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Intelligent Home Environment Monitoring System Based on STM32

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ABSTRACT

In response to the increasing demand of residents for home environment quality, this article designs and implements an intelligent home environment monitoring system based on STM32 processor. The system uses STM32 microcontroller to control multiple sensors to collect real-time environmental parameters such as temperature, humidity, CO, and smoke. The data is uploaded to Alibaba Cloud server through ESP8266 Wi-Fi module. At the same time, a WeChat mini program is designed to obtain cloud server environmental data, monitor home environmental parameters in real time, and implement alarms. After testing, this system has achieved real-time monitoring and early warning of the home environment, with high stability and low cost, and can meet the daily needs of ordinary households very well.

1. Introduction

In recent years, artificial intelligence (AI) is transforming our daily lives and becoming a part of them, which gives birth to intelligent applications such as intelligent healthcare and intelligent driving [1]. Especially, by connecting various household appliances, lighting systems, monitoring systems, etc., intelligent management of the home environment can be achieved, and the living experience can be improved. For example, household appliances can be switched on or off by a slight gesture [2]. As a result, like demands for enterprise management giving birth to smart enterprise system [3], intelligent home systems have emerged demands requirements for health living environment. However, while intelligent home systems improve the convenience of life, they also need to pay attention to addressing a series of environmental quality issues, such as air quality, temperature, humidity, noise, etc. Especially, environmental parameters about temperature, humidity, CO, smoke, etc., have a direct impact on human health [4]. Therefore, real-time monitoring of changes in home environment parameters is particularly important [5]. How to design and implement an effective intelligent home environment monitoring system has become an urgent problem.

Under Internet of Things (IoT) technology and the popularity of smart terminals, home environment monitoring systems are showing a trend towards portability, intelligence, and security [6]. Firstly, various sensors collect real-time indoor and outdoor environmental data. Then, using IoT technology [7], the collected data is transmitted in real-time to cloud servers or mobile devices. Afterwards, data processing and analysis stages of home environment monitoring systems are conducted to automatically identify trends in environmental quality changes and trigger alarms sent to residents' smartphones.

The home environment monitoring system designed in this article uses STM32 microcontroller as the main control chip, and uploads data to Alibaba Cloud server through ESP8266 Wi-Fi module to complete data collection, uploading, remote real-time viewing in WeChat mini program, and alarm functions, realizing the intelligence and security of home [8].

The contributions are summarized as follows:

- An intelligent home environment monitoring system based on STM32 processor is designed and implemented to meat the increasing demand of residents for home environment quality.
- This article expounds how the intelligent home environment monitoring system collect real-time environmental parameters, upload data to Alibaba Cloud server, and implement alarms for risks.

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- Testing demonstrates the functionality and stability of the intelligent home environment monitoring system, with low cost to meet the demand of residents for real-time monitoring and early warning of home environment risks.

The organizational manner of the rest of this article is as follows: Section 2 furnishes an overview of the design of the intelligent home environment monitoring system. Section 3 and Section 4 delve into the specifics of the hardware and software in the intelligent home environment monitoring system, respectively. Section 5 indicates how to assess its performance and analyzes its testing results. Finally, this article is concluded in Section 6.

2. Overall System Design

The home environment monitoring system designed in this article mainly consists of two parts, i.e., remote monitoring terminal and data collection terminal. The system diagram is shown in Figure 1. On the remote monitoring terminal, Alibaba Cloud servers and WeChat mini programs communicate in real-time through the HTTP protocol to send and receive data. When abnormal monitoring of home environment data occurs, instructions are sent to issue warnings and users are promptly notified to handle the situation. At the data collection terminal, STM32 microcontroller is used as the main control chip to control modules, such as temperature and humidity sensors, CO sensors, smoke sensors, to collect temperature, humidity, carbon monoxide, smoke, and other data of the home environment. Wi-Fi module is used to wirelessly transmit the data collected by the sensors, realizing the connection and communication between the remote monitoring terminal and the data collection terminal [6].

