Application Research of Intelligent Control Algorithm in Air Conditioning System

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Abstract. In order to reduce the energy consumption of HVAC system, we analyzed and compared modern intelligent control algorithm applied to HVAC control system, introduced the basic principles of fuzzy control, neural network and genetic algorithm, and analyzed the applicability of intelligent algorithm in HVAC system with engineering examples.

1. Introduction
Since the reform and opening up, China’s economic construction has stepped into the stage of rapid development. The number of new buildings has been increasing rapidly, and people's requirements for residential comfort have been significantly increased with the improvement of living standards. China's building energy consumption accounts for about 35% of the total energy consumption, among which the energy consumption of NVAC system accounts for 50%-60% of the total energy consumption of the building. Therefore, under the requirements of energy conservation and emission reduction, optimal design and automatic control are important means to improve energy conservation of HVAC. This paper mainly introduces several advanced control algorithms and methods in HVAC research and engineering and analyzes their advantages and disadvantages. Finally, the application direction and effect of various algorithms in current research and engineering are compared and summarized to provide reference for the promotion and application of artificial intelligence in the field of HVAC.

2. Control algorithm
2.1. Fuzzy PID control algorithm
Fuzzy PID control algorithm is an improved algorithm based on PID control algorithm, that is, in the traditional PID control process to add a fuzzy control link, so that the real-time PID parameters can be adjusted, to seek the optimal value of each parameter. Compared with traditional PID control algorithm, fuzzy PID control algorithm not only retains its advantages of good steady-state performance and simple control, but also can complete dynamic response well. Its control principle model is as figure 1.
The artificial intelligence fuzzy control algorithm can not only control the terminal equipment of air conditioning equipment, but also reduce the energy consumption of the terminal equipment. It can also be introduced into the central air-conditioning water system to realize the dynamic regulation of the cooling capacity of the chiller, break through the traditional fixed water quantity control mode, ensure the efficient operation of the system and reduce the energy consumption of the system.

2.2. BP neural network model
Propagation BP(Back Propagation) neural network is a multi-layer feedforward neural network trained in accordance with error inverse propagation algorithm. The BP neural network model can well map complex multi-dimensional functions, and the multi-layer feedforward mechanism enables it to carry out pattern classification of different levels of complexity, which can be used to solve xor problems that cannot be solved by conventional perceptron. BP neural network is composed of input layer, hidden layer and output layer.

Obviously, BP neural network is a multi-input-single output model, and its main advantages are its strong ability to fit nonlinear functions. In different use environments, the number of hidden layers and the number of neurons in each layer of BP neural network can be set freely according to the demand. Of course, BP neural network also has disadvantages: the speed of autonomous learning is relatively slow, it is easy to fall into local minimum in the face of complex work, and the number of hidden layers and neurons on each layer requires users to try gradually.

2.3. RBF neural network model
The radial basis function (RBF) neural network and BP neural network are both feedforward neural networks. Compared with other feedforward networks, RBF neural network can approximate complex nonlinear functions more accurately and has global optimal characteristics. It also ensures that the training speed is fast while the structure is not complicated.
2.4. Genetic algorithm
Genetic algorithm is a computational model that simulates the natural selection and genetic mechanism of Darwinian biological evolution. It is a method to search for the optimal solution by simulating the natural evolution process. It is mainly used to solve complex and interrelated combinatorial optimization problems. Compared with other optimization algorithms, the advantage of genetic algorithm is that it can obtain relatively good optimization results in a relatively short time.

3. Comparison of the characteristics of different control algorithms
The following is a summary of the characteristics of several control algorithms introduced above in the operation stage of HVAC system:

| Table 1. Comparison of the characteristics of different control algorithms |
|----------------------------------------------------------|
| **Fuzzy PID control** | **BP neural network model** | **RBF neural network model** | **Genetic algorithm** |
| 1. The advantages of conventional PID control are retained; | 1. It has high accuracy and is suitable for complex nonlinear functions; | 1. Its structure is simple and the training speed is fast; | 1. Its large coverage is conducive to overall selection of the best; |
| 2. It is characterized by anti-interference, simple control and strong robustness. | 2. It can set the middle layer and the number of neurons freely. | 2. It has the best approximation performance and global optimal characteristics. | 2. Its definition domain can be arbitrarily set and its application scope is wide; |
| 1. Its improvement on time delay is limited; | 1. Its learning speed is slow. | 1. When the data is insufficient, the neural network cannot work; | 1. The coding is not standard and the coding is not accurate; |
| 2. Membership functions obtained from experience of experts and operators may not accurately affect the control results. | 2. There is no corresponding theoretical guidance for the selection of the number of network layers and neurons. | 2. Turn all the reasoning into numerical calculations, and the result is a loss of information. | 2. The efficiency is lower than other traditional optimization methods; |

4. Simulation analysis and example analysis of various algorithm applications

4.1. The application of fuzzy control algorithm
Literature [1] takes the fuzzy self-tuning PID controller as the research object, analyzes and compares the performance of the fuzzy self-tuning PID intelligent controller from two aspects. The experimental analysis results are as figure 5. The results show that fuzzy control has better dynamic and static effects than PID control, and it is feasible.

