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Design of the Remote Monitoring System for Pigsty Environment Parameters Based on the on IoT

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Abstract: For the needs of the monitoring requirements for pigsty environment, based on IoT(Internet of Things) framework, a three-tier architectural model for the remote monitoring system of pigsty environment parameter is designed. The system consists of three parts, which are field acquisition control subsystem, remote monitoring subsystem and database. The environment parameters and the states of control equipment are collected using STM32 SCM, and the collected data saved to the database in real time. In order to improve the response speed and interaction of the remote monitoring subsystem, JavaScript and Ajax asynchronous data exchange mechanism is used to upload the collected data in real time to the web page for display, and the control equipment can accept the orders in real time. The experimental results show that the operation of the system is stable and the transmission of data is correct. It can effectively control the environment and satisfy the demand of piggery environmental monitoring.

***Keywords:** Pigsty environment; Remote monitoring; IoT*

1. Introduction

With the development of modern agriculture and animal husbandry, also accompanied by the enlargement of pig-breeding scale and the rise the number of breeding, the annual pig slaughter has reached 735.1 million in 2014, an increase of 2.7% in 2013 on year-on-year basis, and the amount of pig slaughter in our country has accounted for 51% of the world. Detection and control of pigsty environment is key technologies to improve the pig-breeding quantity and to reduce the cost of pig breeding. The traditional mode of breeding fails to achieve accurate monitoring of pigsty environment, and this mode has been unable to meet the needs of the modern breeding.

IoT is a new technology highly integrated with sensors, the Internet and information processing technology, and it has broad application prospects in agricultural breeding. Overall perception, stable transmission and intelligent application are three important aspects of modern pigsty environment monitoring system based on IoT technology framework[7]. A kind of remote monitoring system for piggery environment parameter based on IoT is designed in this paper, and the environmental temperature, humidity, light intensity, carbon dioxide concentration, ammonia concentration, the concentration of hydrogen sulfide are collected through STM32 SCM and uploaded to the web page for display, with precision less than 3%. The data can be saved in database in long-term, able to convey control commands to lower computer through the web page. The control is divided into manual control and automatic control. Automatic control is to automatically send control commands by setting the upper and lower limits of the parameters, and the historical data is displayed on the webpage in the form of graph.

2. The Overall Framework of the System

This system mainly consists of three parts, which are remote monitoring subsystem, database and field monitoring subsystem, as shown in figure 1. The system is independent of each other to achieve data transmission through the interface function, and mutual coupling is low, with good scalability.

2.1. The Field Monitoring Subsystem

Field monitoring subsystem is the C/S structure, and lower computer communicates with server through Ethernet; considering the particularity of the pigsty environment, lower computer sends the collected data to the server via WiFi, and background software in the server implements read-write operation of the data in the database in real time to achieve acquisition and control of pigsty environment parameters. STM32 SCM sends the collected data after finishing to the background software for display via WiFi module through external temperature and humidity sensor, light sensor, carbon dioxide sensor, ammonia sensor and hydrogen sulfide sensor, and writes the data to be stored in database. Background software polls control information stored in the database in real-time and sends to the lower computer STM32 via WiFi. STM32 controls the relay according to the control commands in order to achieve the purpose of controlling the field equipment (ventilation equipment, humidification equipment and heating equipment, etc.). High voltage and strong current may occur in some field devices, thus optical coupling isolation devices need to be added between the controller and the relay to prevent the impact of large current.

2.2. The Remote Monitoring Subsystem

Remote monitoring subsystem is B/S architecture. With the browser as the terminal system, Apache as the web server, communication between the browser and the server is performed by HTTP protocol, and in order to realize dynamic data exchange without refresh, data interaction between front-end and back-end is realized through Ajax technology to achieve the purpose of real-time display and real-time control [8]. In order to achieve the security of data transmission, user registration and login authentication function are added to web interface. Web interface has designed real-time environmental information view, environmental parameter setting and historical data query function, and is compatible with four major browsers (IE, Chrome, Firefox and Opera), so that management personnel far away from the work site can easily view pigsty environment parameters and send control information.