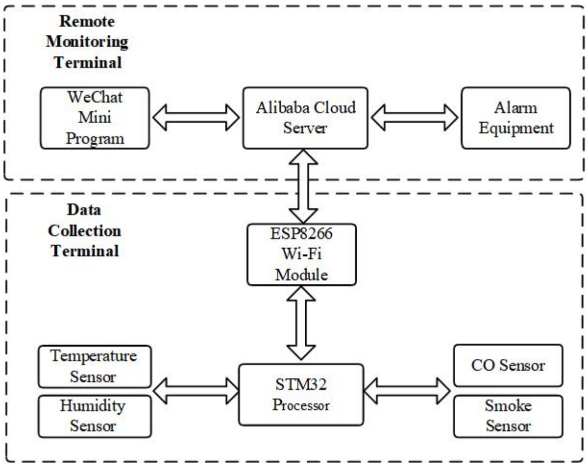

Figure 1: The overall system design diagram.

3. System Hardware Design

The hardware system in the home environment monitoring system of this article consists of STM microcontroller, temperature and humidity sensors, smoke sensors, CO sensors, LED lights, and Wi-Fi modules. The STM32F103C8T6 microcontroller is used as the core processing unit, and DHT11 temperature and humidity sensor, MQ-2 smoke sensor, and MQ-7 carbon monoxide sensor are used as home environment parameter acquisition modules. Each sensor collects relevant data and sends it to the microcontroller for processing. The collected data is transmitted to the mobile client through the ESP8266 Wi-Fi module at the same time [9].

3.1. STM32 Control Module

The STM32F103C8T6 microcontroller used in the home environment monitoring system of this article is a high-performance and low-power microcontroller with powerful processing capabilities that can quickly execute complex algorithms and tasks. It uses a 32-bit ARM Cortex-M4 RISC core with the maximum operating frequency reaching 72MHz, a built-in high-speed flash with a capacity of 128 kB, and 20 kB SRAM. With these components, it can support a low-power mode, with power consumption as low as the nA level in standby mode. At the same time, it can support communication interfaces such as USART, SPI, I2C, as well as peripheral resources such as timers, ADCs, and DACs. The schematic diagram of the STM32 microcontroller module circuit is shown in Figure 2.

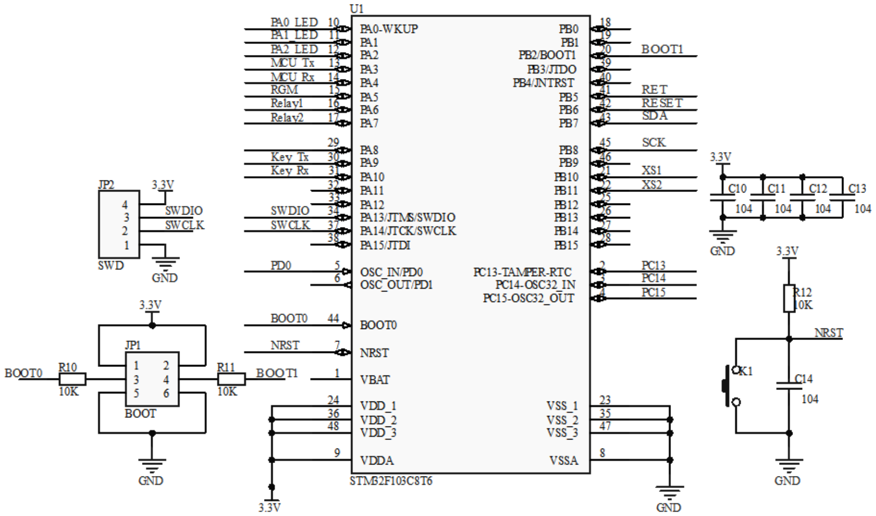

Figure 2: STM32 control module circuit diagram.

3.2. ESP8266 Wi-Fi module

The home environment monitoring system uses the ESP8266 series ESP-12F Wi-Fi module to achieve wireless networking. That module is equipped with an ultra-low power consumption 32-bit micro MCU and onboard PCB antenna, supports standard IEEE802.11 b/g/n protocol, and supports communication with microcontrollers through serial ports. The RXD pin of the module is connected to the PA4 pin of STM32, and the TXD pin of the module is connected to the PA3 pin of STM32.

The ESP8266 module supports three working modes including Station, AP, and Station+AP:

- Station mode: The ESP8266 module achieves remote communication between the system and terminals such as mobile phones and computers by connecting to Wi-Fi hotspots of other routers;
- AP mode: The ESP8266 module serves as a wireless router, allowing mobile phones, computers, and other terminals to directly connect to the module's hotspot for remote communication [10];
- Station+AP mode: The ESP8266 module at Station+AP mode has wireless router functionality and can also connect to other Wi-Fi hotspots.

