Design and Implementation of the Lab Remote Monitoring System Based on Embedded Web Technology

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***Abstract*—Describe a software and hardware design solution of an embedded web-based remote monitoring system for the environment in the laboratories. Build an embedded web server to publish the data of sensor networks and video images to achieve remote monitoring which is based on B / S architecture. Managers can control the equipments in the lab through a web browser which is cross-platform. The embedded database manages the data collected by sensor networks, realizing the local management of environmental data. The experimental results show that the system designed implements safe and convenient remote monitoring and local management of the environment in laboratories and has high availability, reliability and popularization.**

Keywords-embedded web server; S3C2440 ARM microprocessor; embedded database; remote monitoring system

I. INTRODUCTION

The web technology has begun to have a rapid development in the field of embedded systems in the post-PC era. The application of embedded web technology in the remote monitoring system has given rise to the technological change in the field of industrial control. Nowadays the management of the domestic laboratories in the research institute and universities has issues of poor real time, high cost and low precision .It is difficult to determine the quality of the environment of the laboratory [1]. So the Laboratory Intelligent Monitoring System should be developed to implement early warning, remote control, real-time monitoring and other functions. This paper comes up with a design solution of an embedded web-based remote monitoring system for the environment in the laboratories, which realizes the local management and remote publishing applications for large-scale dynamic data of sensor networks and video images.

II. SYSTEM TOPOLOGY

The general framework of the Laboratory Intelligent Monitoring System is divided into two parts which are the local ARM Intelligent Monitoring Center and its peripheral equipments and all kinds of remote monitoring terminals.

ARM Intelligent Monitoring Center uses Samsung's S3C2440 processor as its main controller, the performance and frequency of which are suitable for real-time video image capture and processing applications [2]. Embedded Linux operating system and boa embedded web server run on the main controller to manage various types of equipments including sensor networks, GSM / GPRS dual-band module, USB cameras and so on.

Remote monitoring terminals, including mobile phones, fixed phones, mobile PC, PDA and so on , are connected with the ARM Intelligent Monitoring Center through GSM, PSTN, and TCP / IP networks. Users can log on the ARM Intelligent Monitoring Center through any remote terminal to operate monitoring software, view the data of monitoring center and know about the environmental conditions and video image in the laboratory. The system Topology is shown in Figure 1.

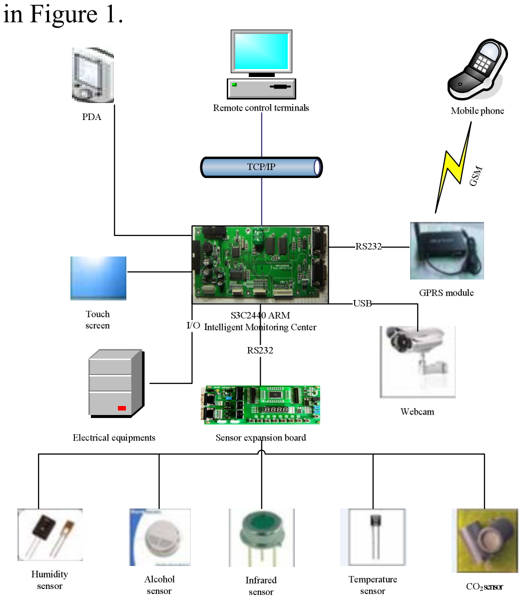

Figure 1. The system topology

For the condition that there are large numbers of laboratories to be monitored, we can consider increasing monitoring PC in the middle-level. Then the monitor information of ARM Intelligent Monitoring Centers can be handled in a centralized way in the monitoring PC to avoid the constraint software and hardware resource in the embedded host to limit achieving demand for large-scale monitoring functions. But the costs of the system will be increased at the same time.

III. DESIGN OF SYSTEM HARDWARE

A. System Controller

The system uses 32-bit RISC processor Samsung S3C2440 with various features and peripherals. It's based on ARM 920T core and supports embedded Linux, WinCE, VxWorks and other embedded operating system. All the properties meet the requirements of the remote monitoring system. The System hardware architecture is shown in Figure 2.