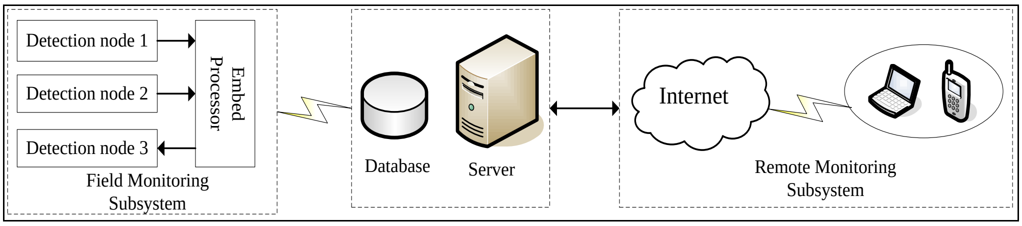

Figure 1: *System overall block diagram*

2.3. The Database

In view of the characteristics of small amount of data and flexible operation, this design chooses the MySQL database, and the information of user registration, user login and user authentication are saved in the database. Data of environment parameters and control information are recorded separately by using two tables for users to carry out historical data query and analysis. Saving time of data can be set, and the database can automatically delete expired data, unlikely to waste storage space of computer.

3. The Hardware Design of the System

The system uses ARM Company's STM32F103VET6 as the main controller, and realizes acquisition, transceiving and control of external data through external sensor module, wireless transceiving module and relay module. The overall structure of the hardware is shown in figure 2.

The sensor include temperature and humidity sensor, light intensity sensor, dioxide carbon, ammonia and hydrogen sulphide sensor. Temperature and humidity sensor selected DHT11. Light intensity sensor selected BH1750. They are all digital signal output, and do not to A/D convert directly to MCU port. Dioxide carbon selected infrared carbon dioxide sensor. Ammonia and hydrogen sulphide sensor selected 4NE-type electrochemical gas sensor. They are all analog output. So need to A/D convert to MCU port. Relay module control circuit uses PC817 optocoupler isolation device to isolate the MCU. Wireless module selected ESP8266wiFi implement the data transmission.

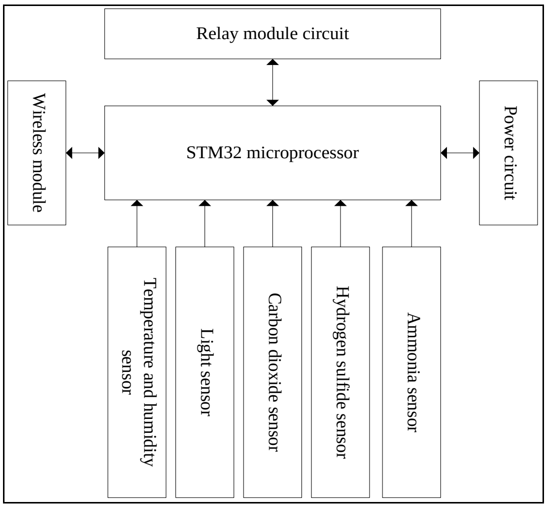

Figure 2: *Overall hardware block diagram*

4. System Software Design

The software design mainly includes three parts: SCM control program, server backstage interface and Web front end interface.

4.1 SCM Control Program

SCM control program mainly for hardware initialization and configuration of network ports. Initialization included sensor and network port initialization. The system has requirements for real-time, so it transplant µC/OS operating system. µC/OS is a ROM-based operation can be cut, and preemptive real-time kernel[3]. It is the characteristic determines theµC/OS suitable for real-time system required. The SCM opened two tasks. One task for receiving data, and the other for send data[2]. So it achieved real-time requirements. The SCM program flow diagram as shown in figure 3.

