is operating in the optimum range. At the same time, there are a lot of tuning the PID algorithm parameter methods, but all kinds of signals of the control process are not easy to quantitative, so fuzzy theory is an effective method to solve this problem. Combining fuzzy inference can adjust the PID parameters automatically, namely fuzzy adaptive PID control.

In this paper, the design of fuzzy adaptive PID controller to set values and actual output difference values, set values and identifier difference values as input, and input quantity of the single channel uses fuzzy rules to fuzzy by a fuzzy controller, on-line adjustment of PID control.
ratio coefficient, integral coefficient and differential coefficient, implementation self adjustment of system parameters. Can calculate the three parameters of the PID control:

\[
K_p = \frac{\sum_{i=1}^{m} (\mu k p_i (z_p) \cdot (z_j))}{\sum_{i=1}^{m} \mu k p_i (z_j)} \\
K_i = \frac{\sum_{i=1}^{m} (\mu k p_i (z_p) \cdot (z_i))}{\sum_{i=1}^{m} \mu k i_i (z_i)} \\
K_d = \frac{\sum_{i=1}^{m} (\mu k p_i (z_p) \cdot (z_{pi}))}{\sum_{i=1}^{m} \mu k i_i (z_p)}
\]

(1)

(2)

(3)

The control output \( U_{(n)} \) algorithm can be expressed as:

\[
U_{(n)} = K_p \left[ e_{(n)} + \frac{T}{n-1} \sum_{i=0}^{T} e_{(i)} + \frac{T_i}{T} \left[ e_{(n)} - e_{(n-1)} \right] \right] \\
= K_p e_{(n)} + K_i \sum_{i=0}^{n-1} e_{(i)} + K_d \left[ e_{(n)} - e_{(n-1)} \right]
\]

(4)

In which \( e_{(n)} \) is article N the sampling input; \( U_{(n)} \) is article N the sampling output; \( T \) is Sampling period; \( K_p \) is ratio coefficient; \( K_i \) is integral coefficient; \( K_d \) is differential coefficient.

4. The design of RBF neural network identifier and the decoupling controller

4.1. The design of RBF neural network identifier

In this paper, the identifier is the control system to realize the on-line adjustment of the function, the input has 3, namely the output of the controller, a moment before the actual output of the system, the identifier and the actual output'difference values. The structure of the neural network model is the same with decoupling controller, the specific content will be introduced in the decoupling controller structure.

4.2. RBF neural network structure

In this paper, both the identifier controller and decoupling controller are RBF network decoupling. RBF neural is a network of local approximation, it can approximate any continuous function with arbitrary precision, especially suitable is solving the classification problem. The model structure of RBF neural network is as shown in Figure 2.

4.3 Application of genetic algorithm in neural network

Through the fuzzy controller, the three the fuzzy variables update the weights through the RBF neural network decoupling controller. This paper uses genetic algorithm to optimize the neural network.
Any random, satisfies the following conditions:

\[ a \text{ satisfies the following conditions:} \]

\[ 0 \leq a_i \leq \sum_{j=1}^{k} f(a_i^*) . \]

In which \( q = \min \left \{ k \left \| \forall k \in \{1,...,\lambda \} , s.t. \sum_{i=1}^{k} f(a_i^*) \leq a_i \leq \sum_{j=1}^{k+1} f(a_i^*) \right \} \)

\[ B. \text{crossover operation} \]

Crossover operation is divided into single point crossover and multi point crossover, here is used multi point crossover. The operation is from the solution set \( p^* \) to get new solution set \( p^* \), can be expressed as:

\[
\left \{ a_i^* \right \} = c_{mp} \left \{ a_i^* \right \} = \bigcup_{j=1}^{L} \left \{ \begin{bmatrix} b_{i,j} \\ b_{i+1,j} \end{bmatrix}, \text{if } \rho_j \geq \rho_c \right \} \bigcup \left \{ \begin{bmatrix} b_{i+1,j} \\ b_{i,j} \end{bmatrix}, \text{if } \rho_j < \rho_c \right \}
\]

\[ \forall i \in \{1, 3, \ldots, 2j + 1, \ldots, \lambda - 1\} \]

