International Journal of Smart Home
Vol. 10, No. 7 (2016), pp. 81-90
http://dx.doi.org/10.14257/ijsh.2016.10.7.09

Research on the Rabbit House Temperature Regulation System based on the Internet of Things and Fuzzy PID

Benzhen Guo, Jingjing Yang, Zhihui Wang

School of Information Science and Engineering, Hebei North University, Zhangjiakou075000, Hebei, China
guozhen.666@163.com, r78z-yang@126.com, iowzh@126.com

Abstract

Since rabbit house is completely enclosed, then the environmental factors such as temperature, humidity, harmful gas and illumination etc will affect severely the health and the reproductive function of the rabbit. In view of this, it has been one of the important measures to improve the economic benefits of rabbit farming through the manual intervention on the micro-climate in the rabbit house. In this paper, it designs a rabbit house temperature regulation system to adjust the temperature of the rabbit house through the water curtain filtration and negative-pressure ventilation method. Also it utilizes the internet of things technology to implement remote management on the regulation system when the data about the temperature and humidity information in every rabbit house and the harmful gas concentration is uploaded to the background server via wifi connection to the network to enable the poultry feeders to make a real-time observation on the environmental information of the rabbit house in addition to the remote control of the water curtain and the running of the blower on their smart phones. Furthermore, it builds a model for the rabbit house temperature with the application of the fuzzy-PID control algorithm and the variable frequency drive technology to design a controller for the further decline in the system power consumption based on the optimal control. In addition to these, a prototype system has been established to conduct the experimental verification. The verification result proves that this system can be controlled reliably with technical feasibility.

***Keywords**: The internet of things, rabbit house, temperature regulation, fuzzy-PID*

1. Introduction

In China, the output of rabbit meat is quite huge accounting for 39% of the gross output of rabbit meat in the world [1]. However the impact of the micro-climatic environment especially the thermal environment in a rabbit house on the rabbit health and breeding is tremendous since rabbits at different days of age in different physiologic phases raise different requirements on the ambient temperature, which is 30-32℃ for the ordinary baby rabbits and 20-30℃ for the growing rabbits. If the temperature is higher than 30℃, rabbits will collapse due to the serious heat accumulation in the body. Moreover, high temperature will stop the female rabbits from breeding for a period of 2-3 months[2][3], giving rise to enormous economic loss. In addition to this, the harmful gas mainly the over concentrated ammonia in the rabbit house will increase the occurrence rate of respiratory disease and eye disease in a rabbit population.

The internet of things technology is such a network technology that has been extended and expanded based on the internet technology for the purpose to achieve an internet of everything by extending or expanding the user end to any object or between any object. The internet of things in essence is a hierarchical network. Currently it's widely recognized that the internet of things architecture consists of the following three layers, including the perception layer, the network layer and the application layer. The perception

ISSN: 1975-4094 IJSH

layer has been established to identify objects and collect information through RFID, camera, sensor and GPS *etc*. The network layer has been constructed to process and transfer all of the information acquired in the perception layer through the mobile communication system and internet *etc*. [4]The application layer is able to analyze and process all of the information acquired in the perception layer and the transmission network to make correct control and decision in addition to the implementation of intelligent management, application and service.

Now the rabbit house temperature regulation technology still lags behind. In the summer when the temperature is high, generally adopt the artificial methods such as air exhausting through fans and watering on the ground to lower the temperature. Also in the winder, raise the temperature with the burner or the electric furnace at high human cost with low intelligence level. However the adoption of the wet curtain-fan negative pressure ventilation shows the characteristics of simply devices and low management cost.[5] Meanwhile the integration of the internet of things technology enables the wet curtain-fan devices to be connected to the internet of things as the equipment of the sensing layer. Moreover, the additional construction of the temperature-humidity and ammonia concentration monitoring nodes is able to achieve a real-time monitoring on the indexes of temperature, humidity and ammonia concentration in the rabbit house. Actually the application of the internet of things technology has improved significantly the intelligence level of the rabbit house environmental regulation system. Compared with the simple switch control mode applied currently in most of the wet curtain-fan motors, variable frequency technology has been implemented in our system to realize fan drive. Also the adoption of the fuzzy-PID algorithm to control the air flow rate of the blower and the spray rate of the wet curtain is able to reduce significantly the system power consumption to improve the precision of temperature control.

