Design of air conditioning energy saving control system based on Niagara Internet of things technology and fuzzy algorithm

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Abstract. With the development of modern science and technology, Internet of things technology is entering people's lives. People put forward higher requirements for the comfort and convenience of life. Air conditioning can bring people cool in hot summer, but it also brings huge energy consumption. In order to meet people's requirements for air conditioning control comfort, and to achieve the purpose of energy saving and consumption reduction, this study is based on the Niagara Internet of things technology framework, through the human body infrared sensor and calendar control schedule, temperature sensor and air conditioning controller to control the start and stop of air conditioning. At the same time, the temperature fuzzy control algorithm is used to control the cooling temperature of the air conditioner according to the room temperature, so as to realize the adaptive adjustment of the air conditioning temperature. Finally, through the presentation XML (PX) view designed in Niagara software, the remote control of air conditioning can be realized. Through the debugging of the air conditioner, the adaptive control of the air conditioner can be realized, the comfort of the control can be improved, and the energy consumption can be reduced.

1. Introduction
With the improvement of social production level, people's comfort requirements for daily living environment are gradually improved, and the application of air conditioning system in building furniture is more and more extensive. Air conditioning has two main control modes, one is through the temperature control panel on the wall, the other is through the infrared remote control. The control mode of wall control panel is mainly used in large shopping malls, office buildings and other occasions, which is not convenient for transformation. Infrared remote control mode, mainly used in office buildings, hospitals, schools, families and other occasions, can be integrated into the control logic through the appropriate infrared remote control to control the air conditioning, hoping to keep the comfort level at the same time, reduce energy consumption to the minimum, bring greater benefits and benefits and reduce unnecessary expenses. Reference [1] points out that in multi partition buildings, personalized operation of HVAC system according to thermal zoning can reduce energy consumption and minimize thermal discomfort of residents. By combining intelligent metering technology with building energy management system in multi area buildings, a single room can be divided into several meaningful end-user groups (i.e. hot areas) according to energy use behavior. In reference [2], the method of avoiding secondary heating of air conditioner is proposed to reduce energy consumption. In reference [3], in order to evaluate the impact of uncertainties in HVAC systems with advanced operating sequences, Monte Carlo uncertainty analysis was applied to a detailed Modelica building energy model programmed with G36 control sequence. In a small time scale, the uncertainty model is combined with the deterministic model of buildings and control
sequences to represent the frequency of real-world building automation system (BAS) acquisition signals. The impact of uncertainty is quantified by annual simulation.

The above-mentioned literatures only aim at the variable of air-conditioning temperature, without considering the key condition of whether there is people in the room. When there is no one in the house, if the air conditioner is not turned off in time, the air conditioner will still run, causing a huge waste of electric energy. When the cooling temperature of the air conditioner in the room is lower than 26 degrees, it is still running at high speed, which not only causes waste of electric energy, but also may cause air-conditioning disease of personnel due to low temperature. According to this requirement, a set of air-conditioning control system based on Niagara Internet of things technology framework is designed. In this system, the infrared sensor of human body is added, and whether there are people in the room, calendar control table and indoor temperature are taken as air conditioning control conditions. The system adopts infrared signal emission control, which can be applied to any brand of air conditioning. The control system is mainly composed of human body infrared sensor, temperature and humidity transmitter, air conditioning controller, network controller Jace, intelligent electricity meter, etc. Through this system, the power of air conditioning can be saved to a great extent and the indoor comfort can be improved.

2. The overall design of the system
The air conditioning energy-saving control system integrated with Niagara Internet of things technology is mainly composed of infrared sensor, human body infrared sensor, temperature and humidity transmitter, air conditioning controller, network controller jace8000, etc. The system structure includes the following parts.

2.1. Perception control layer
The main function of this layer is to "sense" the environmental parameters and the working parameters of electrical equipment, and change the working state of electrical equipment as required. The main equipment includes temperature sensor, humidity sensor, infrared sensor of human body and power meter with electric energy measurement function.

2.2. System access layer
The main equipment of this layer is the Internet of things gateway, which is mainly responsible for connecting many terminals of the perception control layer to the Internet. The system mainly communicates with the terminal of perception control layer through Modbus RTU communication protocol, and forwards the data sent by the terminal to the server or forward the remote control command of the server to the terminal. In addition, it has Ethernet, Wi Fi and other communication interfaces, which can access the local area network and communicate with the remote server. In this design, we also realize to send the detected data to the server through the communication mode of mqtt.

2.3. Logic control layer
The main device network controller of this layer is Jace. The sensor is connected to Jace through RS 485 protocol interface, and the logic building and command issuing are completed on Jace, such as turning off the air conditioner and turning on the air conditioner. At the same time, the PX view can be built in Jace Shanghai to realize the human-computer interaction.

