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Based on Embedded-RAM Smart Home

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Abstract

This design is based on the FS-MP1A development board, using the STM32MP157A processor. The smart home system includes a door access module, data acquisition and monitoring module, device control module, weather forecast module, and Baidu Cloud interaction module. The door access module mainly uses the sqlite3 database to store residents' login information and implements password login for unlocking. The monitoring system primarily uses the V4L2 driver for the OV5640 camera, sets the video capture format to YUYN, converts the YUYN format video raw frames to RGB format, and then converts the RGB data to QImage for display on the screen. Environmental monitoring mainly involves detecting indoor light intensity, temperature, and humidity. The device control module mainly controls the on/off of LED lights, activates the buzzer, and regulates the fan speed. The weather forecast module mainly forecasts the weather conditions of the local city and displays the weather information on the screen. The Baidu Cloud interaction module mainly facilitates information exchange and controls devices such as fans, lights, and the buzzer.

Keywords

FS-MP1A; Smart Home; Embedded.

1. Introuduction

Smart home refers to connecting various devices, systems, and applications within a home through intelligent technology to achieve intelligent management and control of the home environment, thereby enhancing the convenience and comfort of family life. Embedded systems refer to integrating computer hardware and software into specific devices to give them specific functionality and performance, typically used to accomplish specific tasks or meet particular needs. In the field of smart homes, embedded technology plays a crucial role. For instance, embedded systems in smart home devices can monitor and control the home environment, including automated control and intelligent management of devices such as lighting, air conditioning, and security.

Embedded technology can also be applied in devices like smart speakers and smart TVs to enable functions such as voice control and intelligent interaction. Therefore, the integration of smart homes and embedded technology can lead to a more intelligent and convenient home life.

Video surveillance technology is a comprehensive technology that combines embedded technology, network data transmission technology, and audio-video processing technology. With the rapid development of multimedia technology, video surveillance can not only provide real-time monitoring and control of scenes and handle emergencies but also track and record targets in images, quickly identify faces in databases, and include intelligent detection systems to swiftly prevent potential dangers. Through IoT connections, timely feedback can be sent to WeChat programs so that residents can promptly understand situations and make judgments.

The embedded graphical user interface (GUI) design is an essential component of video surveillance systems and facial recognition, serving as a communication bridge between users and devices. The GUI, tailored for applications in video surveillance and facial recognition fields, needs to possess general characteristics like stability, reliability, and effectiveness while

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meeting special requirements such as portability, high real-time performance, multi-channel support, and low power consumption.

The access control system employs password unlocking, with an alarm prompt after three incorrect password attempts, significantly enhancing theft prevention security.

2. Syestem Architecture

The design of smart home systems is based on the concept of the Internet of Things (IoT), which is an important component of the next generation of information technology. The basic idea is to use the Internet as a medium to achieve remote monitoring and control. It has a very wide range of applications in various fields. The overall system design is shown in the diagram below.