2. The Overall Design of the Rabbit House Temperature Regulation System

Based on the internet of things architecture, this paper makes an overall design on the rabbit house temperature regulation system with the system overall framework diagram indicated in Figure 1. In our experiment, the roof of the rabbit house is made of color steel tile, the ceiling is constituted by plastic pinch plate and the wall is of brick-concrete structure. The rabbit house has been built with a length of 30 meters, a width of 5.5 meters and a height of 3 meters containing four rows of rabbit hutches in three layers. Adopt the wet curtain filtration and negative-pressure ventilation method to control the temperature and humidity of the rabbit house by installing 2 negative-pressure exhaust fans (1.5kW) on one side of the gable with each giving an air flow of 16500m3/h in addition to the adoption of the converter drive. On the other side of the gable, the wet curtain that is of tile stack structure has been constructed in an area of 5.5m2. Also 2 axial flow fans with the power of each at 1kW are installed on the central corridor in the rabbit house, where the temperature and humidity sensor and the ammonia concentration sensor are also available to monitor the environmental information of the rabbit house.

The following devices including the converter, the sensor and the wet curtain controller in the perception layer of the internet of things are able to communicate via the RS485 bus with the master controller, which will be connected to the internet through wifi to upload the data about temperature, humidity and ammonia concentration to the background server, where the user authorization management, the management on the devices in the perception layer, data storage and the generation of various analytical statements can be implemented. The administrative staffs in the rabbit farm can utilize smart phones or PC to log onto the server to check the real-time data and the historical statistics. Or they can send real-time command to control the running of the bottom devices including the converter and the wet curtain controller *etc*.

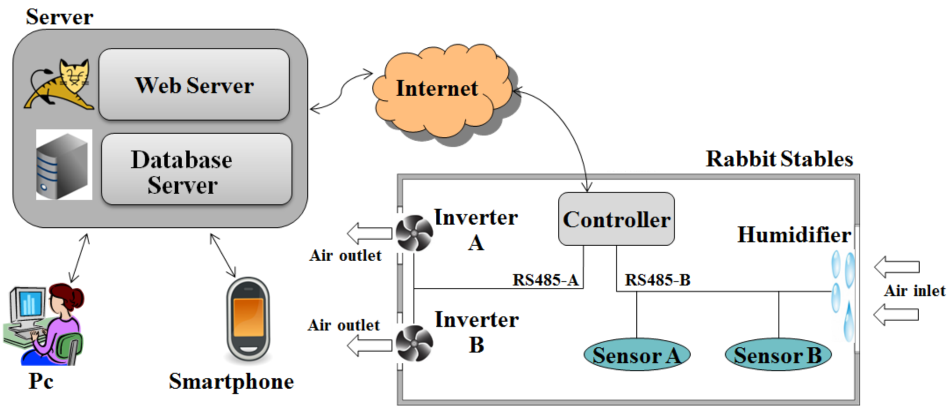

Figure 1. Architecture Diagram of the System

The background server has been built with the integration of the web server and the database server. The web server is set up according to the Apache Tomcat server technology by adopting the JSP technology to feed back any web information and using the JavaBean and Servlet technologies to make a response to the user's request and handle the transaction. Also the web server is able to get access to the SQLSEVER database in the JDBC access mode.

3. Modeling and Analysis on the Rabbit House Temperature

Nowadays there are no sufficient researches made on the temperature modeling for the rabbit house, where there are not only the physical phenomena but also the physiological phenomena in the rabbit itself. Therefore it's quite difficult to establish a comprehensive and perfect model. But in this paper, indoor temperature model that has been built according to the mature thermal equilibrium steady-state method is applied to the rabbit house to enhance the usability of the model when the thermal exchange between the rabbit body temperature and the ambient environment has been taken into account.

