

Research on Environmental Adjustment of Cloud Ranch Based on BP Neural Network PID Control

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Abstract. In order to make the intelligent ranch management mode replace the traditional artificial one gradually, this paper proposes a pasture environment control system based on cloud server, and puts forward the PID control algorithm based on BP neural network to control temperature and humidity better in the pasture environment. First, to model the temperature and humidity (controlled object) of the pasture, we can get the transfer function. Then the traditional PID control algorithm and the PID one based on BP neural network are applied to the transfer function. The obtained step tracking curves can be seen that the PID controller based on BP neural network has obvious superiority in adjusting time and error, etc. This algorithm, calculating reasonable control parameters of the temperature and humidity to control environment, can be better used in the cloud service platform.

1. Introduction

With the development of large-scale pastures, the mode of intelligent management gradually replaced the traditional pure manual management. However, most of the ranch control systems still remain in the manual or semi-automatic operation of the management [1]. Hence, this paper intends to design an intelligent ranch environment control system based on cloud server, and regards the control of animal husbandry environmental factors as a research focus. As we all know, the animal husbandry environment is a multivariable, non-linear, large lag and multi-coupled dynamic system, and it is difficult to carry out a fixed analysis, which leads that the temperature and humidity control is hard to adapt. The use of traditional control method is difficult to meet the high performance requirements when the control object parameters change. But taking the neural network for PID control, it can be a good way to overcome the negative effect when the system parameters are changed [2].

2. Environment Control System for Pasture based on cloud server

In the pasture scale, the temperature and humidity are often the main factors affecting the environment. Control equipment can be summarized as cooling, heating, humidification, ventilation via the analysis of these effects, in which the fan, curtain and warm can adjust the temperature and humidity [3]. According to above, this paper designs a ranch environment control system based on cloud server, which is shown in Figure 1.

The system intends to use DHT11 digital temperature and humidity sensor, installed in the animal husbandry to ensure accurate collection of temperature and humidity. What is more, the collected data



through the main control board, is sent to the cloud server in the help of the wifi wireless network. In the server, a large number of data is analyzed. After calculating, the server issued more reasonable environmental control factors to another main control board, which acts as the center of the control module to control the curtain, fan, floor heating and other devices.

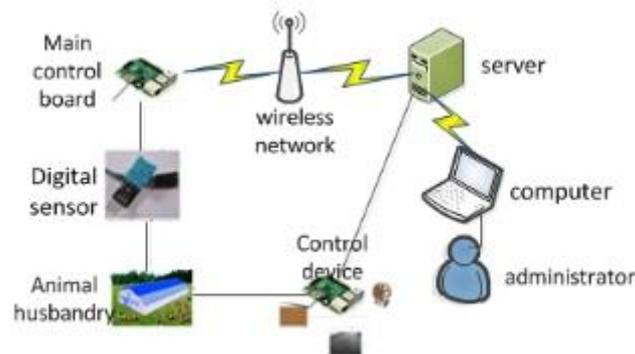


Figure 1 Ranch environment control structure based on the cloud server

3. PID Controller Based on BP Neural Network

3.1. Mechanism of action

Since the traditional PID parameters are difficult to choose, it is hard to control the complex systems. The emergence of neural networks, to a certain extent, deals with the problem of PID parameters. BP neural network has a large-scale parallel processing power, and it can approximate any continuous and complex nonlinear function with arbitrary precision^[4]. The neural network learns to adjust automatically the three parameters of PID via neural learning algorithm, then the PID controller acts on the controlled object. Next, the controlled object returns the error, and the neural network constantly adjusts the weight of each layer. Adjusting over and over again until the error is minimal.

3.2. PID Control Algorithm Based on BP Neural Network

Suppose that the BP neural network is a three-layer with M input nodes, Q hidden nodes, and three output nodes corresponding to the three adjustable parameters of the controller k_p, k_i, k_d .

Assume that the input of the input layer is recorded as $\{x_k, x_{k-1}, x_{k-2}, \dots, x_{k-M+1}\}$, the output of each input layer node is

$$\left\{ \begin{array}{l} O_j^{(1)} = x_{k-j} = e(k-j), j = 0, 1, 2, \dots, M-1 \\ O_M^{(1)} \equiv 1 \end{array} \right\} \quad (1)$$

Where $O_j^{(1)}$ is the output of the j th node of the input layer.

$$\left\{ \begin{array}{l} net_i^{(2)}(k) = \sum_{j=0}^M w_{ij}^{(2)} O_j^{(1)}(k) \\ O_i^{(2)}(k) = f[net_i^{(2)}(k)], i = 0, 1, \dots, Q-1 \\ O_Q^{(2)}(k) \equiv 1 \end{array} \right\} \quad (2)$$

Where $net_i^{(2)}$ is the input of the i -th node in hidden layer, $O_i^{(2)}$ is output, $w_{ij}^{(2)}$ is weight in hidden layer, $w_{iM}^{(2)}$ is threshold and $f[\mathbf{x}] = \tan(\mathbf{x})$ is excitation function.

