Design of Greenhouse Monitoring System Based on ZigBee Technology

Hao Zhu-yin[1,a*], Zhang Ya[1,b], Li Feng[1,c], Chang Hai-jun[1,d]

[1]Anhui University of Science and Technology, Institute of Electrical and Information Engineering, Huainan 232001, China

[a]m18956068897@163.com , [b]zhangya625@126.com, [c]244284833@qq.com, [d]changhai1204@qq.com

Keywords: Zibee, Greenhouse, Wireless monitoring, Smith- Fuzzy control.

Abstract.According to the needs of modern agricultural automation and intelligence, a greenhouse monitoring system based on ZigBee technology is designed. Through the design of the hardware and software of each node and controller, the system realizes the monitoring and control of various environmental factors in the greenhouse by combining the ZigBee and GPRS wireless network technology. According to the actual situation of the greenhouse, a kind of Smith- fuzzy PID temperature control algorithm is designed. The simulation model was built by the Simlink module in MATLAB. The simulation results are compared with common PID and fuzzy PID control. The experimental results show that the Smith- fuzzy PID control algorithm has high accuracy and good stability, and it has strong application prospects.

1 Introduction

At present, China's greenhouse area is the largest in the world, but there is a certain distance of the technical compared with some developed countries. Greenhouse can chang the environmental factors to control the growth of vegetables, and the vegetables are not affected by the season.So, the detection and control of the environmental parameters of the greenhouse is the most important part.The development trend of modern agriculture is how to monitor the environmental factors (including temperature, humidity, CO_2 concentration, light intensity, etc.) by wireless communication technology[1]. Traditional agricultural environmental data acquisition uses the wired sensor network, and it need to lay the cable that can cause wiring complex, inconvenient maintenance and other issues.Or by the artificial collection of data, the greenhouse area is more and more large and the time consuming efficiency is not enough, and it can't meet the requirements of automation and intelligent.Therefore, the ZigBee wireless technology is used to design the greenhouse monitoring system, monitoring environmental data through a variety of sensors, transmitting data through ZigBee network, and the data will be sent to the data center by the gateway. The management personnel can monitor the environmental factors in the greenhouse in real time through the client, and also can send the information to the user mobile phone through the GPRS module.The control of the temperature in various environmental factors is the most important, in the control side, according to the actual characteristics of the greenhouse, this paper designs a Smith- fuzzy PID temperature control algorithm.This system has the characteristics of low power consumption, high reliability and strong stability, and it has strong application and popularization value[2,3,4].

2 Overall Structural Design of the System

The whole structure of greenhouse monitoring system is shown in figure 1. It mainly consists of three parts: the detection / control part, the network transmission part and the terminal control part[5]. The function of detecting and controlling part can collect the environmental data in the greenhouse (room temperature, air humidity, CO_2 concentration, etc.); the terminal control part can store the data and control the environmental factors in the greenhouse according to the data transmitted.

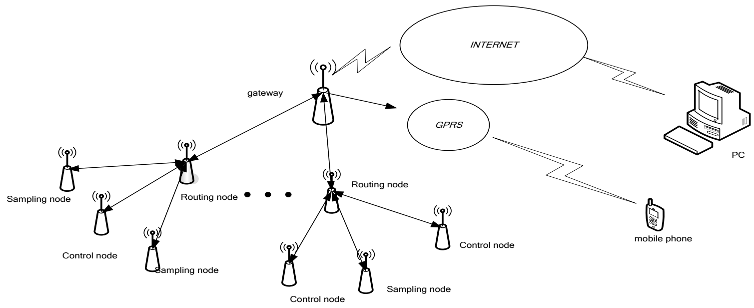


Fig. 1 Overall structure of the system

TI CC2530 ZigBee module is used by the principle of high price to test and control the system. This module has different ways of operation and short switching time, making its energy consumption is low, and the work is stable[6].Sensors are also energy consuming components, the sensor will be selected based on the service life by following options: temperature and humidity sensors choose a composite SHT11 sensor that can detect both air temperature and humidity at the same time; TSL2561 sensor can be used to convert light intensity into digital signal output; MG811 sensor is selected which is little affected by the temperature change.

3 System Hardware Design

Because the area of the greenhouse is more and more big, the ZigBee wireless network of the system uses the tree structure. The hardware design of the system includes the design of the terminal node, the routing node and the coordination node (Gateway).