3.1 Temperature Model in Rabbit House Environment

It was Businger, who was the first person to propose the thermal equilibrium steady-state method in 1963. [6][7]The factors that might affect the ambient temperature of the rabbit house mainly include the rabbit house architecture, the floor, the wet curtain-fan cooling system and the temperature of the rabbit itself with the mass and energy exchange between them and the exchange with the outside world including: the long-wave thermal radiation, heat exchange with good ventilation, heat exchange with wet curtain cooling and the heat exchange between the rabbit body temperature and the environment. The analysis on the sources and the losses of different energies in the rabbit house will facilitate the establishment of a rabbit house energy (thermal) equilibrium model, which is indicated in Figure 2:

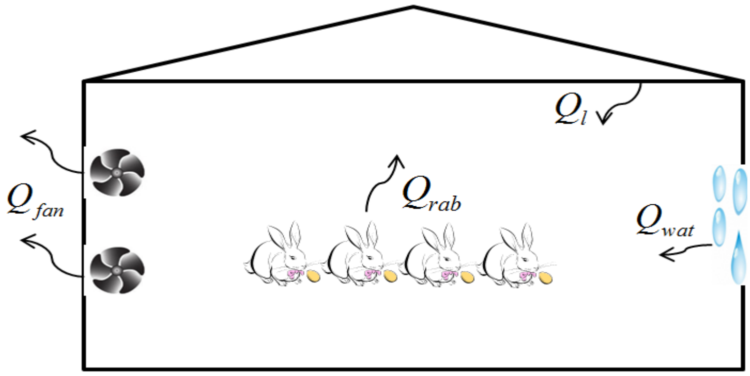

Figure 2 . Eergy (thermal) equilibrium model

Use dT/dt, the temperature variation ratio of a rabbit house to describe the energy equilibrium with the dynamic temperature model able to be established according to the thermal equilibrium steady-state method :

$$\frac{dT}{dt} v\rho C_q = Q_{fan} + Q_l + Q_{rab} + Q_{wat} \tag{1}$$

Where v is the air volume in the rabbit house, ρ is the air density (kg/m^3), C_q is the heat content of air ($Jkg^{-1}k^{-1}$), Q_{fan} is the energy of heat exchange with good ventilation, Q_l is the long-wave thermal radiant energy, Q_{rab} is the energy of heat exchange between the rabbit body temperature and the air and Q_{wat} is the energy of heat exchange with wet curtain cooling.

3.2 Model Analysis

1、Heat exchange with good ventilation, Q_{fan}

With an enclosed structure, rabbit house has been ventilated mechanically with a fan according to the fan law:

$$\phi_2 = \phi_1(n_2/n_1) \text{ , } H_2 = H_1(n_2/n_1)^2 \text{ , } P_2 = P_1(n_2/n_1)^3 \tag{2}$$

Where blast capacity is directly proportional to the rotating speed, while wind pressure and blower power are respectively in direct proportion to the

second and third power of the speed ratio. In this case, Q_{fan} the energy of heat exchange with good ventilation can be expressed as (3):

$$Q_{fan} = \rho C_q \phi \Delta T \tag{3}$$

Since blast capacity is directly proportional to the rotating speed, which however is in direct proportion to the output frequency of the converter, then the above formula can be rewritten as below when the fan is in the converter drive mode:

$$Q_{fan} = \rho C_q \theta(f/F)\Delta T \tag{4}$$

Where θ is the rated air output, 16500m3/h of the fan, f is the output frequency of the converter and F is the maximum frequency (50Hz) of the converter.

2、Long-wave thermal radiation, Q_l

In a rabbit house, there are many long-wave thermal radiations, among which the most major long-wave thermal radiations are those from the walls and the roof of the rabbit house and the sky. Q_l can be expressed as:

$$Q_l = \varepsilon_{12} A\sigma(T_t^4 - T_o^4) \quad (5)$$

Where ε_{12} is the joint emittance from the surface, σ is the Stefan-Boltzman constant, and T_t and T_o represent separately the indoor and outdoor temperature.

3、Energy of heat exchange between the rabbit body temperature and the air, Q_{rab}

Generally, the body temperature of a rabbit is higher than the indoor temperature of the rabbit house, making the heat exchange between the rabbit body temperature and the air realized through convection. According to Newton's law of cooling, the exchanged heat q can be expressed as:

$$q = h_p \Delta T \quad (6)$$

Where h_p is the heat transfer coefficient of the air, which generally is $h_p = 1.95\Delta T^{0.33}$. Because of this, Q_{rab}, the energy of heat exchange between the rabbit body temperature and the air can be expressed as:

$$Q_{rab} = 1.95 nA\Delta T^{1.33} \quad (7)$$

Where n is the number of the rabbits in a rabbit house, A is the surface area of the rabbit and ΔT the difference between the rabbit body temperature and the air temperature.

