Remote Farm Environment Monitoring System Based on Embedded System and ZigBee Technology

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Abstract: Nowadays aquaculture industry requires the real-time control on farm environmental parameters such as humidity, temperature and illumination intensity. This paper presented a remote system for farm environment monitoring which uses ZigBee technology, embedded system and network database. Except obtaining the monitoring function on farm humidity, temperature, light intensity and data query, the system also provides real-time warning for staff through setting the upper and lower limit value of various parameters, which is convenient for farm staff to implement the on-site or remote control on environmental parameters. The test result shows that our proposed system can obtain a cost-effective monitoring solution for farmers with perfect and stable performance.

Key words: farm; Zigbee; embedded system; network database; environment monitoring

1 Introduction

Fine breeding requires that the farm environmental parameter such as humidity, temperature, light intensity should be strictly controlled. Traditional farm environment monitoring systems mainly used a single-chip microcomputer as the main control unit, which worked in the style of local monitoring and control. With the rapid development of mobile Internet and big data technology, remote monitoring, data storage and analysis have become an indispensable function of a monitoring system[1]. This paper then integrates Zigbee, embedded web technology and network database to develop a set of remote farm environment monitoring system with the function of farm environment parameter collection and real-time display, which also employed BOA server and SQLite database for data analysis and storage. By using this system, farm workers can observe and regulate the farm environment in real-time and in remote distance through a terminal (e.g. mobile phone or computer) that can access the Internet.

2 System Framework

Remote farm environment monitoring system consists of sample block, server block and client block. The sample block collects the farm parameters such as temperature, humidity and illumination. The collected data of farm parameter will be sent to the server block through an embedded ZigBee module. The quantity of sample block and its monitoring range is configured according to the scale of a farm. The server block is the core of whole system which receives the data sent from sample block, obtains the detailed information of farm environment to the client block. In addition, the server block judges whether environment information is abnormal through analyzing the corresponding data. If the environment is abnormal, the server block will then transfer the control command to the sample block to implement the real-time control. Farmer staff observes the collected data at the side of client block, sends the instructions to the sample block to control the relevant equipments, which achieves the aim of remote control on farm's temperature, humidity, and light intensity. The system's overall framework is depicted as Figure 1.

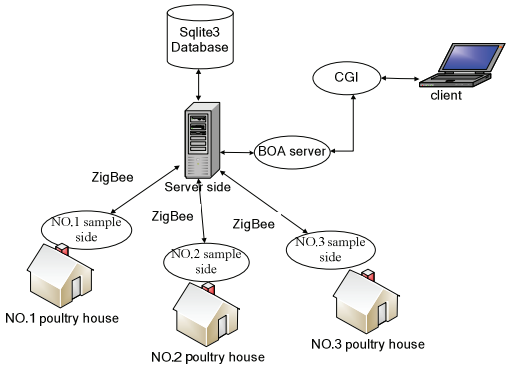

Fig.1 The overall framework of farm environment monitoring system

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3 System's Hardware Design

The system's hardware configuration is shown in Figure 2.