3.1 Terminal Node Design. Terminal node is divided into two kinds of acquisition node and control node.The collecting node is acquisition of the environmental parameters in the greenhouse, and the control node adjust the environment parameters by collecting the data to control the actuator.The terminal node is the most advanced part of the whole system, which is composed of CC2530 microprocessor, sensor and power supply. CC2530 has a leading RF transceiver that contains an enhanced low power 8051 which has different working modes, and the mode conversion time is short can be very good to reduce power consumption. Power supply provide power, the sensor collects the environmental data and send to the CC2530, then CC2530 will send the data to the routing node after initially compressing process.Figure 2(a) is the acquisition node structure diagram, 2(b) is the control structure of the node block diagram.

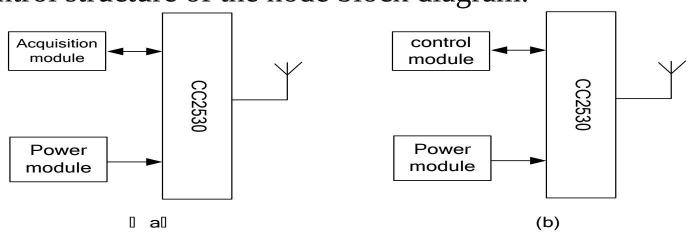


Fig. 2 Structure of the terminal node

3.2 Routing Node Design. The routing node can realize the environment detection and also has the function of routing.Because of routing nodes need more energy consumption to achieve vary function, it does not involve the detection function, which can prolong service life of the routing nodes.

3.3 Coordinate Node Design. The design of the coordination node is shown in figure 3, the 32 bit SAMSUNG microprocessor S3C2440 with ARM9 is used as the main controller.The processor has 1.8V core voltage, 3.3V I/O processor and memory voltage, integrated LCD controller, watchdog, interrupt UART SPI controller and NAND flash, nor flash,USB host and abundant peripheral resources.The WAP server is transplanted to the ARM9 processor to be responsible for the management of the entire wireless network and remote monitoring.CC2530 and S3C2440 through the UART information exchange, GPRS module through the serial port RS-232 and S3C2440 communication.SIM300 has the function of SMS text messages in English, embedded TCP/IP protocol stack, the standard RS-232 serial port, support AT instruction operation, etc..Gateway collect the data and transmit it to the data center, the user can know the real-time situation of greenhouse through the Internet access data center, when the environmental factor exceeds a set threshold, it will send text messages through the GPRS module to the administrator and alarm circuit will work[7]. Display module can display the current greenhouse environmental data. Button module can set the threshold of environmental parameters, etc.. Power supply module provides with power supply.

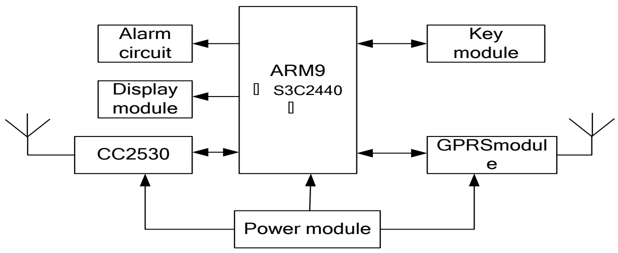
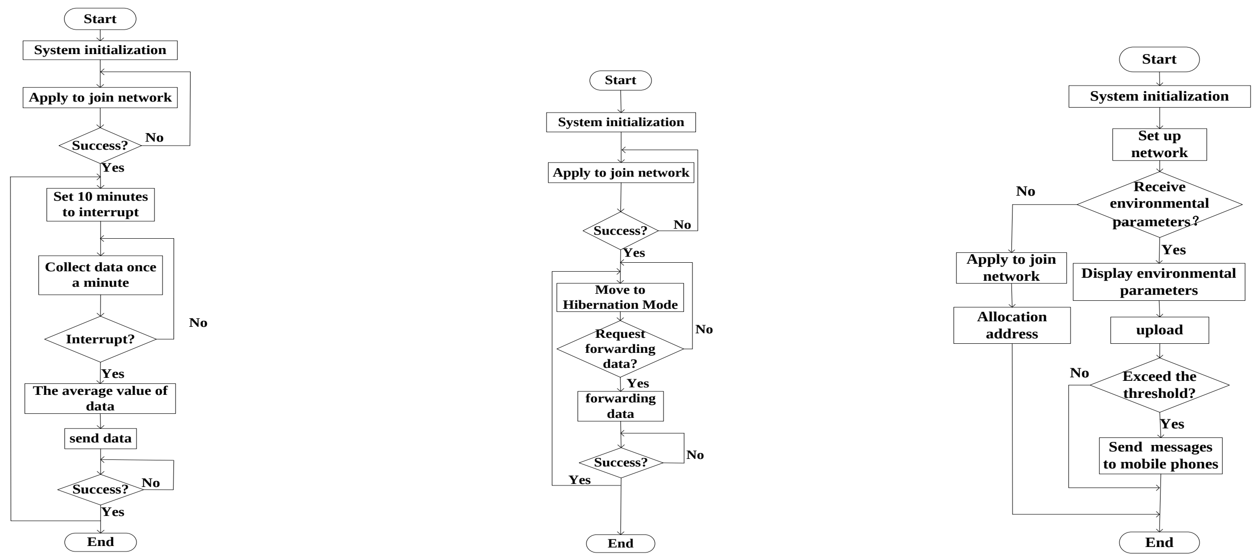