4、Energy of heat exchange with wet curtain cooling, Q_{wat}

Q_{wat}, the heat exchange with wet curtain cooling can be expressed as $Q_{wat} = \lambda\phi\rho\Delta X$, where λ is the latent heat of water evaporation Mj/kg, ϕ is the ventilation rate or the air flow of the fan, ΔX is the humidity difference before and after air flowing across the wet curtain and ρ is the air density.

4. Fuzzy-PID Control on the Environment of Rabbit House

Now it's very hard to make a steady and precise control on the temperature and humidity through the classical logic control (Bang-Bang) that is widely applied currently. With simple structure, although the PID controller shows good stability with high reliability, it's required to control the objects in a very precise way. [8]However the micro-climate in the rabbit house environment is a complex large system; therefore it becomes very hard for the model proposed in the previous chapter to make a precise control. Through the fuzzy control method, the fuzzy self-tuning of the parameters in the classical PID controller enables the controller independent from the mathematical model to show high resistance to interference with quick response rate and a strong robustness to the changes in the system parameters. [9][10]

4.1 Structure of the fuzzy-PID controller

Figure 3 is the structure diagram of the fuzzy-PID temperature controller used in the rabbit house, showing that the controller consists of a conventional PID controller and a fuzzy inference mechanism. As the input variables in the system, the temperature error e and the rate of error change ec are able to realize the fuzzy self-tuning of the control parameters such as Kp, Ki and Kd after the fuzzy inference, making the control parameters able to vary with the changes of e and ec to improve thus the dynamic and static performance of the controlled object.

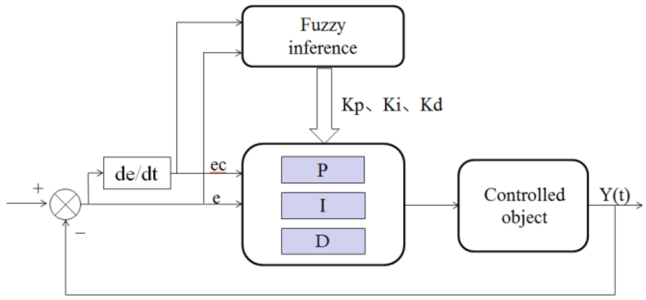

Figure 3. Structure Diagram of the Fuzzy-PID

4.2 Description of the input & output variables with fuzzy language

According to the real situation of temperature regulation in a rabbit house, this paper takes the error in temperature sensor into account, assuming that the domain of discourse for the temperature error e is [-4℃, +4℃] and the basic domain of discourse for the rate of temperature change ec is [-2℃, +2℃]. Then adjust the range according to the PID coefficients to determine the basic domain of discourse, which is [-5, +5] for ΔKp, [-0.6, +0.6] for ΔKi and [-10, +10] for ΔKd. Also quantize the temperature error e, the rate of temperature change ec and the output variables of ΔKp, ΔKi and ΔKd into totally 13 grades from -6 to +6 to get the assignment table, which is shown as below in Table 1 for various linguistic variables after the membership function of every variable is considered as the uniform trigonometric function:

Table 1. Assignment Table for Fuzzy Linguistic Variables

variables Fuzzy variables	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6
PB	0	0	0	0	0	0	0	0	0	0	0	0.5	1
PM	0	0	0	0	0	0	0	0	0	0.5	1	0.5	0
PS	0	0	0	0	0	0	0	0.5	1	0.5	0	0	0
ZO	0	0	0	0	0	0.5	1	0.5	0	0	0	0	0
NS	0	0	0	0.5	1	0.5	0	0	0	0	0	0	0
NM	0	0.5	1	0.5	0	0	0	0	0	0	0	0	0
NB	1	0.5	0	0	0	0	0	0	0	0	0	0	0

4.3 Establishment of Fuzzy Rules

The fuzzy controller will adjust continuously the control parameters of Kp, Ki and Kd according to the fuzzy relations as it's able to detect the error e and the rate of error change ec during the running of the system to make the controlled object show good dynamic and static performance. Also a rule query form that is shown in Table 2 for the fuzzy regulation of the various PID parameters such as ΔKp, ΔKi and ΔKd has been created after the following aspects such as the traditional stability, the response rate, the overshoot and the stable accuracy are taken into account.

