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Research of High Precision Humidity Fuzzy Control Algorithm of One Kind Humidity Verification Device

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Abstract. Aiming at different accuracy requirements of humidity in a variety of environment, a fuzzy control algorithm is applied to design a humidity fuzzy control system. Based on the quantification of humidity, a membership function, fuzzy rules and a rule table are established. The experimental results show that this method has high control accuracy, small overshoot and good stability, and achieves high-precision intelligent control of humidity.

Key words. high precision, humidity, fuzzy control, intelligence.

1. Introduction

At present, humidity control has been widely used in various fields such as agricultural production, industrial manufacturing, and daily life in China. The temperature and humidity test is an experiment that evaluates the performance of a product placed in an artificially set specific environment[1]. Chen Shucheng proposed that vegetables in the agricultural greenhouse growth process, its output and quality directly affected by temperature, humidity and other parameters, the design completed a temperature and humidity fuzzy control system, and make the actual observation[2] of the temperature and humidity control effect. Li Shuangxiu proposed that although the living standards of the people are significantly improved, the understanding of air quality and the degree of understanding of pollutants purging have lagged far behind of western countries. Through the use of fuzzy mathematics and grey theory to evaluate air quality, a focused study of air purification methods has been conducted[3]. He Wenbo et al. proposed that some warehouses are located in a complex environment, with high temperature and high humidity, large variations in temperature difference between day and night, and difficulty in control of temperature and humidity. An adaptive fuzzy PID controller that can adjust parameters online is designed to have higher control accuracy and stronger ability to adapt to the changes in the environment[4]. Ruilan Wang proposed to control the hatching system through fuzzy control algorithm. This algorithm can improve the robustness of control algorithm and self-adaptive ability[5]. J.Y. Zheng obtained experimentally that DBHCBM can control the humidity performance better, and the porosity is smaller, providing the experimental basis for the preparation of high-performance humidity control materials[6]. Xiao Min Shan applied fuzzy inference to the greenhouse environmental control system and established a fuzzy PID system with temperature and humidity as control variables. Through simulation, the PID system has a fast response speed and strong anti-interference ability[7]. Liu Jinhua et al proposed to adopt the fuzzy control algorithm to solve the requirements of temperature and humidity control of the equipment warehouse. Effectively solves the adverse effects of strong coupling and large time delay on the control process and improves



the control accuracy of the system[8].

Therefore, research and development of highly intelligent humidity control systems with superior performance, reliable operation, and low cost are hot topics of our research[9]. Because the humidity control system is a non-linear, strong coupling, multi-interference, time-delay system, the relationship during the production process is complex, and it is difficult to control the humidity. It is difficult to establish an accurate data model and control it. In recent years, the fuzzy control algorithm has the characteristics of higher control precision because it does not need to know the exact mathematical model of the controlled object. Therefore, the fuzzy control algorithm has been widely researched and used in dealing with the problems of nonlinearity and model uncertainty in complex systems. Based on this, this article has carried on the thorough research to the humidity control algorithm, has designed a set of humidity fuzzy control system, has completed the application of the fuzzy control algorithm, has carried on the actual observation to the humidity control effect. The feasibility of high precision humidity fuzzy control algorithm is verified. The algorithm has fast response speed, rapid and stable control process, small overshoot, high control precision, and satisfies control error of $\pm 1\%$ RH, which has a good application prospect.

2. Fuzzy control

Fuzzy control is a kind of intelligent control method that uses the knowledge of fuzzy mathematics to imitate the way of thinking of the human brain, recognizes and judges the fuzzy phenomenon, gives precise control quantity, and controls the controlled object [10].