Fig. 3 Structure of the coordinate node

4 System software design

System software design is the main ZigBee wireless transmission module of the program design, due to the system uses a tree based network structure, it mainly include the terminal node, routing node and coordination node programming. The terminal node’s flow chart is shown in figure 4(a); the routing node’s flow chart is shown in figure 4(b); the coordinate’s flow chart is shown in figure 4(c).



(a) Flow chart of the terminal node (b) Flow chart of the routing node (c)Flow chart of the coordinate node

Fig. 4 Flow chart of all node

At first, the terminal node request access to the network, then control the sensor to acquire data. Due to the real-time nature of the greenhouse is not very high and in order to reduce the consumption of power, the system will send a data in every 10 minutes.In order to improve the reliability of the data, the sensor detect environment every minute, and the data taken from the monitor in 10 minutes will sent to the parent node which take the average value as the final data.The parent node is the routing node, which need to join the network first, and then every ten minutes to transmit the data from the terminal node to the coordinator node, it is on the state of sleep in the other time.The only coordinator node is mainly responsible for organizing network, addressing allocation for the network request sent by the routing node, dealing and displaying the transmitted data, then it will be stored up in the data center which is available to client download.When the data is found to exceed the preset threshold, the GPRS module sends the SMS message to the administrator's cell phone, and the administrator can timely understand the situation and deal with it.

5 Greenhouse Temperature Control Algorithm Design

At present, PID control algorithm is widely used in industrial control algorithm. This algorithm has simple structure and strong robustness, but it needs accurate control model, which is not good at solving the problem of time delay. The temperature control is a typical time lag problem, and the influence factors of the temperature in the greenhouse is very complicated, and the model can not be determined accurately.Based on these problems, this paper designs the control algorithm which combines Smith pre-estimation and fuzzy control with PID control.

5.1 Fuzzy Controller Design. The function of the fuzzy controller in the control system is that the three parameters of the PID controller will be controlled by the difference between a given temperature value and the detected temperature and the rate of change[8]. So the fuzzy controller's input is the difference in temperature E and the rate of the difference in temperature EC, the output is the three parameters of the PID correction ΔK_p, ΔK_i, ΔK_d.

According to the agricultural greenhouse technical personnel's experience, E、E_C、ΔK_p、ΔK_i and ΔK_d will be fuzzed separately.The domain of E、E_C、ΔK_p、ΔK_i and ΔK_d is discretized into 7 levels: {-3，-2，-1，0，1，2，3} ;The ΔK_i is discretized into 7 levels： {-0.3，-0.2，-0.1，0，-0.1，0.2，0.3} .Fuzzy subset are: {NB, NM, NS, Z, PS, PM, PB}.NB, NM, NS, Z, PS, PM, PB present separately large negative, middle negative, small negative, zero, small, middle, large.NB and PB using the Gauss type membership function, NM, NS, Z, PS, PM using triangle membership function.The fuzzy control rules table is determined by the control rules of "if A and B then C"[9].The function of the link proportion can adjust the deviation quickly, when the deviation is larger, the value of K_p is increased.Proportional coefficient should be controlled within a reasonable range, K_p over the general will increase the overshoot which can cause the system unstable.The function of the integral part can regulate the steady-state error, the integration is a process of accumulation of errors, to avoid the phenomenon of large errors when the error is not used points.The main role of the differential link is reflected in the rate of change of the error, with a leading role, select the appropriate Kd value can not only reduce the overshoot but also shorten the adjustment time[10,11].The specific control rules are shown in Table I.