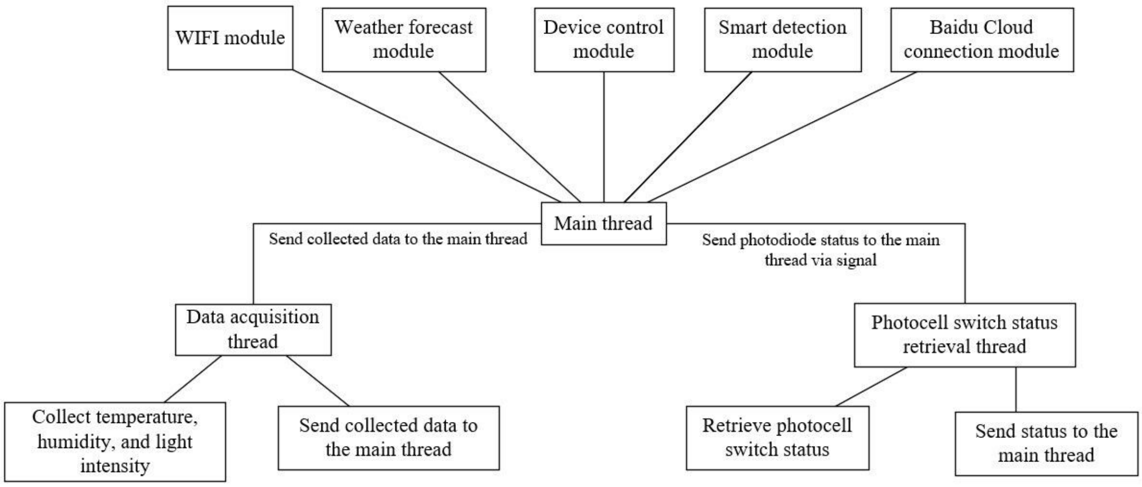

Figure 1. Overall System Design

The project is divided into WIFI connection module, smart access control module, data acquisition module, intelligent detection module, device control module, weather forecast module, and Baidu cloud interaction module. The WIFI connection module uses wireless networks for management and control to establish connections between clients and servers. The smart access control module intelligently recognizes if someone is approaching based on the infrared switch. When someone triggers the infrared switch, the login interface will automatically pop up, prompting the user to enter their username and password, which will be automatically matched with the database. The data acquisition module opens another thread to continuously read the temperature and humidity data from the sensor device file, calculate the temperature and humidity values, and obtain the light intensity values in the same way. These values are then passed to the main thread through signal passing to update the UI interface. The intelligent detection module will detect based on the set threshold values. The device control module allows users to control the lights, fans, and buzzer through the UI interface buttons. The weather forecast module retrieves JSON data from the internet using the GET method, parses the data, and displays the parsed data on the UI interface. The Baidu cloud interaction module is mainly used for connection, automatically publishing the collected temperature, humidity, and light intensity to the specified topic in JSON format. When the development board receives the JSON data forwarded from the cloud, it will respond accordingly.

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3. System Design

3.1. Hardware Configuration

The FS-MP1A development board is designed based on the STM32MP1 series of microprocessors from STMicroelectronics. This series of processors provides a heterogeneous architecture integrating the Arm ,Cortex -A7 and Cortex-M4 cores, enabling high-performance and flexible multi-core architecture as well as image processing capabilities while ensuring low-power real-time control and high functional integration. The FS-MP1A development board adopts the STM32MP157AAA3 chip, which is the most performance- and resource-rich in the series. Its dual-core ARM Cortex-A7/@650MHz processing performance, 3D GPU, and MIPI interfaces are the main performance differences from other products in the series. It mainly stores user door opening information, collects data, monitors video storage, and controls corresponding devices, all of which require hardware support.

3.1.1. Embedded Platform

The STM32MP1 microprocessor series is mainly characterized by high integration, fast efficiency, simultaneous complex multitasking processing and computation, and consideration for hard real-time characteristics. The STM32MP157A processor also embeds a Cortex-M4 32-bit RISC core, capable of operating at a maximum frequency of 209 MHz. The Cortex-M4 core features a Floating Point Unit (FPU) for single-precision, supporting single-precision data processing instructions and data types. Cortex-M4 supports a complete set of DSP instructions and a Memory Protection Unit (MPU) that enhances application security. The FS-MP1A development board comes with default configurations of 8GB eMMC flash and 512MB DDR3 memory. It supports WiFi/Ethernet connectivity, GPIO interfaces, USB interfaces, SD card interfaces, and various expansion interfaces to provide hardware support. The specific structure is as shown in the following diagram:

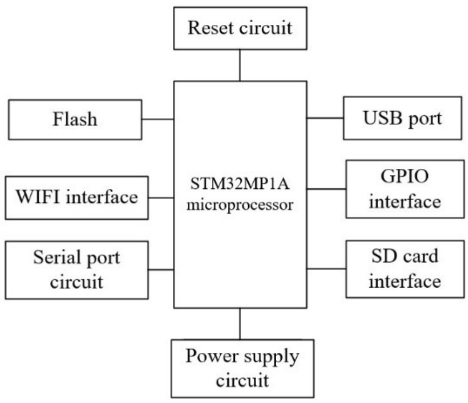

Figure 2. Hardware Design

3.1.2. Access Control Device

For the access control module in this project, the GPIO pin used for the photoelectric switch is PE15. When the photoelectric switch is obstructed, a command execution returns 0; when there is no obstruction, it returns 1.

