Research on Intelligent Home Adaptive Control Strategy

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Keywords: Smart Home, Comfort Index, Adaptive Control.

Abstract. Adaptive control of smart homes is a new requirement for building intelligent technology. This paper analyzes the influence of different environmental factors on the indoor comfort index, and uses the optimal state of the indoor comfort index to reversely find the indoor environmental factors, so as to formulate the control strategy of the controlled equipment. So that the controlled equipment can adjust the state by itself, and have the ability to automatically adapt to the current environment, in order to maintain the indoor environment in the most comfortable balance.

Introduction

The development of smart home technology meets the needs of people for intelligent control of home systems. Its core function is to connect homes through wireless or wired network technology for centralized control and to realize the purposes of remote control of home appliances and real-time monitoring of indoor environment. The intelligent level of smart home technology has always been the measure of the maturity of the industry. Faced with the endless stream of intelligent control technology and intelligent control system processing mode, how to find the optimal solution has become a hot topic of current research.

A feasible solution of the intelligent adaptive control technology is to establish the relationship between the adaptive control system and the indoor environment prediction of the smart home, and to form a comprehensive prediction system. The results are used to optimize the intelligent control system and improve the intelligent and adaptive processing capabilities of the control system [1-4]. The influence of various factors on the comfort of indoor environment is analyzed in this paper aiming at achieving the best state of indoor environment comfort. The linkage control strategy of indoor electrical equipment is developed to improve the adaptive ability of the smart home control system, and then adjust the comfort of the indoor environment automatically.

Indoor Environment Thermal Comfort Index

The current research and analysis of indoor environment is based on the theory of predictive mean vote (PMV) and predicted percentage of dissatisfied (PPD) proposed by Professor P. O. Fanger, which is currently the most widely used comfort evaluation standard [5].

The indoor environmental comfort index proposed by Professor P. O. Fanger is composed of five factors: $\varphi_a$-the indoor relative humidity, $t_a$-the ambient air temperature, $v$-the indoor wind speed, $M$-human caloric metabolic rate and $I_{cl}$-the clothing insulation [5]. The first three are objective factors and the latter two are subjective factors. Therefore, the control strategy for adjusting the comfort state of the current indoor environment according to a single environmental variable is obviously not comprehensive and not objective. The control scheme of the smart home equipment will be formulated according to the change of PMV. Because PMV is calculated following the consideration of all the factors, its change has macroscopic character. If the system can respond to the changes of PMV and adjust the state of the related controlled equipment in time, it has the macro-control ability which abandons the defect of a single control strategy. The specific process is shown in Figure 1.
Figure 1. PMV index control.

**Linkage Control Strategy**

In order to analyze the influence of different environmental variables on indoor thermal comfort indicators, the influence law of each environmental variable on PMV is explored in this paper by setting specific scenarios and specific variable range [6]. Due to the randomness and uncertainty of subjective factors, it cannot be used as a basis for strategic recommendations on the state of controlled devices. Therefore, only the influence of objective factors on comfort indicators is discussed. 982 sets of test samples collected in laboratory are selected for analysis.

The change of temperature and humidity is positively correlated with the indoor thermal comfort index PMV. For the adjustment of indoor comfort, the temperature should be changed preferentially. The wind speed is negatively correlated with the change of the indoor thermal comfort index PMV, and the combination of temperature and wind speed has a greater impact on PMV. When the wind speed is in the range of 1.5m/s to 2m/s, PMV is almost unaffected by the wind speed. While when it is greater than 2m/s, PMV will change significantly according to the increase of wind speed.

Excluding the subjective factors affecting factors, the principle of linkage control strategy for the controlled equipment is shown in Figure 2. When the predicted value of PMV needs to be changed greatly, the temperature and wind speed values are preferentially changed, that is, the state of the air conditioner and the exhaust fan are preferentially controlled, and the result of PMV can be greatly changed. While when the predicted value of PMV is close to the optimal range and only needs small changes, the humidity of the air conditioner is adjusted to meet the comfortable balance of the current indoor environment.