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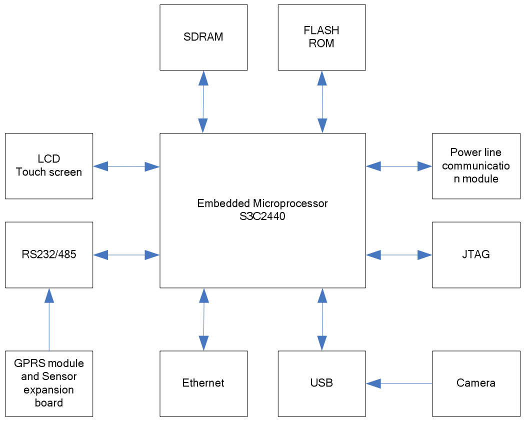

Figure 2. The system hardware architecture

B. *Sensor Networks*

We use MEGA 8 as the master chip of the sensor extension board, which is connected to various types of sensors to constitute a sensor network. This network collects environmental data and transmits them to the ARM Intelligent Monitoring Center through serial ports. The sensor network includes DS18B20 temperature sensor, HSl101 humidity sensor, TGS822 alcohol sensors, E200B infrared sensors and TGS4161 carbon dioxide sensor. These sensors automatically monitor the temperature, humidity, carbon dioxide and other gas concentrations as well as the availability of external material intrusion in the laboratory.

C. *Design of GPRS Module*

This system uses SIM100-E GSM / GPRS dual-band module for voice transmission, messages and data services. It provides wireless interface and communicates with the ARM Intelligent Monitoring Center through the RS232 interface .We write AT commands into the serial device file and control the GPRS module to achieve functions such as the SMS / MMS mode automatic alarm to the managers when an exception occurs with the laboratory monitoring data.

D. *Webcams*

Most of the current securities monitoring system are based on PC with cameras, which is costly and troublesome to implement. This system uses an embedded host to connect cameras, which handles the real-time image acquisition and image capture of laboratory environment. Through image processing and special algorithm [3], the images can be used to determine whether an exception illegal invasion event occurs. In conjunction with infrared detectors for functional complementation, the system has better implementation of security features.

In addition, the ARM Intelligent Monitoring Center can also control a variety of electrical equipments in the laboratory and is equipped with a TFT LCD touch screen, on which a friendly GUI developed by QT runs under embedded Linux system.

IV. Design of System Software

A. *Acquisition of Environmental Monitoring Data*

As for the design of the Intelligent Lab Monitoring System, we need to implement the local storage and dynamic update of the data collected by sensor networks for the achievement of local management and remote publishing of environmental data, which can be implemented through an embedded web server. The remote monitoring client browser posts a HTTP request and then CGI programs operate SQLite database. The System software architecture is shown in Figure 3.

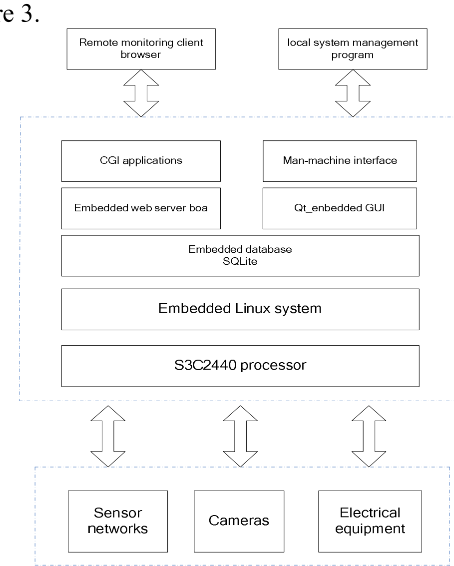

Figure 3. The system software architecture

The well-known open-source database SQLite which abandons many complex features of traditional enterprise database and only implements the necessary functions in terms of a basic database is one of the most widely used embedded database [4-5].The system overhead is small and it has retrieval efficiency, supporting ACID properties and SQL92 standard. This system uses SQLite database on the embedded Linux operating system to manage data.