The home environment monitoring system sets the ESP8266 working mode to Station (STA) mode and exchanges data with the server by accessing the wireless routing network [11].

3.3. Each Sensor Module

3.3.1. DHT11 Temperature and Humidity Sensor

The DHT11 temperature and humidity sensor achieves accurate and reliable temperature and humidity measurement through its internal resistive humidity sensing element and NTC temperature sensing element. It has four pins, uses single-wire communication, and comes with an A/D converter. The DHT11 temperature and humidity sensor's DATA pin is directly connected to the I/O interface of the STM32 microcontroller to output digital temperature and humidity values.

3.3.2. Smoke and CO Sensors

Both of MQ-2 smoke sensor and MQ-7 carbon monoxide sensor use gas sensitive material tin dioxide (SnO2) inside, which can detect smoke concentration and CO gas concentration through the change in resistance value after reacting with the target gas. The data collected by MQ-2 and MQ-7 sensors are both analog quantities, which need to be converted into digital quantities through A/D conversion circuits and input into the I/O interface of STM32 microcontroller to obtain the concentration value of ambient gas [12].

4. System Software Design

4.1. Program Design for Data Collection Terminal

The home environment monitoring system uses Keil μ Vision 5 as the program development environment of data collection terminal, and the used programming language is C language. Keil μ Vision is an integrated development environment (IDE) developed by Keil Software, which supports multiple microcontroller architectures and provides a complete tool chain including compilers, assemblers, linkers, debuggers, etc. It can efficiently write, compile, and debug code and is widely used in microcontroller driver development, embedded system application development, and other fields.

The data collection terminal program adopts a modular design, consisting of modules such as initialization program, Wi-Fi configuration connection program, initialization and data collection programs for each sensor, wireless communication program with cloud server, etc [13].

After the device is powered on, the first step is to perform system initialization, including clock, timer, GPIO, etc. Then, the device network is connected to the router and further connected to the Alibaba Cloud server. After the data collection terminal is connected to the Alibaba Cloud server, the microprocessor collects home environment data at a frequency of 1Hz and uploads the data to the Alibaba Cloud server at a frequency of 5Hz. When the collected environmental data exceeds the specified threshold, the receiving server sends a command for warning. The software design process for the data collection terminal is shown in Figure 3.

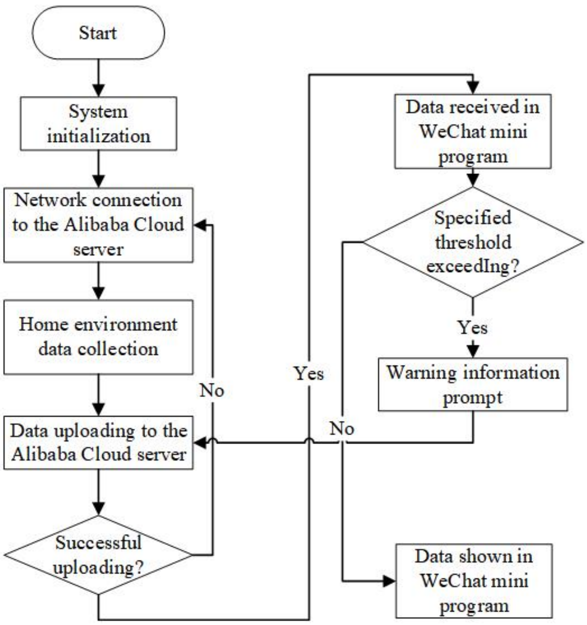

Figure 3: Software design flowchart.

4.2. Design of WeChat Mini Program for Remote Monitoring Terminal

The remote monitoring terminal uses WeChat Developer Tools for WeChat mini program development. WeChat Developer Tools is an integrated development environment (IDE) provided by Tencent for WeChat mini programs, providing full process support from code writing, debugging, to publishing. The developed WeChat mini programs rely on the WeChat platform and do not require the downloading of other applications, which makes it is easy to use and of low maintenance costs [14].

The WeChat mini program in the home environment monitoring system uses HTTP communication protocol to communicate with cloud servers and obtain environmental data from each sensor. The design of WeChat mini program is mainly divided into two parts, i.e., environment monitoring page and message page. The environment monitoring page receives data from various sensors pushed by the cloud server, and the message page displays system warnings and other information.