The input and output of the output layer of the network are

$$\left. \begin{aligned} net_l^{(3)}(k) &= \sum_{i=0}^Q w_{li}^{(3)} O_i^{(2)}(k) \\ O_l^{(3)}(k) &= g[net_l^{(3)}(k)], l = 0, 1, 2 \\ O_0^{(3)}(k) &= K_p \\ O_1^{(3)}(k) &= K_i \\ O_2^{(3)}(k) &= K_d \end{aligned} \right\} \quad (3)$$

Where $w_{ii}^{(3)}$ is weight in out layer, $w_{iQ}^{(3)}$ is threshold and $g(\mathbf{x}) = 1/2[1 + \tan(\mathbf{x})]$ is excitation function.

Correcting the network weight coefficient according to the gradient descent method ^[5], we can get the network output layer weight coefficient, and it is calculated as:

$$\left. \begin{aligned} \Delta w_{li}^{(3)}(k+1) &= \eta \delta_l^{(3)} O_i^{(2)}(k) + \alpha \Delta w_{li}^{(3)}(k) \\ \delta_l^{(3)} &= e(k+1) \operatorname{sgn}\left(\frac{\partial y(k+1)}{\partial u(k)}\right) * \frac{\partial u(k)}{\partial O_l^{(3)}(k)} g'[net_l^{(3)}(k)], l = 0, 1, 2 \end{aligned} \right\} \quad (4)$$

Similarly, the formula for the implicit layer weight is calculated as follows

$$\left. \begin{aligned} \Delta w_{ij}^{(2)}(k+1) &= \eta \delta_i^{(2)} O_j^{(1)}(k) + \alpha \Delta w_{ij}^{(2)}(k) \\ \delta_i^{(2)} &= f'[net_i^{(2)}(k)] \sum_{l=0}^2 \delta_l^{(3)} w_{li}^{(3)}(k), i = 0, 1, \dots, Q-1 \end{aligned} \right\} \quad (5)$$

Where $g'(\mathbf{x}) = g(\mathbf{x})[1 - g(\mathbf{x})]$, $f'(\mathbf{x}) = [1 - f(\mathbf{x})^2]/2$.

3.3. The steps of PID control algorithm based on BP neural network

As shown in figure 2, when using the neural network algorithm, we first choose the BP neural network structure, that is, setting the number of nodes in each layer of the neural network, initialize the weighting coefficient, and selecting the learning rate. Then the signal input is normalized to calculate the input and output of each layer of the neural network, by which we obtain the control output $u(k)$ and let it participate in the further calculation. Next, adjusting the weighting coefficient of each layer to make the second or three times or the N th study.

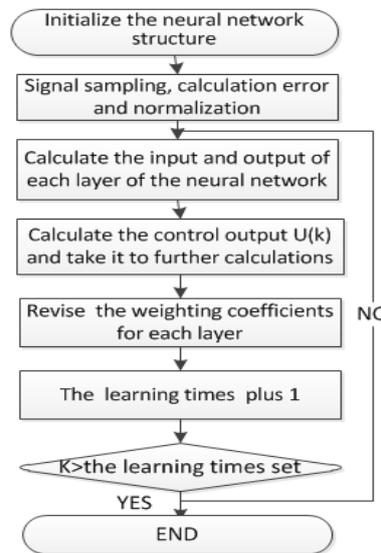


Figure 2 The steps of PID controller based on BP neural network

4. Simulation Experiment of PID Controller Based on BP Neural Network

4.1. Establish model of temperature and humidity in livestock shed

The model's assumptions are as follows:

- ① Do not consider the impact of heat radiation, heat almost comes from the warm [6];
- ② Ignore the impact of the pipeline on the air and water vapor, the rated ventilation of ventilation port does not change, and all the ventilation and humidity are the same. The rated ventilation volume is Q_{all} , the ventilation area is constant, recorded as S_2 .

According to the law of energy conservation, the amount of energy stored in the livestock shed is equal to the difference between the energy and the outflow energy flowing in the unit time:

$$C \frac{d(T_i)}{dt} = Q_i - HS_1(T_i - T_{i-1}) - nv \quad (6)$$

Where C is the specific heat capacity provided by ground, T_i is the temperature at time i , Q_i is the heat generated per unit time, H is the heat transfer coefficient, S_1 is the total area of the livestock shed, n is the number of vents, v is the vents Air volume transmission speed, and

$$v = \frac{Q_{all}}{S_2} \quad (7)$$

Considering the infinitely small change, we introduce $\Delta Q, \Delta T$. Because the number of vents, size, and ventilation is constant, then the ventilation speed unchanged. nv is the constant, whose the amount of change is ignored.