Table 2. Fuzzy Rule Query Form

ΔKp\ΔKi\ΔKd				e			
ec	PB	PM	PS	ZO	NS	NM	NB
PB	NB\PB\PB	NB\PB\PB	NM\PB\ZO	NM\PM\ZO	NS\PS\ZO	NS\ZO\PS	ZO\ZO\PS
PM	NB\PB\PS	NM\PB\PS	NM\PM\ZO	NM\PM\NS	NS\PS\NS	ZO\ZO\NS	ZO\ZO\NM
PS	NM\PM\PS	NM\PM\PS	NS\PS\ZO	NS\PS\NS	ZO\ZO\NS	PS\NS\NM	PS\NS\NB
ZO	NM\PM\PM	NM\PS\PS	NS\PS\ZO	ZO\ZO\NS	PS\NS\NM	PS\NS\NM	PM\NM\NB
NS	NM\PS\PM	NS\PS\PS	ZO\ZO\ZO	PS\NS\NS	PM\NS\NM	PM\NM\NB	PM\NM\NB
NM	ZO\ZO\PM	ZO\ZO\NS	PS\NS\ZO	PM\NM\NS	PM\NM\NS	PB\NB\NS	PB\NB\NS
NB	ZO\ZO\PB	PS\ZO\PB	PS\NM\ZO	PM\NM\ZO	PM\NB\ZO	PB\NB\PS	PB\NB\PS

4.4. Fuzzy Solution and Control Algorithm

Adopt the minimum and maximum centroid method, which is also called as the Mamdani method to implement fuzzy inference, after which utilize the created fuzzy variables and the fuzzy control rule to determine the output control variables including ΔKp, ΔKi and ΔKd. The PID controller is able to correct continuously the parameters of Kp, Ki and Kd according to the output from the fuzzy controller until a satisfactory control effect is achieved with the control algorithm provided as below: [11][12]

$$u(kT) = Kp\{e(kT) + \frac{T}{T_i}\sum_{j=0}^{k} e(jT) + \frac{T_d}{T}[e(kT) - e(kT-T)]\} \quad (8)$$

Where Kp is the proportionality coefficient, $Ki = Kp\,\frac{T}{T_i}$, $Kd = Kp\,\frac{T_d}{T_i}$ and T is the sampling period.

5. Experimental Verification

5.1 Simulation Result

Since the measurement of the rabbit house temperature model is performed according to the real data, then the transfer function for the rabbit house temperature can be expressed as:

$$G(s) = \frac{0.65}{1810s + 1} \quad (9)$$

Utilize the Simulink tool to build a simulation model and compare the control effects obtained separately through the conventional PID and the fuzzy PID with the controlled temperature set to be 10℃. Figure 4shows the response curve through the conventional PID, indicating that the overshoot of the control system is around 2.1℃ and the regulating time is around 600 seconds. Also in Figure 5, it shows the response curve through the fuzzy PID, indicating that the overshoot is around 0.2℃ and the regulating time is around 500 seconds, proving that the fuzzy-PID control outperforms the conventional PID control from the perspective of control performance.