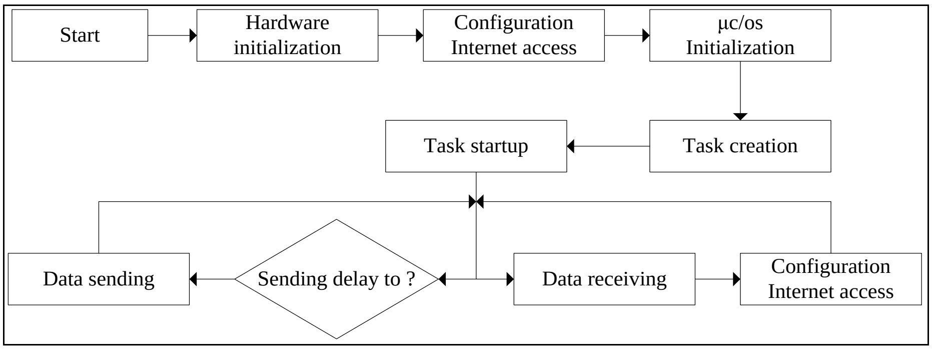

Figure 3: *SCM program flow diagram*

4.2 Server Background Interface Design

The main task of the server backstage interface is the communication with lower computer through the socket on one hand and it is the operation of the database on the other hand[4]; the database that the system uses is MySQL database. Lower computer sends the collected information to the background interface through the socket and via the sensor, and the background interface then writes the data to the database to save it. The background interface not only accepts the data, but also sends the control signal saved in the database to the lower computer through the socket. In order to meet the requirements of real-time, the background interface has opened two threads; one is used to receive the data sent from the lower computer, while another thread is used to send the control signal to the lower computer[6].

Because socket communication is a mode of long connection, that is, data can be sent and received once connection is established, no need to request[5]. Therefore, background interface sends control signal to the lower computer when there is change in the control signal read from it. Interface design is as shown in Figure 4.

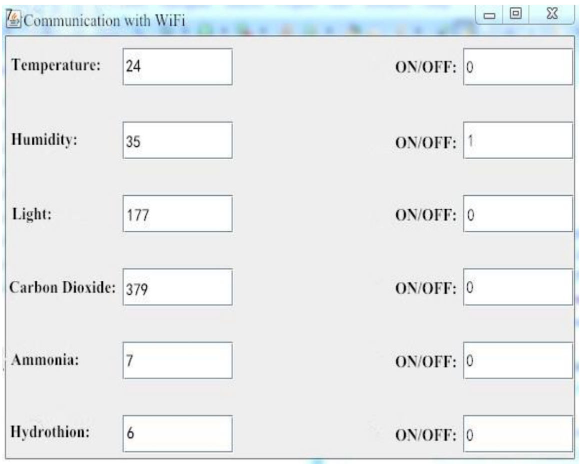

Figure 4: *Server background interface*

4.3 Web Front-End Interface Design

The main interface of Web as shown in Figure 5. User login interface verifies user name and password[1]. Display control interface displays the value of temperature and humidity on the day, light intensity, carbon dioxide concentration, ammonia and hydrogen sulfide concentration in dynamic and real-time manner. Control mode is divided into manual mode and automatic mode; manual mode is to control the opening of the field equipment by clicking the control button, while automatic mode is to set the upper and lower limits of each parameter. When the acquisition value is not within the scope of the system, the system will automatically open the field equipment. The historical data query interface is displayed on the page in the form of graphs for users to query.

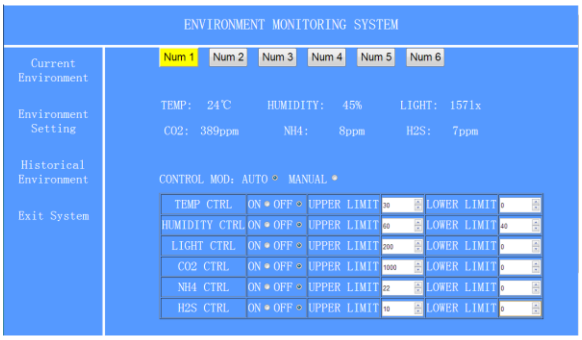

Figure 5: *Main interface*

5. Control Strategy

The variables controlled by the system are temperature, humidity, concentration of carbon dioxide, ammonia and hydrogen sulfide in piggery environment, the characteristics of the change of every variable is nonlinear, time-varying and hysteretic because of a large amount of uncertain factors in piggery environment, and a mutual coupling exist among variables, it's very difficult to establish an accurate mathematical model for it. So the fuzzy control algorithm was adopted to realize a control to piggery environment.