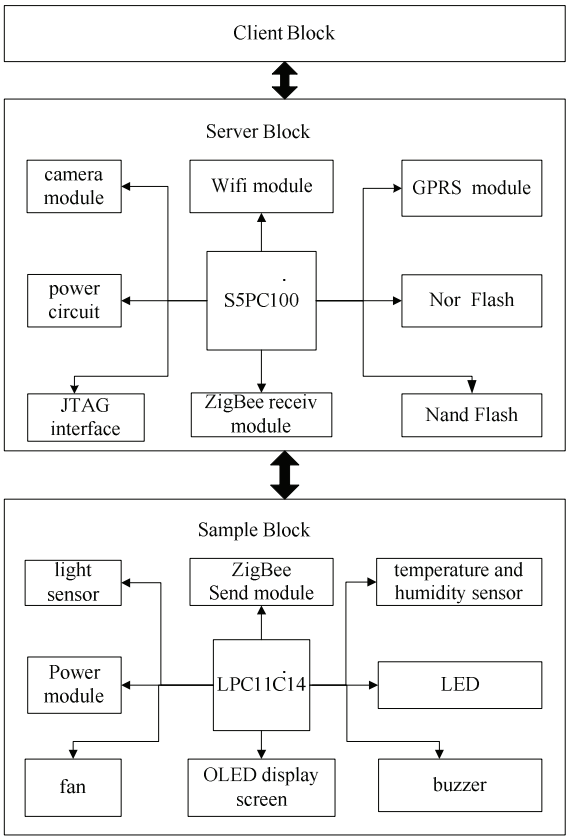

Fig.2 The hardware configuration of farm environment monitoring system

The sample block employs LPC11C14 due to its lowest power consumption, and the server block uses SAMSUNG S5PC100 microprocessor. LPC11C14 processor is based on ARM Cortex-M0 architecture that is used for the embedded applications requiring extensively high integration and low power consumption. S5PC100 microprocessor is based on ARM V7 architecture which has very fast processing speed that can be up to 833 MHZ. This processor also supports a variety of hardware codec especially with a very strong capability on video encoding and decoding. The feature of effective cost, low power consumption, and high performance makes S5PC100 being suitable for embedded systems which has a larger quantity of data to be processed[2].

Besides LPC11C14 microprocessor and FLASH, the sample block uses temperature and humidity sensors, light sensors, LED lamps, fans, OLED display screens, buzzers and other hardware. OV9650 camera is used for video monitoring to take the scene of poultry house and transmit the scene to video module in server block. DHT11 sensor is used for data collection of temperature and humidity, while ISL29003 sensor is used for data collection of light intensity.

S5PC100 microprocessor, FLASH and SDRAM consists of the server block which can be further expanded with GPRS module, WIFI module, camera module and other hardware modules. As the wireless connection between sample block and server block, Zigbee obtains a cost effective solution that uses ZICM2410 as the radio frequency transceiver[3].

3.1 Hardware design of temperature and humidity module

As the value of temperature and humidity of farm is in a common range, the temperature and humidity sensor is not required to have the feature of high or low temperature resistance. But the system requires the sensor must have the high sampling precision and low response time. For the value of sampled temperature, its error should be within 1℃. While for the value of sampled humidity, its error should be within 3%RH. All sensor's response time should be less than 15 seconds. According to these regulations, DHT11 was chosen as the temperature and humidity sensor for the reason that DHT11's specifications can satisfy the system's requirements very well[4]. DHT11 uses a single wire for the serial interface, which ensures the system integration simple and flexible. The connection diagram between DHT11 and LPC11C14 is shown in Figure 3.

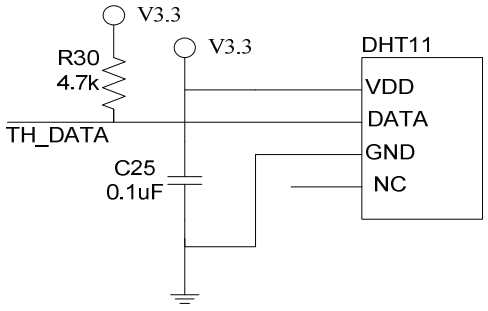

Fig.3 The connection diagram between DHT11 sensor and LPC11C14 microprocessor

3.2 Hardware design of light intensity module

The range of the sampled value of light intensity sensor is not large because the actual light intensity in a farm is not very strong. In this case an ordinary light intensity sensor can meet the system's requirements. ISL29003 was chosen as light intensity sensor for its feature of small volume, high stability, short response time, strong anti-interference and waterproof ability.

ISL29003 which has a detection range of 1~ 64000 lux is a kind of integrated optical sensor embedded with ADC and standard IIC interface[5]. Sampled light intensity is converted to digital components by ADC chip, then digital components are transferred to IIC interface for output. The connection diagram between ISL29003 and LPC11C14 is shown in Figure 4.