2.1 Determining the Fuzzy Control System

The temperature and humidity sensors are mainly used to measure the air humidity. The fuzzy controller determines the working position within a certain period of time based on the data of the air humidity. The fuzzy control flow is shown in Figure 1

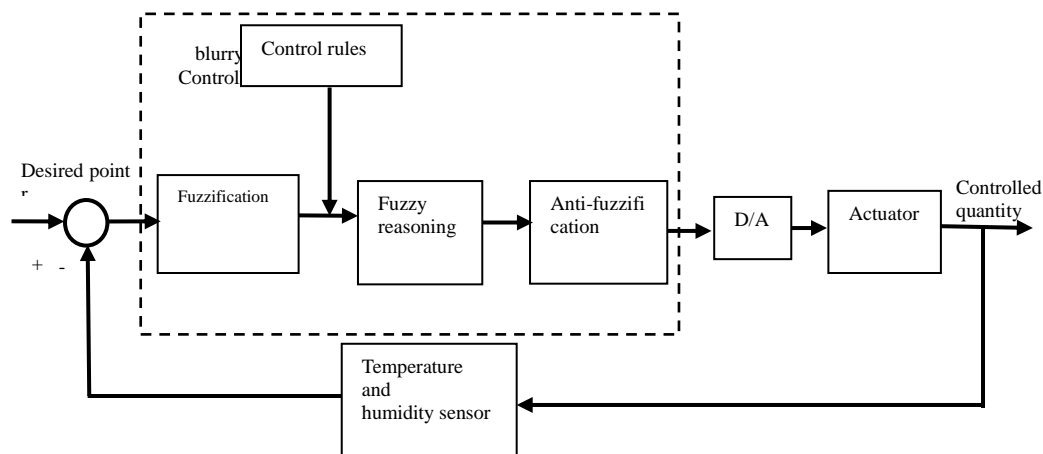


Figure 1 Fuzzy control chart

2.2 Input variables and output variables of the fuzzy controller

Under the condition of changing humidity t_0 , the stable humidity is measured as $t(K)$, then the error $e(K) = t_0 - t(K)$ is taken as the input variable of the fuzzy control.

The output variable is the control voltage K , which can be achieved by changing the thyristor conduction angle or PWM ratio.

2.3 Fuzzy Language Description of Input Variables and Output Variables

Let the fuzzy subset of the language value describing the input and output variables be: {negatively large, negatively small, 0, positivesmall, positive large} or denoted as {NB, NS, 0, PS, PB}

Let the domain of error e be X , and divide the error size into seven levels: -3, -2, -1, 0, 1, 2, 3, then

there are: $X = \{-3, -2, -1, 0, 1, 2, 3\}$

The controversy of the control variable λ is Y , and it is also divided into seven levels: $-3, -2, -1, 0, 1, 2, 3$, then: $Y = \{-3, -2, -1, 0, 1, 2, 3\}$

Define its membership function as shown in Figure 2.

This gives the fuzzy variable assignment Table 1:

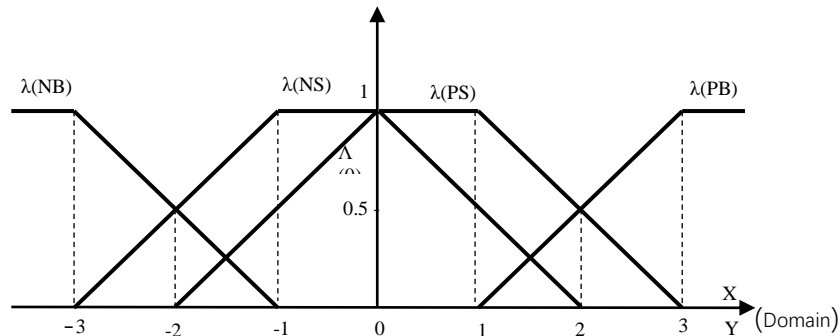


Figure 2 Membership function graph

Table 1 Fuzzy variable assignment tab

| Membership | -3 | -2 | -1 | 0 | 1 | 2 | 3 |
|------------|----|-----|-----|---|-----|-----|---|
| PB | 0 | 0 | 0 | 0 | 0 | 0.5 | 1 |
| PS | 0 | 0 | 0 | 0 | 1 | 0.5 | 0 |
| O | 0 | 0 | 0.5 | 1 | 0.5 | 0 | 0 |
| NS | 0 | 0.5 | 1 | 0 | 0 | 0 | 0 |
| NB | 1 | 0.5 | 0 | 0 | 0 | 0 | 0 |