Literature [2] selects the central air conditioning system of Hankou Railway Station as the research object, and tests the power consumption of the cooling host, cooling water pump and cold water pump respectively under power frequency operating condition and fuzzy control condition, and then compares them with the calculated theoretical values. The data are shown in the figure 6.

The results show that the difference between the measured power value and the theoretical value calculated by the power model under the fuzzy PID control mode is very small, and the relative error of the power model is less than 5%. In the whole operation process of the air conditioning system, the power consumption of the refrigeration host machine will change in real time, while the cold water pump and cooling water pump basically keep stable operation at rated power. The total power consumption and energy saving efficiency of the refrigeration system running under 24 h internal fuzzy PID intelligent
control are up to 26%. It is not difficult to see that the same central air conditioning system in the fuzzy PID control mode can achieve effective energy saving.

4.2. Application of BP neural network algorithm

Literature[3] uses a source heat pump air conditioning system to analyze and compare the reliability of BP neural network model established. The following figure shows the comparison of the predicted and measured hourly load of the building's ground source heat pump air conditioning system in July 2012. It is not difficult to see that the BP neural network model's predicted value and load variation trend of the building's cooling load are basically consistent with the measured load. In the case of sudden change of the building's cooling load every time, the BP neural network model can still get close to the measured cooling load.

The linear regression correlation coefficient between the hourly load prediction value and the actual value of the system is 0.93, indicating that the load prediction of the BP model is very close to the real value. Considering the actual application requirements, in the annual seasonal transition period, the climatic conditions change greatly in the short term, which will cause the system load to change greatly in a short period of time. The BP neural network model needs a large amount of data and a long time to learn, otherwise the accuracy of its load prediction results will be relatively poor.

The load prediction model of ground source heat pump air-conditioning system based on neural network can accurately predict hourly loads in the next 24 hours. However, the load forecasting performance of this model still needs to be improved in the transitional season.

4.3. Application of RBF neural network algorithm
Literature[4] takes an office building in Guangzhou city as the research object to verify the practicability of comparing BP neural network model and RBF neural network model in load forecasting. First, two neural network models are trained, and then two neural network models are used to predict the load of the office building. The error values of the two models in the training process are very small, indicating that the two models have established a perfect and reliable relationship between the building load and the operating parameters of the air conditioning system during the training process. For the 4-month test sample set, the RBF model predicted RMS error is 63.76% and the average relative error is 63.81% of BP network method.

4.4. Application of genetic algorithm
In literature[5] and[6], genetic algorithm is used in the fuzzy control system of air conditioning for optimization, and membership functions and control rules are automatically optimized and compared with ordinary fuzzy control for simulation. The results show that when genetic algorithm is applied to the fuzzy control system, the response speed of the whole system is faster and the overshoot is lower than that of the simple fuzzy control system.

5. Conclusion
Fuzzy control overcomes the shortcomings of PID control to a certain extent, and its cost is relatively economical, which is suitable for most comfort requirements. Neural network model and genetic algorithm can meet higher requirements, and a large number of studies have proved their reliability. Although limited in practical engineering applications, neural network model and genetic algorithm are bound to become a major driving force to promote the progress of HVAC systems in the future under the environment of mature technology and energy conservation and emission reduction.

Now, the HVAC industry, like many other industries, is undergoing rapid technological innovation. In the future, machine learning, intelligent control and other technologies are likely to become green and intelligent propelling forces for HVAC systems.

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References
[1] Li Feng, Li Ping, Zhao Hu, et al. (2004) Fuzzy control of VAV system [J]. Journal of Instrumentation, (S2): 261-263.
[2] Yu Zhongyi, Chen Yanhua, Yu Shiping, et al. (2012) Energy-saving operation of centralized air conditioning system in railway passenger station under different control modes [J]. HVAC, (2): 105-108.
[3] Li Fan, Qu Shilin, Yu Dan, Cao Yong, MAO Xiaofeng. (2014) Hourly load prediction of air-conditioning system based on operational data artificial neural network [J]. Building science, 30(02):72-75.123
[4] Li Qiong, Meng Qinglin. (2008) Building Hourly Air Conditioning Load Prediction Model Based on RBF Neural Network [J]. Journal of South China University of Technology (Natural Science edition), 10:25-30.
[5] Chen Jie, RUI Yannian, Zhang Jian. (2006) Research on intelligent Variable Frequency Control Method of Air Conditioning Based on Genetic Algorithm and Fuzzy Theory [J]. Mechanical and Electrical Engineering Technology, 9: 79-82.
[6] Guo Xuhong, RUI Yannian, LI Juntao. (2005) Research on fuzzy Intelligent Variable Frequency Air Conditioning Simulation System based on Genetic Algorithm [J]. Journal of System Simulation, 05:1237-1240+1243.