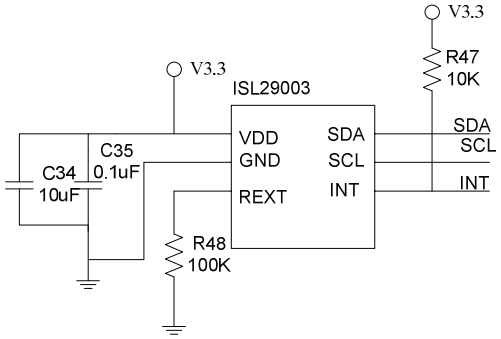

Fig.4 The connection diagram between ISL29003 sensor and LPC11C14 microprocessor

4 System's Software Design

Corresponding to hardware architecture, software of remote farm environment monitoring system includes software implemented in the sample block, server block and client block respectively. Software in the sample block was developed in keil integration environment. Software in the server block was developed in Ubuntu10.04, which is jointly compiled and run on S5PC100. Software in the client block was developed using a plain text editor.

Software in the sample block includes main program, system initialization module, ZigBee transceiver module, temperature and humidity acquisition module, light intensity sampling module, data sending module, and control module, etc. Software in the server block includes main program, ZigBee transceiver module, database module, video acquisition module, alarm message sending module, and the processing module that processes client request, etc. Software in the client block includes user operation interface and CGI programs.

4.1 Main program in sample block

The sample block samples farm's temperature, humidity, and light intensity information every second, then judges the collected data format. The correct data will be packaged and sent to the server block to receive the corresponding instructions from the sample block. For the convenience of viewing the farm's real-time state, each poultry house is equipped with OLED screen to display the video information on site. In the normal state, the control instructions are generated by the server block and transferred to the sample block. When there are some faults occurred in the server block, which results in the abnormal state that the server block can't generate any control instructions, the sample block will start its self-control procedure within 30 seconds. The self-control procedure guarantees the sample block can monitor and control whole farm independent of the server block in some abnormal states. Figure 5 shows the framework of software running in the sample block.

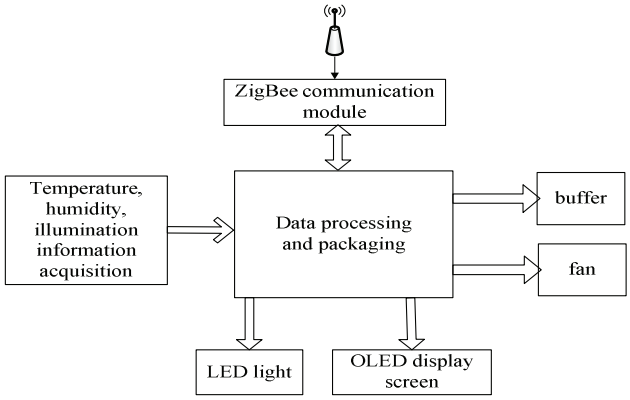

Fig.5 The framework of software running in the sample block

The running steps of software in sample block can be generalized as follow:

(1) Each device in the sample bock is initialize after the system is powered on. System's tick timer is set to 1ms. The response time of system's interruption procedure is configured as 1 second. The video

information of each poultry house will be displayed on OLED screen.

(2) Main program in sample block runs polling procedure to collect the sampled value of temperature, humidity, light intensity every second without the external interruption that is defined as the procedure of Zigbee module to receive instructions from the server block.

(3) If there is an external interruption generated by ZigBee module to receive instructions from the server block, the sample block will control the corresponding device according to the received instructions besides the polling procedure.

The detailed flow chart of the main program in sample block is shown in Figure 6.

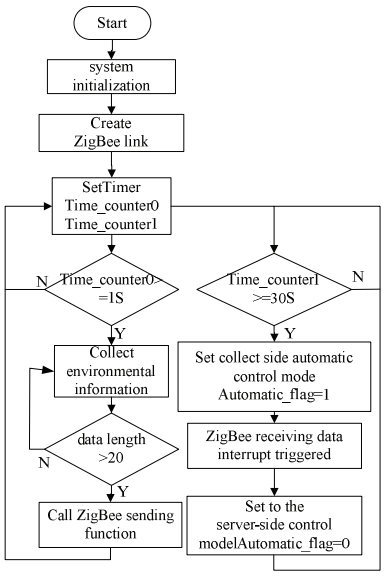

Fig.6 Flow chart of the main program in sample block

4.2 Software in server block

Software in the server block includes two main modules, i.e., BOA and the main program. BOA is a very small Web server with 60KB executable code. BOA supports CGI, which can create a process for CGI program[6]. The main program receives and processes the acquisition data from the sample block. In addition, the main program also receives control commands from the client block and transfers these control commands to sample block. Therefore the main program uses multiple threads to implement multiple tasks. The architecture of software is shown in Figure 8.