2.4. Internet layer
The main equipment in this layer is the general network equipment which is responsible for connecting the gateway of Internet of things into LAN and then accessing the Internet or directly accessing the computer network of network operators. The former can be network equipment such as switches and switches or routers in office buildings, while the latter can be ADSL modems, cable
modems, wireless routers, fiber routers and other equipment. Of course, both of them include many office devices of operators.

2.5. Service management layer
This layer mainly includes application server and web server. The application server is responsible for regular communication with each Internet of things gateway, and obtains the data of the perception control layer equipment through the gateway, and saves it to the database server in time, while the web server is responsible for publishing these data to the Internet for users to view the relevant information remotely through the browser. On the contrary, when a user needs to control a device remotely, the control command is written to the database server through the web server, and then the application server takes it out of the database and sends it to the corresponding IOT gateway. Finally, the IOT gateway is responsible for forwarding the command to the controlled device.

2.6. Application layer
This layer mainly includes desktop computers, portable computers, tablet computers and smart phones and other computing devices. Its main function is to provide users with a human-computer interface which can interact with the system remotely through web browser.

The overall control block diagram of the system is shown in Figure 1.

![Figure 1. Overall control block diagram of the system.](image1)

3. System hardware access design
This paper studies the logical construction of various sensors connected to control the air conditioning controller. The selected devices are all devices supporting Modbus RTU protocol. The connection relationship of all devices is shown in Figure 2.

![Figure 2. System hardware access diagram](image2)

I will briefly introduce the hardware devices below.
- Air conditioning controller
  Rs-ktc-n01 is a universal air conditioner thermostat with MODBUS interface. With the learning function, it can learn the control code of the air conditioner remote controller, so as to control the air
conditioner instead of the remote controller. With temperature and humidity collection function, it can display indoor temperature and humidity. Its power supply is DC24 V, baud rate is 9600 bit/s, parity bit is none, stop bit is 1. Set the corresponding MODBUS address to communicate with Jace.

- **Human body infrared sensor**
  Rs-hw-n01 is a passive infrared detector with high stability. Using advanced signal analysis and processing technology, it has ultra-high detection and anti false alarm performance. When the detector has a high detection rate of 9600 bit in the detection area, it will automatically stop detecting the intruder when the detection area is within the range of 9600 bit.

- **Jace controller**
  The biggest characteristic of jace8000 control engine is its high compatibility and openness. It is based on HTML5 web interface, its chart and data visualization, and universal design language. All these make jace8000 have stronger security and superior equipment management ability. The data measured by temperature sensor and infrared sensor of human body are transmitted to Jace controller through Modbus protocol. The corresponding proxy point is established in Niagara software to establish connection with these data, and the logic is built.

4. System software design
Using Niagara development platform for logic programming and software development, the control process can be real-time monitoring, with alarm, historical curve, real-time curve and other common monitoring functions. Meet the process control logic requirements. For example, in the air conditioning refrigeration mode, when there is someone in the room and the temperature reaches the upper limit of the air conditioning setting value, the air conditioning will be turned on. When there is no one in the room or the temperature reaches the lower limit of the set value, the air conditioner will be turned off. In this process, a fuzzy algorithm controller is designed, which can adjust the temperature of air conditioning according to the actual indoor temperature, so that the indoor temperature can be maintained to a comfortable temperature range as soon as possible.

4.1. Design of fuzzy algorithm controller
The fuzzy algorithm controller designed in this paper can adjust the temperature of air conditioner intelligently according to different room temperature, so that the indoor temperature can be maintained in a comfortable temperature range[6]. The fuzzy control system designed in this paper has two inputs, one is the unbalance degree R (t) between the room temperature and the starting set value of the air conditioner, and the other is the refrigeration command strength D (t).

\[
R(t) = \frac{T(t-1)-T_{max}+T_{min}}{T_{max}-T_{min}}/2
\]

(1)

Where \( R \in [-1,1] \), the value of \( R(t) \) should be determined according to the temperature \( T(t-1) \) of the previous time. The closer \( R \) is to 1, the higher the temperature is, the stronger the refrigeration capacity of the air conditioner is. The closer \( R \) is to -1, the lower the temperature is, the stronger the heating capacity is and the weaker the refrigeration capacity is. \( R \) tends to 0, which means that the room temperature is near the refrigeration set value of the air conditioner. At this time, the charging capacity and discharge capacity of the energy storage system are very strong.

\[
D(t) = \frac{T_{order(t)}}{T_{set}}
\]

(2)

Where \( T_{order(t)} \) represents the output command received by the air conditioning system at time t. When \( T_{order(t)} \) is positive, it means heating instruction, when \( T_{order(t)} \) is negative, it is refrigeration command. \( D \in [-1,1] \), when \( D \) is equal to 1, it means that the air conditioning system receives the command of heating at the set temperature; when \( D \) is equal to -1, it means that the air conditioning system receives the command to cool at the set temperature.