2.4 Language Description of Fuzzy Control Rules

According to the strategy rules:

- (1) If e is negatively large, then λ is positive large;
- (2) If e is negatively small, then λ is positive small;
- (3) If e is zero, then λ is zero;
- (4) If e is positive small, then λ is negatively small;
- (5) If e is positive large, λ is negative large;

This results in the control rule table 2:

Table 2 The table of fuzzy rules

| e | λ |
|-----|-----------|
| NB | PB |
| NS | PS |
| 0 | 0 |
| PS | NS |
| PB | NB |

2.5 Matrix Forms of Fuzzy Control Rules

The fuzzy control rule is actually based on the fuzzy relation R between the error domain X and the control quantity domain Y , which yields formula (1):

$$R = (NB_e \times PB_\lambda) + (NS_e \times PS_\lambda) + (O_e \times O_\lambda) + (PS_e \times NS_\lambda) + (PB_e \times NB_\lambda) \quad (1)$$

From the fuzzy assignment table, equations (2) and (3) can be obtained.

$$NB_e \times PB_\lambda = (1, 0.5, 0, 0, 0, 0, 0) \times (0, 0, 0, 0, 0.5, 1) \quad (2)$$

$$= \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0.5 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0.5 & 0.5 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \quad (3)$$

Similarly, we can get the formula (4)

$$NS_e \times PS_\lambda \quad O_e \times O_\lambda \quad PS_e \times NS_\lambda \quad PB_e \times NB_\lambda \quad (4)$$

Put these into the summation formula, then there is formula (5):

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0.5 & 1 \\ 0 & 0 & 0 & 0 & 0.5 & 0.5 & 0.5 \\ 0 & 0 & 0.5 & 0.5 & 1 & 0.5 & 0 \\ 0 & 0 & 0.5 & 1 & 0.5 & 0 & 0 \\ 0 & 0.5 & 1 & 0.5 & 0.5 & 0 & 0 \\ 0.5 & 0.5 & 0.5 & 0 & 0 & 0 & 0 \\ 1 & 0.5 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \quad (5)$$

2.6 Fuzzy Decision

When the fuzzy input is $e(K)$, corresponding to its output, we get the formula (6)

$$\lambda(K) = e(K) \circ R \quad (6)$$

For example, when $e(k) = PS$, $\lambda(K) = e(K) \circ R = (0.5 \ 0.5 \ 1 \ 0.5 \ 0.5 \ 0 \ 0)$

2.7 Anti-fuzzification

Anti-fuzzification [11] is to transform the fuzzy control quantity obtained by fuzzy inference into a certain control quantity, so that the output can control actual physical things. The specific process of the anti-fuzzification of this system: First, the quantification level is obtained by quantifying the humidity error or its error change rate, and the corresponding control rules in the control rule table are queried according to the quantification level. Then execute the mechanism by calculating the output value of each actuator. Based on this idea, a fuzzy control query table for each implementing agency can be established, and a corresponding program can be written to realize the control of the fuzzy controller to the executing agency.

Table 3 Fuzzy Control Table

| e | λ |
|-----|-----------|
| -3 | 3 |
| -2 | 2 |
| -1 | 1 |
| 0 | 0 |
| 1 | -1 |
| 2 | -2 |
| 3 | -3 |

2.8 Fuzzy Output Becomes Accurate Value

This algorithm uses the average method to obtain formula (7):

$$\lambda = \frac{1}{7} [Rn1 * (-3) + Rn2 * (-2) + Rn3 * (-1) + Rn4 * (0) + Rn5 * (1) + Rn6 * (2) + Rn7 * (3)] \quad (7)$$

2.9 Fuzzy Control Table

The above result can be used for actual control, but in order to increase the control speed, various situations are generally calculated in advance and stored in a table to form a fuzzy control table 3. The input and output values can be defined by themselves.

Definition ϵ : -3=-5%RH; -2=-2%RH; -1=-1%RH; 0=0%RH; 1=1%RH; 2=2%RH; 3=5%RH.