Table I fuzzy control rule table

E \ E_c	NB	NM	NS	Z	PS	PM	PB
NB	PB\NB\PS	PB\NB\NS	PM\NM\NB	PM\NM\NB	PS\NS\NB	Z\Z\NM	Z\Z\PS
NM	PB\NM\PS	PB\NB\NS	PM\NM\NB	PS\NS\NM	PS\NS\NM	Z\Z\NS	NS\Z\Z
NS	PM\NB\Z	PM\NM\NS	PM\NS\NM	PS\NS\NM	Z\Z\NS	NS\PS\NS	NS\PS\Z
Z	PM\NM\Z	PM\NM\NS	PS\NS\NS	Z\Z\NS	PS\PS\NS	NM\PM\NS	NM\PM\Z
PS	PS\NM\Z	PS\NS\Z	Z\Z\Z	NS\PS\Z	NS\PS\Z	NM\PS\Z	NM\PB\Z
PM	PS\Z\PB	Z\Z\PS	NS\PS\PS	NM\PS\PS	NM\PM\PS	NM\PB\PS	NB\PB\PB
PB	Z\Z\PB	Z\Z\PM	NM\PS\PM	NM\PM\PM	NM\PM\PS	NB\PB\PS	NB\PB\PB

5.2 Smith- fuzzy PID control design. The three parameters in PID are shown in the following formula 1,2,3.

$$K_p = K_{p0} + \Delta K_p , \tag{1}$$

$$K_i = K_{i0} + \Delta K_i , \tag{2}$$

$$K_d = K_{d0} + \Delta K_d . \tag{3}$$

And K_p, K_i, K_d are the ratio of coefficient, integral coefficient and differential coefficient of PID. K_{p0}, K_{i0} and K_{d0} are the initial value of the ratio coefficient, integral coefficient and differential coefficient. ΔK_p, ΔK_i and ΔK_d are the output corrected value of modified fuzzy controller. The critical proportion method is adopted for the whole set of parameters. Firstly, the integral coefficient and the differential coefficient are set to zero; then using the method of constant trial and error to adjust the value of K_p to make the system appear continuous oscillation and record the Critical scaling factor K_r and Critical oscillation period T_r. Finally, the integral coefficient and the differential coefficient are calculated according to the formula 4,5,6.

$$K_p = 1.7 * K_r , \tag{4}$$

$$K_i = 1.2 * K_r / T_r , \tag{5}$$

$$K_d = 0.075 * K_r * T_r . \tag{6}$$

In the feedback loop, the Smith predictor is an early estimation of the dynamic response of the system which is compensated by itself. The role of the Smith predictor can reduce the time delay and weaken the delay in temperature control. Smith predictor connect the part of fuzzy PID in parallel.

5.3 Simulation results and analysis of control system. This control system uses the SIMLINK module in MATLAB to simulate, and the mathematical model of the greenhouse is approximated as a first order system from the aspect of reducing the complexity. In order to reflect the advantages of Smith- fuzzy PID control, the common PID control, fuzzy PID control and Smith fuzzy PID control will respectively be simulated, and compare the simulation results of the three. To assume T is 149, K is 1, τ is 20 in the mathematical model of the design.

Figure 5 is the Smith- fuzzy PID control built in the SIMLINK module. The simulation results of the three models are compared in the same graph which is shown in Figure 6.