The fuzzy control system of piggery environment is shown in the figure 6, the control system of environmental parameters is made up of curtain fan control system and mechanical ventilation control system, which adopts two controllers with the type of multiple input - single output, control I takes the changes in relative humidity and harmful gases (carbon dioxide, ammonia and hydrogen sulfide) as input, while the number of opened fans as output, controller II takes temperature change and change rate as input, while the number of opened curtain fans as output.

Take temperature as example to explain the control theory of fuzzy controller, the fuzzy controller's inputs are temperature deviation e and deviation change rate ec, while the output is the number of opened curtain fans u. Set the range of deviation e as[-6℃~6℃], the corresponding fuzzy set is E, the temperature's fuzzy set of deviation is {NB, NM, ZO, PS, PM, PB}; set the range of deviation change rate ec as [-2℃~2℃], the corresponding fuzzy set is EC, the fuzzy set of deviation change rate of temperature is {NB, NM, ZO, PS, PM, PB}; set the fuzzy set of output ΔU as {ZO, PS, PM, PB}.

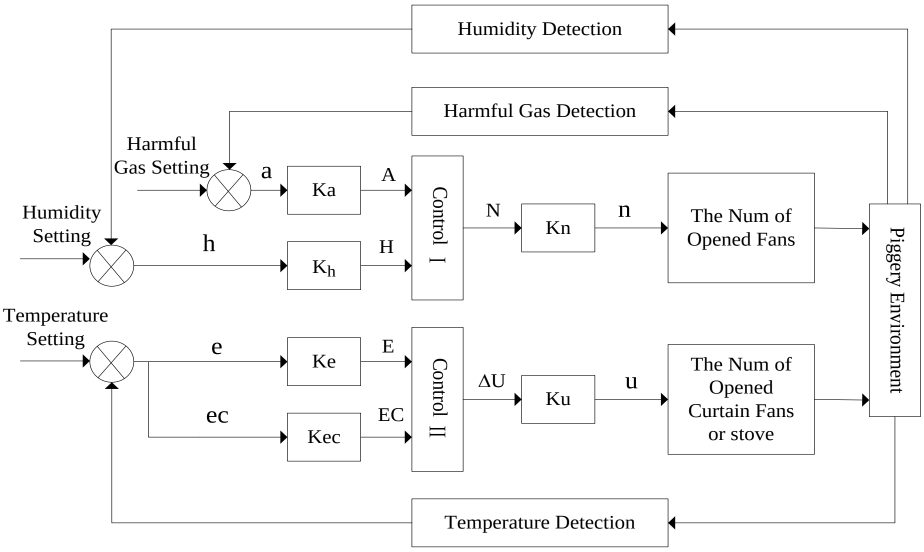

***Figure 6:** The Fuzzy Control System of Piggery Environment*

It is needed to determine the elements' membership degree in the domain to fuzzy language after determining the deviation and change rate of aforesaid fuzzy variables, the controller determines membership degree by using triangle-shaped membership functions, the expression of triangle-shaped membership functions as shown in Equation (1). The membership degree's vector value of fuzzy variables e ec, Δu as shown in Tables 1 to 3.

$$\mu(x)=\begin{cases}\dfrac{x-a}{b-a} & (a\le x\le b)\\ \dfrac{x-c}{b-c} & (b\le x\le c)\end{cases} \tag{1}$$

***Table 1:** The membership degree's vector value of fuzzy variables e*

E	Grade												
	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	-6
NB	1	0.6	0.3	0									1
NM	0.3	0.6	1	0.6	0.3	0							0.3
NS		0	0.3	0.6	1	0.6	0.3	0					
ZO				0	0.3	0.6	1	0.6	0.3	0			
PS						0	0.3	0.6	1	0.6	0.3	0	
PM								0	0.3	0.6	1	0.6	
PB										0	0.3	0.6	

***Table 2:** The membership degree's vector value of fuzzy variables ec*

EC	Grade								
	-4	-3	-2	-1	0	1	2	3	4
NB	1	0.6	0.3	0					
NS	0	0.5	1	0.5	0				
ZO		0	0.3	0.6	1	0.6	0.3	0	
PS					0	0.5	1	0.5	0
PB						0	0.3	0.6	1

***Table 3:** The membership degree's vector value of fuzzy variables Δu*

Δu	Grade								
	-4	-3	-2	-1	0	1	2	3	4
NB	1	0.6	0.3	0					
NS	0	0.5	1	0.5	0				
ZO		0	0.3	0.6	1	0.6	0.3	0	
PS					0	0.5	1	0.5	0
PB						0	0.3	0.6	1

Fuzzy control rules came from experiences and summaries, open curtain fan more if the discounted temperature is high, otherwise open less. The control rules are:

<If e=NM> and <ec=NB> then <Δu=PB >;
<If e=PM> and <ec=PS> then <Δu=NB >;

Similarly, By such analogy we can get control rules using empirical method as shown in Table 4.