The ARM Intelligent Monitoring Center acquires sensor data via the sensor expansion board. The sensor expansion board with Mega8 as its master chip is used for data acquisition and communicating with intelligence monitoring center. SCM software is in charge of the local polling to obtain the status of each sensor and monitoring data. It can send out an interrupt request signal. The ARM Intelligent Monitoring Center sends control commands to SCM according to the definition of serial communication protocol, the latter returns the state or data of specified sensors according to the commands. The sensor data is acquired and updated in a fixed time interval managed by SQLite database.

B. *Environmental Monitoring Data Analysis Algorithm*

The environmental monitoring data analysis algorithm analyzes the current data stored in the SQLite database collected by sensor networks and compare them with the threshold value. If there is an exception for the sensor data in comparison with the threshold, then the system will call the GPRS module and electrical device driver functions to make corresponding processing such that when the temperature is too high, we may think a big fire must be caused .So the system sends an alarm message to the user, dial the phones, cut off the power of large electrical equipments at the same time. The photos which record the accident scene will be saved in the root directory of the boa web server in order to provide the proof of the cause of the accident. The flow chart of the environmental monitoring data analysis algorithm is shown in Figure 4.

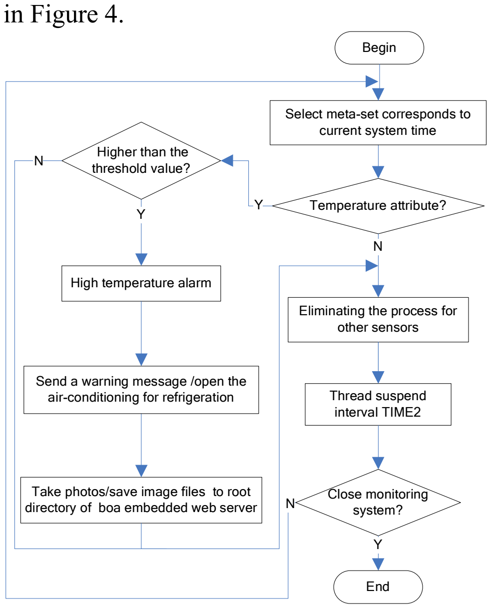

Figure 4. The environmental monitoring data analysis algorithm

C. Publishing Environmental Monitoring Data Based on the Embedded Web

To achieve the remote publishing of the sensor data and video images, we can build an embedded web server. As for resource-limited embedded devices the light weight web servers we can choose are Boa, httpd, thttpd, etc. Boa is a single-task web server which runs on UNIX /Linux system. If there are two users' simultaneous accesses to it, in which a user must wait for a moment, the server creates a separate process to handle CGI programs, taking up less system resources. The advantages of Boa lie in its rapidity and reliability. This system uses the open-source Boa web server which supports CGI program. However, the principles of remote publishing are totally different due to the differences between the two types of environmental data.

1) Remote Publishing of Sensor Data

The remote publishing of sensor data is achieved through the CGI technology. CGI is a standard interface for external applications to interact with a web server [6].We transplant embedded Linux system to the ARM Intelligent Monitoring Center and build Boa web server, which is responsible for listening to customer requests from the Internet as a running process in the background. When users send requests through IE browsers to the local embedded web server to start the corresponding CGI program to accomplish the parsing and processing of the parameters, the web server translates the request parameters into environment variables or standard input. CGI programs perform the corresponding query and update operations of SQLite database and the results are converted to the format which is recognized by the web browsers. Then they are returned to the clients as HTTP response messages, thereby achieving the remote query of monitoring data collected by sensor networks.

2) Remote Publishing of Video Image Data

To achieve the remote publishing of video image data we needed to complete three steps which are image acquisition, image compression and dynamically displays through web pages.

Image acquisition module completes the capture of the video images through the video device driver V4L (video4linux) in the embedded Linux kernel.V4L is the basis of imaging systems of Linux system and provides a range of application programming interface function for the control of the video devices [7].These video devices include TV cards, video capture cards, USB cameras and so on. The flow chart of image captures based on V4L is shown in Figure 5.