Definition λ : 3=100%W; 2=50%W; 1=10%W; 0=0%W; -1=10%W; -2=50%W; -3=100%W.

If the negative deviation of the relative humidity is set larger, the power output of the humidifier is larger; if the negative deviation of the relative humidity is smaller, the output of the humidification power is smaller; if the relative humidity deviation is set to zero, the power output of the device is zero; If the relative humidity has a small positive deviation, the power output of the drying device is small; if the relative humidity has a large positive deviation, the drying device has a large power output.

3. Experimental

3.1 Experimental device

The experimental device uses a humidity test box. The test box is used to test the hair hygrometer (meter) and other types of humidity sensors. As shown in Figure 3. It is mainly composed of a box body and a measurement and control system. The verification box used humidity standard which adopts the JBB1 type digital standard dry-wet meter. The humidity within the humidity verification box can be automatically adjusted, controlled, data processing of humidity verification and results printing through the communication interface and the measurement and control system. The hardware of the automatic control part is 32-chip STM32F103VET6. The control algorithm is the fuzzy control algorithm designed in this paper.



Figure 3 Humidity verification device

3.2 Experimental Design

The design and debugging of the high-precision humidity control system is completed and the experiment and verification of the humidity control algorithm are completed on the system. The experimental environment was a $0.5 \times 0.5 \times 0.5$ (m^3) closed space, and the ambient air humidity was 15% RH.

Experiments were conducted on the target humidity of high humidity stability test (75% RH), medium humidity stability test (50% RH), and low humidity stability test (30% RH). Designing experimental schemes respectively to verify the effectiveness of the algorithm and collect and record humidity changes as a basis for data analysis.

Experimental software design and debugging, including fuzzy controller design, data acquisition and control system, and communication control, realize high-precision and constant control of environmental humidity.

3.2.1 Full Scale Experiment. Through experiments, the humidity adjustment range of the experimental device was obtained. Humidification: The humidity of the experimental device was reduced to a minimum (13%Rh), and then the humidity was increased to a maximum value (88%Rh). The collected data was as shown in Figure 4. After about 340S, the humidity of the enclosure reaches a steady state.

Dehumidification: The humidity of the experimental device was increased to a maximum (88% Rh), and then the humidity was reduced to a minimum (13%Rh). The collected data was as shown in Figure 5. After approximately 780S, the humidity of the enclosure reaches a steady state.

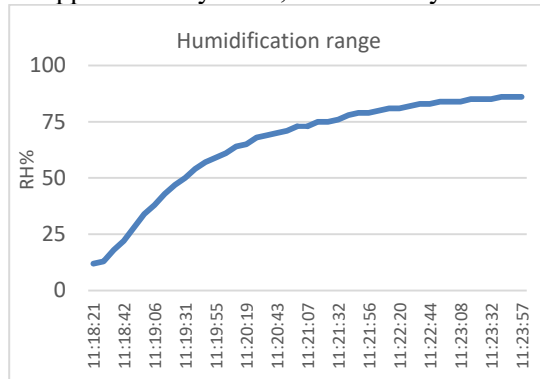


Figure 4 Humidification range under the control of the algorithm

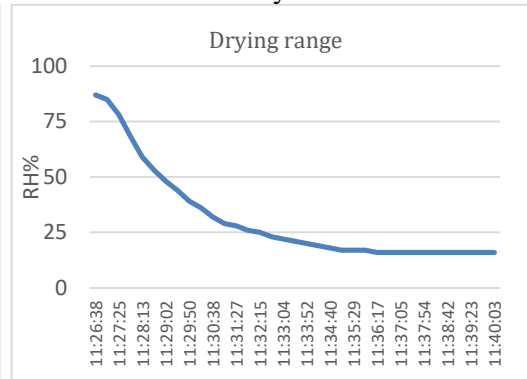


Figure 5 Drying range under the control of the algorithm

3.2.2 The target humidity is a high humidity stability test. Dry environment humidification: The initial humidity is 25% Rh, and the target humidity is 75% Rh. The collected data is as shown in Figure 6. After about 150S, the humidity of the enclosure reaches a steady state, and the maximum humidity is %Rh within 10 minutes of the experiment. The minimum value is 74%Rh, and the error is $\pm 1\%$ Rh, meeting the precision control requirements.