When the system heats up,

$$\begin{cases} T_i = T' + \Delta T \\ Q_i = Q_i' + \Delta Q \end{cases} \quad (8)$$

Boundary conditions in the livestock shed is both temperature and humidity reach a stable state, namely:

When

$$\frac{dT_i}{dt} = 0, \text{ then } Q_i' = HS(T' - T_0) \quad (9)$$

Combining formula (8) and (9), and brought into formula (6), we can obtain:

$$C \frac{d(T)}{dt} + H\Delta T = \Delta Q \quad (10)$$

Making:

$$C/HS_1 = T, \quad \frac{1}{HA} = K \quad (11)$$

Combining formula (10) and (11), we can get the expression of transfer function:

$$Y(t) = \frac{K}{Tt + 1} \quad (12)$$

There is also a delay in the transmission of temperature and humidity [7], which is recorded with τ . According to the characteristics of the livestock shed, we can get $K = 1.5, T = 5.6, \tau = 2$, thus, the transfer function:

$$Y(t) = \frac{1.5}{5.6t + 1} e^{-2\tau} \quad (13)$$

4.2. Simulation results and analysis

According to the above-mentioned transfer function of temperature and humidity, the traditional adjustment algorithm can be compared with the PID adjustment algorithm based on BP neural network with Matlab. The two algorithms are applied to the transfer function of the controlled object, and tracked by the step signal. In the experiment, for the PID control algorithm, the three parameters of PID are constantly adjusted artificially. For the PID control algorithm based on neural network, the BP neural network is selected as three layers, and the learning rate is 0.1, and the number of learning times is 500. The step response curves and errors of the two control algorithms are shown in Fig. 3 and Fig. 4.

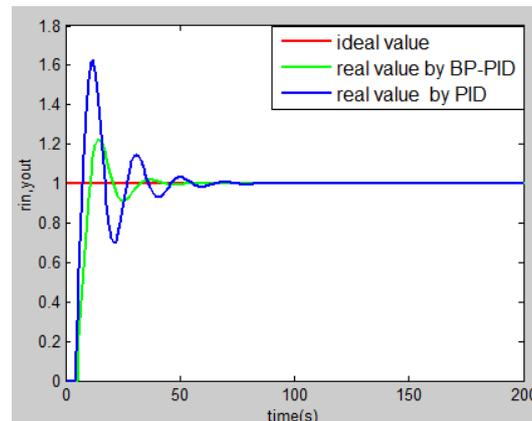


Figure 3 Step response curves for each control algorithm

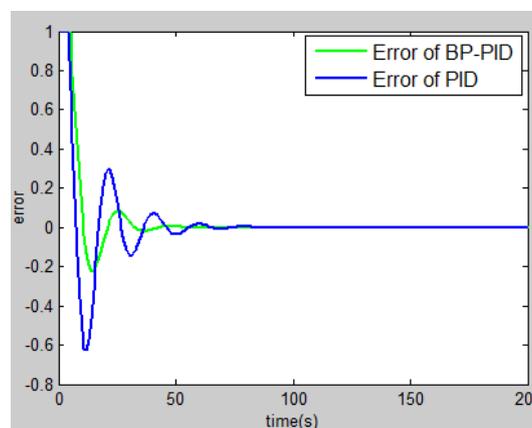


Figure 4 Error Curves of Each Control Algorithm

In Fig.3, the step response controlled by the traditional PID control algorithm changes greatly between 0 and 60 seconds, and the steady signal is recovered after about 60 seconds. The PID control algorithm based on BP neural network is through continuous learning to get the value of the three parameters of the PID. It takes about 40s to start recover steady. In figure 4, it can be seen that the PID algorithm error based on BP neural network is smaller, indicating that the transfer function of temperature and humidity controlled better. This algorithm can be used to find better PID parameters and get good applicability in real time, which improves the stability and robustness of temperature and humidity control process.

5. Conclusion

This paper proposes a cloud control system based on cloud server, and discusses how to adjust the temperature and humidity intelligently. This paper puts forward the PID control algorithm based on BP neural network. By Matlab simulation, the traditional PID regulator and the PID controller based on BP neural network separately acts on the transferred function of the controlled object. From the step tracking curves and the error, we can obtain that the PID controller based on the BP neural network can better adjust the parameters by its own learning, so as to better adjust the temperature and humidity. Using this algorithm on the cloud server can promote the progress of animal husbandry control methods.

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References

- [1] Jie Zhao, Weiyi Li. Control and improvement of the environment within the barn [J]. Shanghai Animal Husbandry and Veterinary Communication, 2012(6): 65-66.
- [2] HouseHK, Huffman.HE. A computer for designing Livestock ventilation system [J]. ASAE. 2002: 87-93.
- [3] Hao Chen, Xing Qin. Design of Intelligent Environment Control System Based on Cloud Ranch [J]. Industrial Control Computer, 2016, 29(1): 21-23.
- [4] Yuanheng Tang, Zhanyong Wang. Design and simulation of PID controller based on BP neural network, Electronic Test, 2017.8: 37-38.
- [5] Shoubing Wang. Simulation research of PID controller Based on BP neural network [J]. Electric Drive Automation, 2008(6): 22-25.
- [6] Shihai Xiao. Design of Temperature and Humidity Controller Based on ARM [D]. Hangzhou: Zhejiang University. 2017.
- [7] Chuanchuan Tu. Simulation Research on Greenhouse Environment Control System Based on BP Neural Network PID Control [D]. Jilin Agricultural University, 2012.