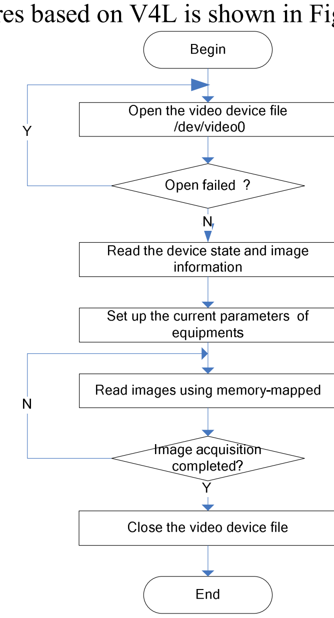

Figure 5. The flow chart of image captures based on V4L

The video data collected in the memory can be saved as files and it could also be compressed for transmission through the Internet. This design will choose to compress the video data with the MJPEG algorithm to generate data stream .Finally, we need to dynamically displayed the video data on web pages, but this is difficult to be implemented through the traditional CGI technology. Because CGI programs run on the server, which has high demand for the hardware resources, they increase the burden of servers. They aren't suitable for the embedded environment of which the memory and storage space is very limited .This paper develops Java Applets to achieve flexible manmachine interaction and the dynamic display of video image data.

Java Applets are provided by the web server and they are downloaded to the clients when the browser accesses the server with requests. The client browser can run the program only if it supports Java VM. The system uses Java Applets to provide access interfaces for users, so it is convenient to develop client applications, reducing the burden of web server at the same time. In the ARM Intelligent Monitoring Center we build a small embedded website, the main content of which is monitored environmental data and information of video images.

The process of the service provided by the embedded website of the Laboratory Intelligent Monitoring System is shown in Figure 6.

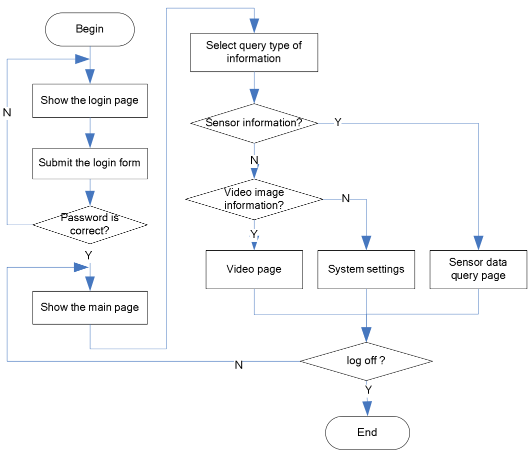

Figure 6. The process of the service of the embedded website

V. EXPERIMENTAL RESULTS

The main page of the embedded website to remote publishing the monitoring data of sensors and video image information which is implemented by the combination of embedded database SQLite and an embedded boa web server is shown in Figure 7 .It can realize the remote access of sensor monitoring data and video image information in the laboratory, supporting the query of the historical records and download of the environmental monitoring data to the client according to requests. The remote video monitoring centers can implement both real-time image monitoring and the query of the photo image files automatically captured when the monitoring system in abnormal states.

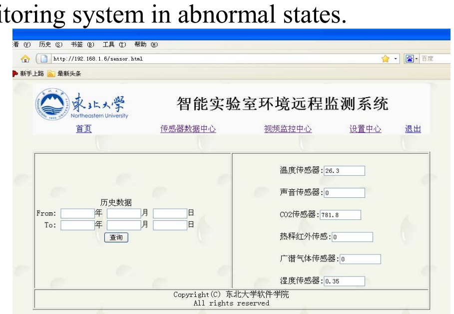

Figure 7. The main page of the embedded website

VI. CONCLUSION

This paper focuses on solving the issues of poor real time, high cost, low precision and incapability of determining whether the lab environment is in line with the body’s health in the laboratory management of domestic institutions of higher learning and designs an embedded web-based remote monitoring system to realize the local management and remote publishing applications for large-scale dynamic data of sensor networks and video images. Build an embedded web server to publish the data of sensor networks and video images to achieve remote monitoring which is based on B / S architecture. Managers can achieve remote monitoring for devices in the laboratory through a web browser which is cross-platform. The experimental results show that the system designed realizes safe and convenient remote monitoring and local management of the environment in laboratories and has high availability, reliability and popularization.

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