High-humidity environment dehumidification: The initial humidity is 85%Rh, the target humidity is 75%Rh. The collected data is shown in Figure 7. After about 20S, the humidity of the enclosure reaches a steady state. Within 10 minutes of the experiment, the maximum humidity is 76%Rh, the minimum value is 73%Rh, but only once, it is accidental data, the entire process meets the error of $\pm 1\%$ Rh, to meet the precision control requirements.

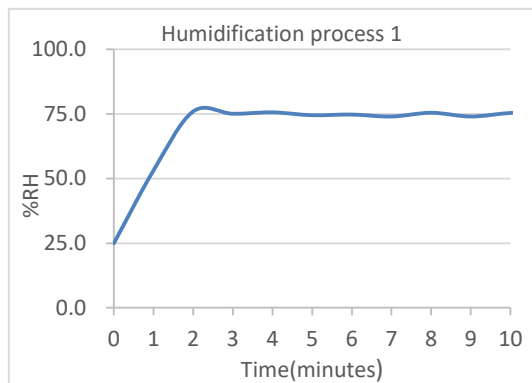


Figure 6High Humidity Stability Experimental Humidification Process

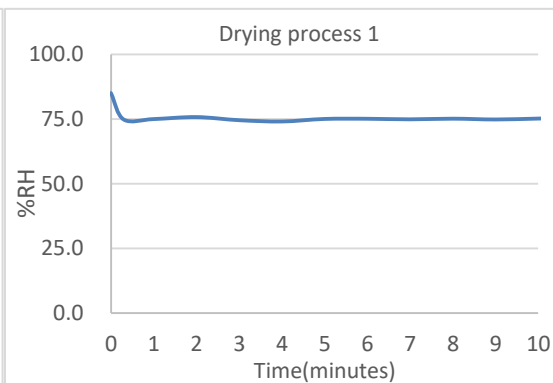


Figure 7High Humidity Stability Experimental Drying Process

3.2.3 The target humidity is the medium humidity stability experiment. Dry environment humidification: the initial humidity is 25% Rh, the target humidity is 50% Rh, and the collected data is shown in Figure 8. After about 100S, the humidity in the cabinet reaches a steady state, and the maximum humidity is 51%Rh in 10 minutes in the experiment. The minimum value is 49%Rh, the error is $\pm 1\%$ Rh, meet the precision control requirements.

High-humidity environment dehumidification: The initial humidity is 85% Rh, and the target humidity is 50% Rh. The collected data is shown in Figure 9. After 90S or so, the humidity of the cabinet reaches a steady state. Within 10 minutes of the experiment, the maximum humidity is 51%Rh, the minimum value is 49%Rh, the maximum error is $\pm 1\%$ Rh, to meet the precision control

requirements.