**Adaptive Control Simulation Analysis**

According to the division of the indoor functional area, the equipment and user requirements of different locations are different, so the number and requirements of the controlled objects in the area are different. All the controlled devices in the control range of a sensor is selected for simulation in this paper. The controlled devices that must be included in this area include detection sensors, air conditioners, ventilator and electric curtains.
The data selection criteria in this paper is shown in Table 1. The quantitative analysis of the indoor comfort prediction results and the optimal joint control strategy are based on the control strategy principles. The results verify the accuracy of the control strategy. According to the model proposed in [7], PMV and PPD values are predicted as shown in Figures 3 and 4 in which abscissa is the data group number corresponding to the prediction result, indicating that the predicted PMV result is obtained from the data set in the group. The accuracy of the control strategy principles is verified by analyzing the trends of PMV and PPD.

According to Fig. 3 and Fig. 4, it can be concluded that the sample group 1 and 2 are the control groups with temperature changes, and PMV<<-1, PPD>>25%. According to the policy principle, the temperature should be preferentially adjusted. As shown in Table 1, for sample group 1 and 2, other influencing factors are constant, while the temperature is from 22.2°C to 26°C. The PMV and
PPD diagrams change greatly, and the slope is also large, indicating that when the PMV value needs to be changed greatly, the strategy of preferentially changing the temperature is correct which can quickly alleviate the uncomfortable situation in the room.

Table 1. Parameter values.

| Indoor temperature °C | Indoor humidity % | Indoor wind speed m/s | Metabolism W/m² | Clothing thermal resistance clo | PMV      | PPD % |
|-----------------------|-------------------|-----------------------|-----------------|-------------------------------|-----------|------|
| 22.2                  | 32                | 1.8                   | 47              | 0.9                           | -3.2627   | 99   |
| 26                    | 32                | 1.8                   | 47              | 0.9                           | -1.45     | 48.4 |
| 26                    | 50                | 2.5                   | 47              | 0.9                           | -1.33     | 45.3 |
| 26                    | 50                | 1.8                   | 47              | 0.9                           | -1.25     | 39.7 |
| 26.5                  | 50                | 1.8                   | 47              | 0.9                           | -0.95     | 24.1 |
| 31                    | 65                | 4.5                   | 98              | 0.5                           | 1.789     | 66.8 |
| 31                    | 65                | 2.5                   | 98              | 0.5                           | 1.649     | 69   |
| 26                    | 65                | 2.5                   | 98              | 0.5                           | 0.3183    | 5.7  |
| 26                    | 45                | 2.5                   | 98              | 0.5                           | 0.0377    | 4.95 |
| 26                    | 75                | 2.5                   | 98              | 0.5                           | 0.34      | 6.1  |

Sample group 3 and 4 are control groups with wind speed changes with PMV<-1 and PPD>25%. According to the policy principle, when the temperature is appropriate, the wind speed is regulated which is 1.8 to 2.5. Since the wind speed is positively correlated with PMV, when the wind speed increases, a slow upward trend can be seen on the curve, but the slope is small, indicating that when the temperature is suitable, adjusting the wind speed can make the room more comfortable, but the influence of wind speed on PMV is smaller than that of temperature on PMV.

Sample group 8 and 9 are control groups with humidity change with 1>PMV>-1, PPD<25%. It can be seen that when the indoor temperature and wind speed are appropriate, the humidity is from 65% to 45%. With the decrease of humidity, PMV showed a slight downward trend which verified the strategy that humidity is positively correlated with PMV is correct. The effect of humidity on indoor balance is relatively small compared to that of temperature and wind speed.

The sample group 5 and 10 are the indoor balance control groups with 1>PMV>-1 and PPD<25%. The indoor environment is in equilibrium. It can be concluded that with the difference of clothing thermal resistance and human metabolic rate, the indoor balance should be a result of the interaction of all the factors. It needs to find the best combination of all the factors to obtain the optimal balance of the interior and single regulation is not in line with actual needs, which is the purpose of the linkage control strategy of the smart home adaptive control system.
**Summary**

Based on the prediction results of indoor environmental comfort, the linkage control scheme of indoor controlled equipment is analyzed according to the standard indoor comfort interval of the building, and an adaptive optimization control scheme to automatically adjust the state of the controlled equipment is developed according to the comfort requirements. The linkage control scheme and the scene mode can also be customized according to the individual needs of the user, which maximizes the adaptability and user requirements of the system.

**Acknowledgement**

This research was financially supported by National Key R&D Program of China, Research and Demonstration of Key Technology of Net-Zero Energy Building (2016YFE0102300); Research Program of Beijing City Board of Education (KM201610016002); Research Fund Project of Beijing University of Civil Engineering and Architecture (00331616040) and Fundamental Research Funds for Beijing University of Civil Engineering and Architecture (X18031).

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