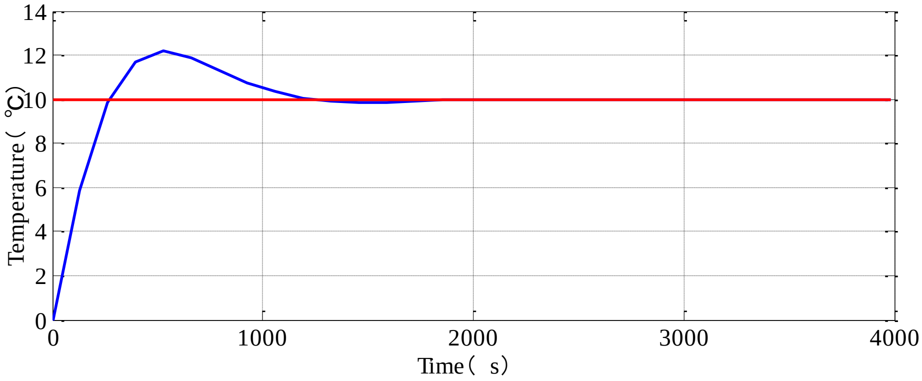

Figure 4. Response Curves based on the Conventional PID

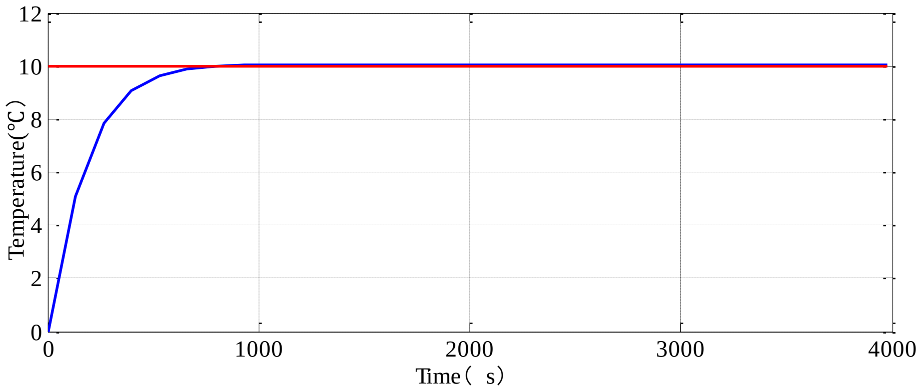

Figure 5.Response Curves based on the Fuzzy PID

It's inevitable that there's interference from the outside signal on the system, which requires that the system must give certain resistance to interference. On account of this, Exert ,-2℃step disturbance to the system when T=2000s and T=3000s. Then the response curves of the system under the conventional PID control and the fuzzy-PID control in the presence of additional interference are separately shown in Figure 6and 7

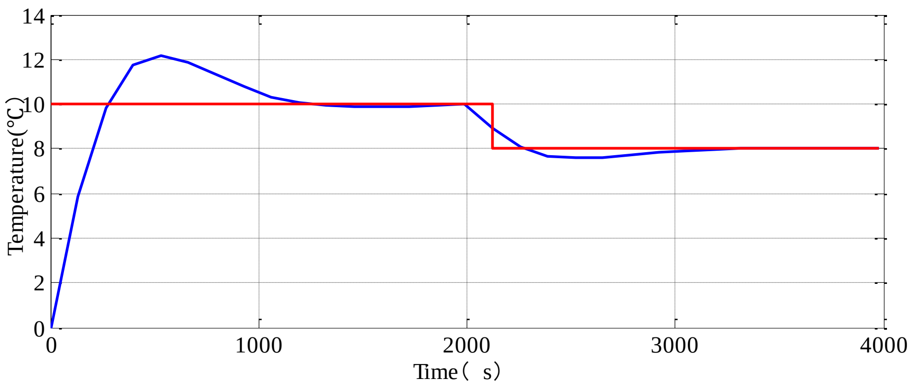

Figure 6. Conventional PID with Interference

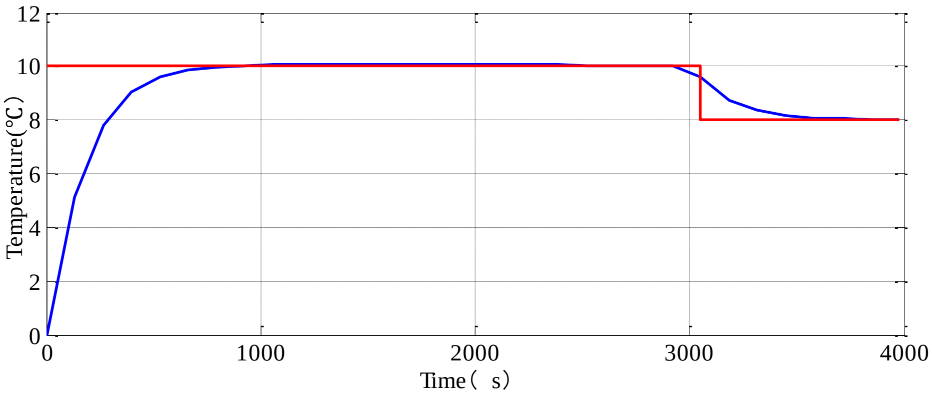

Figure 7. Fuzzy PID with Interference

5.2 Temperature Control Experiment

System simulation is performed to provide reference and guidance for the adjustment of system parameters. However system availability and accuracy steadiness must be verified in the practical experiment. Figure 8 shows the experimental result about the rabbit house temperature regulation after the application of the fuzzy-PID technology with the initial temperature set to be 30℃ and the target temperature set to be 25℃. The background server will record the measured temperature value every three minutes. The experimental result reveals that compared with the simulation, the system shows longer regulating time with less temperature overshoot and the control precision is rather stable between -0.3℃ and +0.3℃.