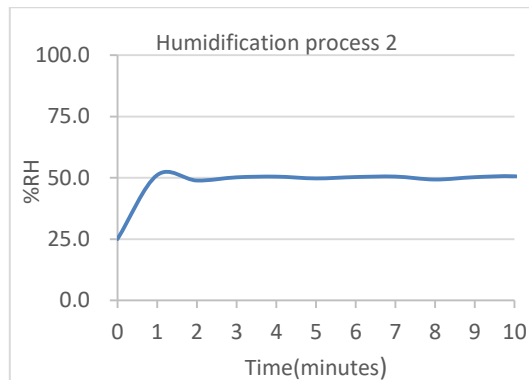


Figure 8 Middle Humidity Stability
Experimental Humidification Process

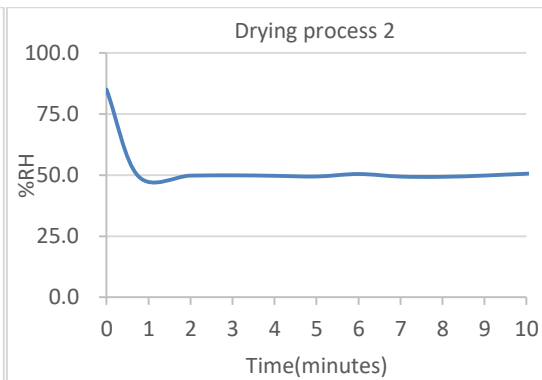


Figure 9 Middle Humidity Stability
Experimental Drying Process

3.2.4 The target humidity is a low humidity stability experiment. Dry environment humidification: The initial humidity is 15% Rh, and the target humidity is 30% Rh. The collected data is as shown in Figure 10. After about 60S, the humidity of the enclosure reaches a steady state, and the maximum value of humidity is 31%Rh within 10 minutes in the experiment. The minimum value is 29%Rh, and the error is $\pm 1\%$ Rh, meeting the precision control requirements.

High-humidity environment dehumidification: The initial humidity is 50% Rh, and the target humidity is 30% Rh. The collected data is as shown in Figure 11. After about 50S, the humidity of the cabinet reaches a steady state. Within 10 minutes of the experiment, the maximum humidity is 31%Rh, the minimum value is 29%Rh, the maximum error is $\pm 1\%$ Rh, which meets the precision control requirements.

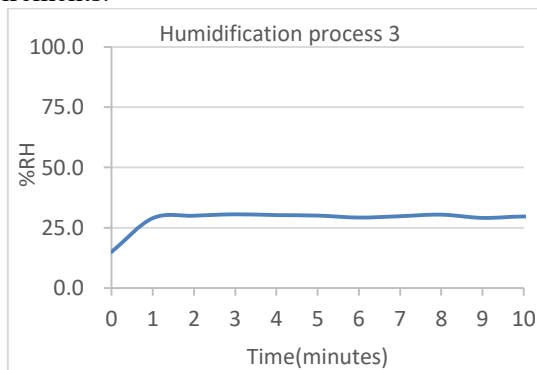


Figure 10 Low Humidity Stability Experimental
Humidification Process

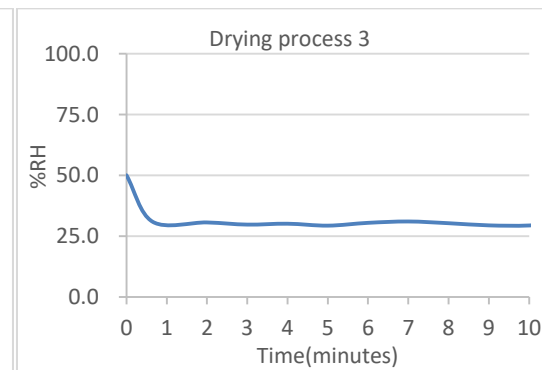


Figure 11 Low Humidity Stability Experimental
Drying Process

3.3 Experimental Analysis

The experiment takes humidity as the research object, constructs the fuzzy control algorithm, applies the fuzzy control theory, creates the fuzzy control rule, and carries on the actual observation to the humidity fuzzy control effect. The results show that the humidity adjustment range of the system is between 13Rh and 88Rh. Through the humidity control of the three application environments of high humidity, medium humidity, and low humidity, the algorithm responds quickly, and the steady state time does not exceed 180 seconds. The control process is rapid, smooth, small overshoot, high control accuracy, meet the requirements of $\pm 1\%$ RH of control error, verify the high-precision humidity fuzzy control algorithm in the three conditions of high humidity, moderate humidity and low humidity performance. The algorithm can be applied in industrial, agricultural, and civil applications, and it can achieve good humidity control and meet high-precision humidity control requirements in various environments.

4. Conclusion

This article uses a high precision humidity fuzzy control algorithm, small space accuracy can be controlled at $\pm 1\%$, with advanced domestic level. The algorithm was applied to the humidity verification box and achieved a very good control effect. Through simulation experiments in different environments, the performance of the algorithm was verified, providing an effective method for high-precision humidity control in more fields.

Acknowledgments

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