The fuzzy sets of input R (t) and D (t) are defined as \{Nb, BS, Ze, PS, Pb\}, and the universe of discourse is \([-1,1]\). The membership function is shown in Figure 3. And the output is selected as fuzzy
set \( \{ \text{vs, s, MS, Zo, MB, B, VB} \} \); the universe is \([-1,1]\), and its membership function is shown in Figure 4.

The output of fuzzy controller is the correction coefficient \( K(t) \) of energy storage output, which corrects the air conditioning temperature to the following formula.

\[
T(t) = T_{order}(t) + K(t)T_{set}
\]  \hspace{1cm} (3)

Where \( T(t) \) is the corrected actual temperature of the air conditioner; \( T(t) \) is the actual temperature of the air conditioner after correction \( T_{set} \) is the default value of air conditioning setting. The universe of the output correction coefficient \( K(t) \) is set as \([-1,1]\), that is, the maximum power correction value cannot exceed the maximum value of charge discharge power.

The specific regulation instructions are shown in Table 1, and the output value diagram of its correction coefficient is shown in Figure 5.

| R(t) | D(t) |
|------|------|
| NB   | NB   |
| VB   | NS   |
| B    | ZE   |
| B    | PS   |
| ZO   | PB   |
| ZO   | ZE   |
| ZO   | PS   |
| MS   | PB   |
| VS   | ZO   |
| S    | ZO   |
| S    | ZO   |

Figure 3. Input membership function

Figure 4. Output membership function

Table 1. Fuzzy control rules table
4.2. Logical design of software
In order to realize the logic control function, the overall control flow is designed, as shown in Figure 6. After the system is running, the system will default to refrigeration mode. The air conditioner sets a temperature value $T_{\text{set}}$, such as 26 °C. When there are people in the room and the room temperature is higher than $T_{\text{set}}$, the air conditioner will be turned on. Then, according to the actual value of room temperature collected by the temperature sensor, the temperature of air conditioning refrigeration is automatically controlled by fuzzy control algorithm. For example: when the indoor temperature is higher than 30 °C, the air conditioner will refrigerate at a lower temperature (such as 20 °C). When the room temperature gradually decreases, the cooling intensity of the air conditioner will gradually weaken, and the final room temperature will maintain around 26 °C.
In order to achieve the above functions, it is necessary to connect the sensor to the Jace controller to collect the sensor data. Then, in Niagara4 platform, different types of data points are established to connect with the actual data of sensors, and the control logic is built in wisheet view. The data points of air conditioner controller are shown in Figure 7. The control logic of air conditioning control system is shown in Figure 8.
4.3. Implementation of control page

In order to monitor and control the operation of the air conditioner in real time, the air conditioning control system interface is designed, as shown in Figure 9.

![Air conditioning control page](image)

Figure 9. Air conditioning control page

The interface can clearly see the indoor temperature value, humidity value, air quality level, air conditioning operation status, air conditioning control calendar schedule, air conditioning opening history curve records, etc. Air conditioning has manual mode and intelligent mode. When in the intelligent mode, the air conditioning control system will carry out the control logic for intelligent control according to the human body infrared sensor value, calendar control table, room temperature value and air conditioning temperature setting value, and the air conditioning temperature setting value can also be modified. By viewing the history of the air conditioning on, you can see that the air conditioning can be controlled manually or intelligently, as shown in Figure 10.

![Opening history of air conditioning in some time periods](image)

Figure 10. Opening history of air conditioning in some time periods
5. Conclusion

This system is based on Niagara of Tridium company Development platform for design and development, this unified, open platform with rich functions can simplify the development process and reduce the development cost. The platform is based on visual graphic programming, with simple program development, powerful function, beautiful interface, strong compatibility with field equipment and high industrial control network integration, which greatly improves the reliability and intelligence of each part of the system. In the development process, a set of air conditioning intelligent control system is integrated through equipment hard wire connection, logic design, interface design and data communication. The hardware part adopts standardized and modular structure, which has the characteristics of flexible system layout and can realize system integration and application. The software part uses graphical programming environment to realize logic programming and interface design easily, which improves the efficiency of system development. The experimental results show that the air-conditioning control system is reliable, and can control the air-conditioning temperature intelligently by fuzzy control algorithm according to the indoor temperature and whether there is anyone in the air-conditioning control system.

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