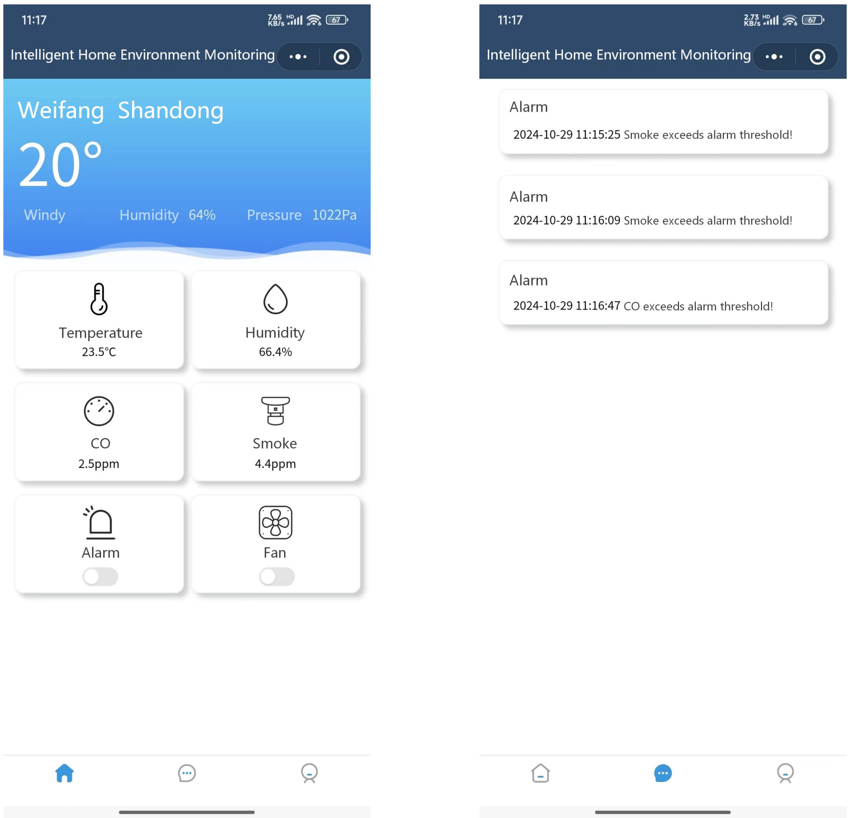

Figure 4: The environment monitoring page and message page in WeChat mini program. Left: Environment monitoring page. Right: Message page.

5. System Testing

5.1. Hardware Debugging

After the hardware circuit design is completed, it needs to be debugged. Specifically, the hardware debugging includes the following steps:

- First, it is necessary to use a multimeter to check if the wiring on the circuit board is exposed, and if there are any short circuits or open circuits in the components.
- After soldering the components, it is necessary to compare the circuit board with the design schematic, check whether the components are placed correctly, and check whether there is pseudo soldering or lack of weld at each solder joint in the circuit board.
- After powering on, it is necessary to check whether the circuit power supply is suitable to ensure stable system power supply and prevent the chip and microcontroller from being burned out due to unstable power supply.

5.2. Overall Testing

After powering on the system terminal, it needs to be placed indoors to collect home environment parameters and conduct an overall testing of the system's functionality.

The conducted overall testing results have shown that the home environment monitoring system can upload real-time environmental data collected by various sensor modules to the Alibaba Cloud server. At the same time, the WeChat mini program can successfully display the data pushed by cloud servers and provide remote warnings, achieving the expected design requirements of the home environment monitoring system [15]. The display interfaces of environment monitoring page and message page of the WeChat mini program in the overall testing are shown in Figure 4.

6. Conclusion

This article presents a smart home environment monitoring system designed using ESP8266, Alibaba Cloud servers, and WeChat mini programs. It is capable of real-time monitoring temperature, humidity, smoke and special gases such as carbon monoxide in the home environment. The ESP8266 module is used to connect the device to the cloud server platform and upload the detected environmental data to the cloud server in real time. When abnormal monitoring data occurs, the WeChat mini program immediately alerts. After overall testing, the smart home environment monitoring system has achieved the expected functions. It is stable, reliable, and cost-effective, which meets people's basic needs and can better ensure family safety.

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