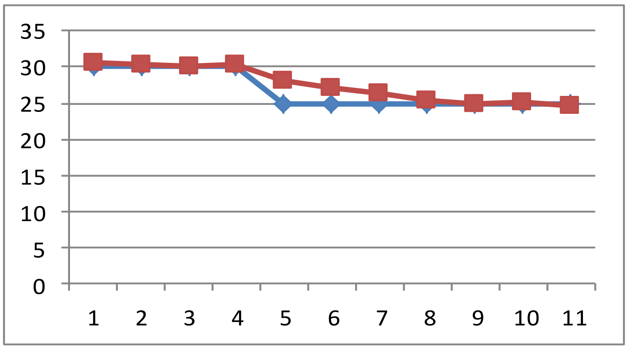

Figure 8. Experimental Result

6. Conclusions

This paper designs an internet of things-based rabbit house temperature regulation system with the application of the thermal equilibrium steady-state method to build a mathematical model for the rabbit house temperature. Also it adopts the fuzzy-PID technology to control the system and utilizes the Simulink tool to make a simulation according to the fuzzy-PID control algorithm. The simulation result shows that the fuzzy-PID algorithm outperforms the conventional PID algorithm in terms of the control effect. Also the actual data obtained in the temperature regulation test proves that there is no overshoot in the system with the precision controlled between -0.3℃ and +0.3℃.

Acknowledgements

The work of this paper was supported by the Youth Foundation of the Education Department of Hebei Province (No.QN2015225).

References

[1] Ma futuan. " Effects of seasonal and temperature on the propagation properties of New Zealand rabbits " Chinese rabbit (2008), Vol.4:6-7.

[2] Zhang guizhong. " The relationship between rabbit production and small environment " Livestock and poultry industry (2007) No. 1, 28-29

[3] Chen zanmou. " The Influence of temperature factor on the fecundity of female rabbit meat " Livestock ecology,(1994), Vol.15, No. 4:9-11.

[4] G.Mingming,S. Liangshan.The Design of Wireless Smart Home System based on ZigBee. IACSIT.proceedings of 2010 3rd International Conference onComputer and Electrical Engineering (2010).

[5] Zhao Shumei, Yaguchi Tomoharu, Zhou Qing, et al. "Study on pad and fan cooling system in modern greenhouse". Journal of Agricultural Mechanization Research, (2007), NO.9: 147-157.

[6] Boulard,T.andA.Baille. "A simple greenhouse climate control model incorporation ventilation and evaporative cooling". Agricultural and Forest Meteorology,(1993).vol(65):145- 157

[7] Takami S.A "model of the greenhouse with a storage-type heat exchanger and its Veritification".Journal of Agricultural Meteorology,(1995),76:129~148.

[8] Coelho J.P., de Moura Oliveira P.B., Boaventura J. " Greenhouse air temperature predictive control using the particle swarm optimisation algorithm". Computers and Electronics in Agriculture, (2005), Vol .49 : 330–344.

[9] Song minggang, Fan shangchun. "A Combined Method of High Precision Temperature Control". Journal of Beijing University of Aeronautics and Astronautics, (2001), vol.27, No.5: 560-563

[10] Sun xuxia ,Li Shengmin,Lin kuiming. "The applied study on the warm dummy temperature control system". Automation &Instrumentation, (2000), No.3: 27-31

[11] Karendra K S. Parthasarathy, "Identification and control of dynamical systems using neural networks". IEEE Trans on Neural Networks, (1996), Val.11,No.1: 11-27.

[12] G.J.Silva, *et al*. New Result on the synthesis of PID controllers[J].IEEE Transactions On Automatic Control, (2002), Vol.47, No.2 ,241-252

Authors

Benzhen Guo. A lecturer in the School of Information Science and Engineering, Hebei North University, China. His research interests are in the field of medical information and internet of things.

Jingjing Yang. A lecturer in the School of Information Science and Engineering, Hebei North University, China. His research interests are in the field of computer technologyand internet of things.

Zhihui Wang. A lecturer in the School of Information Science and Engineering, Hebei North University, China. His research interests are in the field of computer technologyand internet of things.