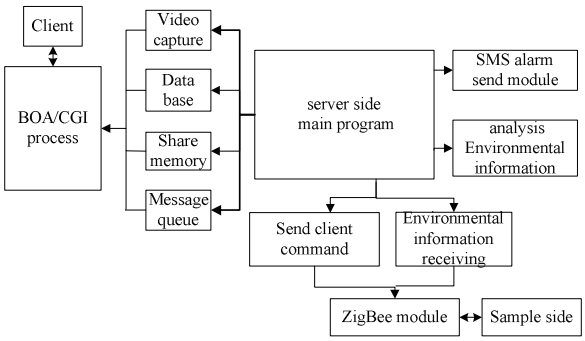

Fig.8 Architecture of software in server block

The thread of receiving farm environmental information in the main program in the server block is responsible to receive environment parameters acquired by the sample block. The received data will be added into a list of cache. Thread of environment parameter processing then extracts data from the list of cache for the further processing. If environment parameter is abnormal, warning message will be sent to the sample block, which can be sent to reserved mobiles through SMS. Abnormal environment parameters will be recorded in database. It is noted that environmental parameters will be added into another list after they were processed, which will be accessed by the thread of shared memory update and database operation. Environment parameters stored in the shared memory will be refreshed every 1 second, during which the client block will read environment parameters from shared memory. For those commands produced by the client block, a thread that is responsible to process client request will analyze these commands stored in a message queue. Relations between the various threads in the software in server block are shown in Figure 9.

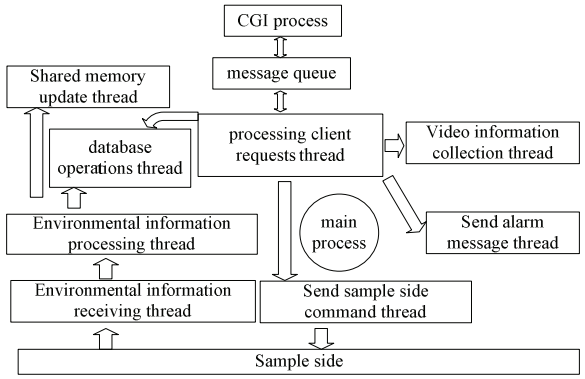

Fig.9 Relationship of the threads in the software in server block

4.3 Software in client block

The user interface in software in client block was developed integrating with HTML, CSS, and JavaScript. The software in client block will be implemented to accomplish a variety of functions such as user login, environmental information display, setting upper and lower value of environment parameters, photo capture, configuration of mobile number to receive alarm SMS, etc. Communications between the client and server block is based on BOA and CGI. Figure 10 shows the architecture of software in the client block.

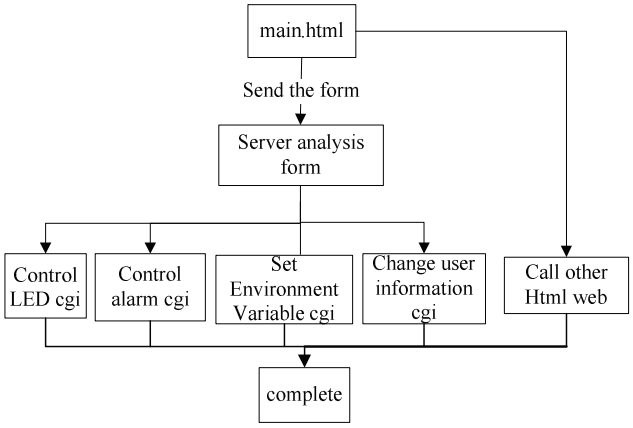

Fig.10 Architecture of software in the client block

5 Conclusion

Remote farm environment monitoring system that is based on Zigbee and embedded system has been tested on site. The test results prove that the system has a good performance on the data acquisition of farm temperature, humidity, and light intensity. The system can find the abnormal state and give the warnings in real-time, which is achieved by setting the upper and lower value of environment parameters. The system helps the farm staff implement the remote monitoring and control on the equipments, therefore it has a strong promotion value in practical applications.

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