In which \( \rho_j \) is the random number, \( \rho_c \) is the cross threshold.
C. mutation operation

\( \rho_m \) is the threshold value, \( \rho_j \) is the random number, \( 0 \leq \rho_j, \rho_m \leq 1 \). When \( \rho_j \geq \rho_m \), it will mutate, \( 0 \rightarrow 1 \) or \( 1 \rightarrow 0 \). Mutation operation is defined as:

\[
a_i' = m(a_i) \quad \forall i \in \{1, \ldots, \lambda\}
\]

\[
b_{i,k}' =\begin{cases} b_{i,k}, & k \in \{1,2, \ldots, p-1, p+1, \ldots L\} \\ b_{i,k}, & k = p \end{cases}
\]

4.4 Optimization design of genetic algorithm parameter

In this paper uses genetic algorithm to optimize RBF neural network parameters, so that the optimized RBF neural network can have better predictive output function. Selection of the individual as a string, contains all of the input layer and the core layer, core layer and output layer weights and central values. Consisting of a neural network in the network structure of identified cases with determined structure, weight, center value. Then the trained RBF neural network to predict the output of the whole system, the predicted output and absolute error of the preferred output as the individual fitness value \( F \), suppose network output access points is \( n \), \( y_i \) is RBF neural network expected output of \( i \) node; \( x_i \) is the predicted output of \( i \) node, then the fitness value is:

\[
F = k \sum_{i=1}^{n} |y_i - x_i|,
\]

the smaller individual fitness value, the better excellent individuals. In this paper chooses three layers neural network structure, the input layer nodes, the center layer nodes and the output layer node, each number set as 3,3,1, evolutionary iteration number is 200, population size selection is 100, crossover probability is 0.1, mutation probability set to 0.05.

5. Simulation

In order to verify the reasonableness of the control scheme in this paper. We made a simulation experiment. In this paper, control object adopts second-order model, its transfer function is:

\[
G(s) = \frac{ke^{-\tau s}}{(T_1 s + 1)(T_2 s + 1)}
\]

Among them, \( T_1 = 12 \), \( T_2 = 5 \), \( k = 18 \), \( \tau = 12 \). So,

\[
G(s) = \frac{18}{60s^2 + 17s + 1} e^{-12s}
\]

Set current temperature 12 °C, current humidity 60%. Set desired temperature 20 °C, desired humidity 40%, and then observe the simulation curves of common PID decoupling temperature and humidity control and adaptive decoupling temperature and humidity control which puts forward in this paper. Then add disturbance at 30-40 min, and observe the changes of temperature curves.

Because VAV air conditioning system is a large time delay system, so the response of temperature control has delayed a period of time. From the temperature simulation curve, we can know that adjusting current temperature to desired temperature, the adaptive decoupling control curve has faster response speed and smaller overshoot, after achieving desired temperature, the temperature curve keeps invariant. But common PID decoupling control curve has large overshoot and large amplitude changing, tend to be stable after a long time. From humidity simulation curve, the method put forward in this paper achieves desired humidity faster and after adding disturbance at 30-40min, common PID decoupling control has slower response speed and then the temperature control corresponding with it has produced disturbance. But temperature curve of adaptive decoupling control has uninfluenced, it proves that decoupling is successful. Therefore, the whole control process has fast adjusting response, small steady state...
error, high control precision and strong robustness. Compared with common PID, it has higher control precision, and more obvious decoupling effect.

![Simulation diagram of temperature and humidity decoupling control effect](image1)

![Simulation diagram of temperature and humidity decoupling control effect](image2)

Figure 3. Simulation diagram of temperature and humidity decoupling control effect

6. Conclusion

In this paper, we put forward a fuzzy neural network control method based on genetic algorithm optimization. The method combines fuzzy controller and neural network decoupling controller, which is not only reflecting strong robust characteristics of fuzzy control, but also using strong adaptive learning ability of neural network. System simulation experiment shows that aiming at the problems that multi-variable control system has low control precision and bad control performance which caused by strong coupling effect, the neural network decoupling control method in this paper has stronger control solving ability, and improves performance of steady state and dynamic state, it also improves control effect of air conditioning system and energy saving control effect.
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References