Table 4: *Fuzzy Control Rules*

△U	EC				
	NB	NS	ZO	PS	PB
NB	ZO	ZO	PM	PM	PB
NS	ZO	ZO	PM	PM	PB
ZO	PM	PM	PB	PM	PB
PS	PB	PB	PB	PB	PB
PB	PB	PB	PB	PB	PB

The fuzzy inference adopted by the system is Mandani reasoning method, the fuzzy relations are shown in the form of direct product, that's shown in equation(2).

$$R(u,v) = A(u) \wedge B(v) \quad \text{or} \quad \mu_R(u,v) = \mu_A(u) \wedge \mu_B(v) \tag{2}$$

If given an input, the conclusion can be introduced, that's in equation(3).

$$B^* = [A^*(u) \wedge (A(u) \wedge B(v))] \tag{3}$$

The maximum membership degree method is used to blur. Clear value use the $df_m(x)$ to express as shown in equation (4).

$$df_m(x) = \frac{1}{k}\sum_{i=1}^{k} x_i \tag{4}$$

The $x_i(i = 1,2,\cdots)$ is get the point of maximum membership degree.

The ambiguity-resolving strategy is maximum membership degree method, the control rule table is shown in Tables 5.

Table 5: *The Look-up Table of Control Rules*

	△U	EC								
		-4	-3	-2	-1	0	1	2	3	4
	-6	0	0	0	0	1	2	3	3	3
	-5	0	0	0	0	1	2	3	3	3
	-4	0	0	0	0	1	2	3	3	3
	-3	0	0	0	0	1	2	3	3	3
E	-2	0	0	0	0	1	2	3	3	3
	-1	0	0	0	0	1	2	3	3	3
	0	1	1	1	1	2	3	3	3	3
	1	2	2	2	2	2	3	3	3	3
	2	2	2	2	2	2	3	3	3	3
	3	2	2	2	2	2	3	3	3	3
	4	3	3	3	3	3	3	3	3	3
	5	3	3	3	3	3	3	3	3	3
	6	3	3	3	3	3	3	3	3	3

6. System test

The system is tested in a closed pigsty, and the test includes temperature and humidity, light intensity, carbon dioxide concentration, ammonia concentration and hydrogen sulfide concentration. The equipment to control includes fluorescent lamp, heater, humidifier and exhaust fan. The automatic control mode is opened by setting the upper and lower bounds of each parameter.

When the system is opened, the maximum temperature is 23 ℃, a minimum of 18 ℃, the maximum temperature variation of 5 ℃. The maximum relative humidity is 52% inside the pigsty, and the minimum is 40%. Both temperature and humidity are within the proper range. The average concentration of carbon dioxide for the system in the beginning is 385ppm. The average concentration of ammonia in the pigsty is 7.6ppm, and the average concentration of hydrogen sulfide is 7.1ppm, and which is in the standard range.

7. Conclusions

(1) This paper has designed and implemented a remote monitoring system for pigsty environment parameters combined with management demand for pigsty and based on IoT technical framework, and the system is composed of three parts, namely, remote monitoring subsystem, field acquisition control subsystem and database. Independence between the parts has ensured higher scalability, maintainability and applicability of the system.

(2) Functions of environmental data display, historical data query and device control are realized using Ajax asynchronous data interaction technology in the webpage, and users neither need to refresh nor wait for the server's response.

(3) Automatic control mode and manual control mode have been designed according to the actual demand for the management of pigsty, the. Automatic control mode only needs to set the upper and lower limits of each parameter, and the system can control the equipment switch according to the comparison between the current environment data and the set value.

8. Acknowledgments

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