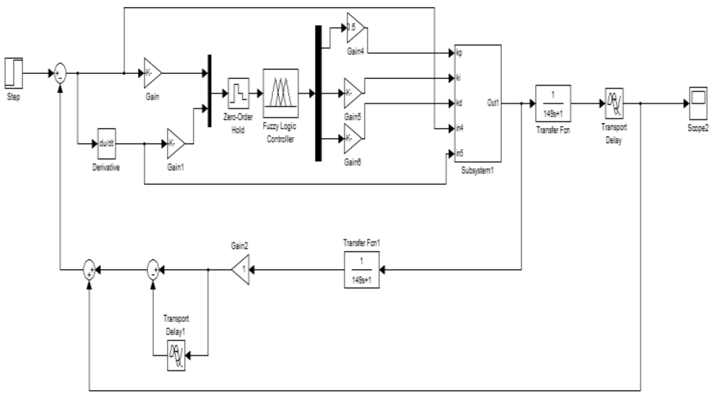


Fig. 5 Smith fuzzy PID control model

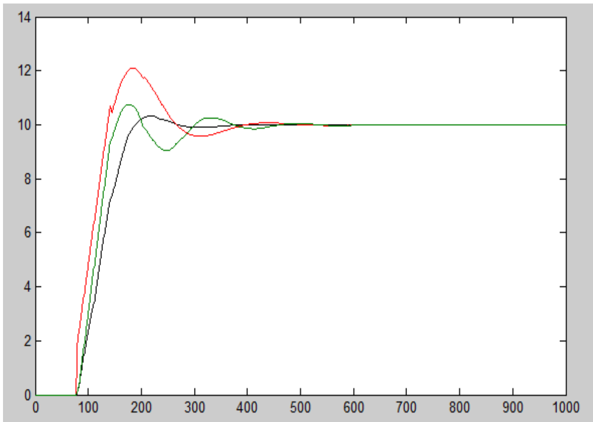


Fig. 6 Simulation results of control system

The red, green and black curves in the image are fuzzy PID control, common PID control and Smith- fuzzy PID control simulation results.It is clear that the stable time is short but the overshoot is too big in the ordinary PID control; the stable time is longer and the fluctuation is bigger in the fuzzy PID control.It is easily to find that although the rise time of Smith- fuzzy PID control is slightly more than the other two kinds of control,overshoot and settling time are greatly improved, and the performance of the system is greatly improved.

6 Conclusion

The system uses ARM microcontroller as the control core, through the ZigBee wireless technology to monitor the internal environment of the greenhouse, so that farmers can better understand the internal environment of the greenhouse.Compared to the artificial cultivation of vegetable environmental information, this automatic monitoring system can not only reduce the amount of labor, but also allows growers to know more detailed and accurate environmental information. The simulation results show that the control algorithm has a significant improvement on the control algorithm compared with the conventional PID and fuzzy PID control. This system has the advantages of simple network, strong real-time, easy to use, a good solution to the problems in the traditional vegetable greenhouses, with a strong application prospects.

References

[1] Lu Xiaozheng,FENG Minsheng .Design of Greenhouse Parameters Monitoring System Based on ZigBee.Journal of Electronic Science and Technology.27(2014):162-164.

[2] Zhang Jingjuan,Wang Min,Lang Hong. Design of monitoring system of agricultural vegetable greenhouse based on GPRS.Journal of Agricultural Science & Technology and Equipment,.238(2014):34-39.

[3] Wang Xiaoyan,Zhou Zhiwen,Wu Tao. Design of temperature control system of greenhouse.Journal of Automation and instrumentation..167(2013):63-64.

[4] Zhou Meng,Li Yuedong,Li Jie. Organic vegetable greenhouse monitoring system based on Internet of things.Journal of Nan Yang Instiute of Technology.6(2012):40-43.

[5] LI Wei yao,WANG Jian xi,WANG Wei.Design of ZigBee based environment monitoring system for vegetable greenhouse.Journal of Modern Electronics Technique.38(2015):51-54.

[6] Guo Jie, Lei Gang,Luo Guangwei,Chen Jiansheng,Shi Yun.Farmland monitoring system based on pro net and wireless mesh networks.Journal of Manufacturing Automation.35(2013):77-81.

[7] He Longlong.The Research on Embedded Internet and GPRS Agricultural Greenhouse Environment Parameter Monitoring System.Degree thesis of Anhui Agriculture University(2012).

[8] Zheng Xiangjun,Xu Feng,Ying Yizhen， Yang Yanqing.Application of the PID Controller Based on Fussy Control in Permanent Temperature Control.Journal of Electrical Automation.37(2015):13-16.

[9] Tan Zhijun,REN Zhengyun.Advanced Control of Greenhouse Temperature and Humidity Based on Predictive PI..Journal of Control Engineering of China.22(2015):495-500.

[10] Wang Weiyu. System Design and Algorithm Research of Rapid Temperature Controller.Degree thesis of Huazhong University of Science & Technology(2012).

[11] Zhang Lianhui. Fupid Temperature Control Algorithms Research Base on the Smith Predictor.Degree thesis ofHarbin Institute of Technology(2012).