3.1.3. Networking Equipment

The network connection in this design utilizes the FS-MP1A development board with the onboard AP6212 module, featuring a 2.4G WiFi + BT4.1 module. This module employs an external antenna with an IPEX Generation 1 (gold-plated, ¢2, 33.11.25, 0.5 inner core) RF connector. The antenna used is a 4dB omnidirectional PCB antenna.

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Figure 3. Antenna

3.1.4. Display Device

The display in this design utilizes the FS-MP1A development board equipped with a 1-channel RGB LCD interface. The interface features a flip-type FPC connector with a 40-pin spacing of 0.5mm, and it has the following characteristics:

(1)Supports up to WXGA (1366x768) @ 60fps.

(2)Supports 2 display layers and programmable colors, compatible with displays without built-in RAM.

(3)24-bit RGB interface, compatible with 16-bit/18-bit.

(4)I2C interface for capacitive touch screen.

(5)PWM output for backlight adjustment. The physical appearance and the LCD screen are shown below:

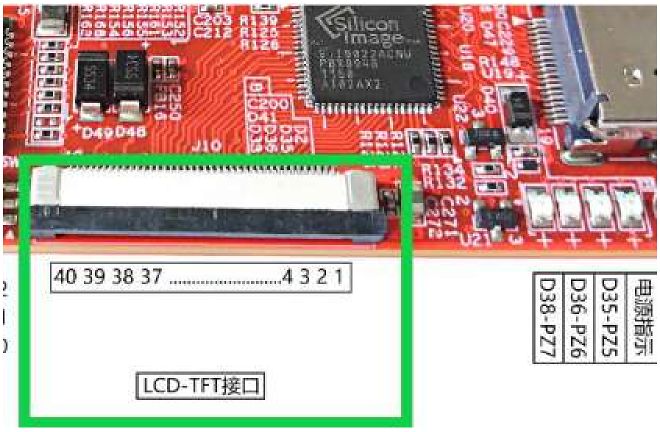

Figure 4. LCD Screen

Figure 5. Physical LCD (7-inch)

3.2. Software Design

According to the requirements, this project is implemented using a multi-threaded design to pass data obtained from multiple threads back to the main thread and display it on the UI interface. The project design includes six parts: network connection, access control design, data acquisition and detection, device control, weather forecast, and interaction with Baidu Cloud.

3.2.1. Network Connectivity Design

The principle of operation of this module involves using the wpa_supplicant tool to manage and control wireless networks. It serves as an application-layer authentication client for WPA,

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responsible for tasks such as authentication, login, and encryption. The wpa_supplicant tool consists of two programs: wpa_supplicant and wpa_cli. The wpa_supplicant program runs as a server in the background, serving client requests from wpa_cli to configure and connect to WiFi networks.

3.2.2. Access Control Design

This module is designed to intelligently recognize the presence of individuals using a photoelectric switch. When a person triggers the photoelectric switch, the login interface will automatically pop up, prompting the user to enter their username and password. The program will then automatically match the entered credentials with the database. If the username or password is entered incorrectly more than three times, an alarm will be triggered. If the login information is correct, the door will be opened.

When an object obstructs the photoelectric switch, it will return a value of 0. If there is no obstruction, it will return a value of 1. To achieve this functionality, a thread needs to be created to continuously monitor the status of the PE15 photoelectric switch. When the switch returns a value of 0, indicating the presence of a person, a signal will be sent to the main thread to prompt the display of the login interface. Upon successful login, a success signal will be sent, and in case of failed login attempts, a failure signal will be sent.

3.2.3. Data Acquisition and Detection Design

Data collection needs to be done in a separate thread, real-time reading of temperature and humidity sensor driver data, calculating the temperature and humidity values, and obtaining the light intensity values in the same way. These values are passed to the main thread through signal parameters and set on the UI interface. When the smart detection is enabled, the program will monitor based on the threshold you set. If the temperature exceeds the temperature threshold you set, the fan will automatically turn on; if the light intensity is below the threshold you set, the light will be turned on to increase the brightness of the illumination.

Temperature and humidity scale calculation:

$$Scale_{temp} = \frac{175.72 \times 1000 \times 4}{65535} = 10.7250097656 \tag{1}$$

Temperature and humidity data offset:

$$offset_{temp} = \frac{-46.85 \times 65536}{4 \times 175.72} = -4368 \tag{2}$$

Raw temperature and humidity data:

$$raw_{temp} = \frac{code_{temp}}{4} \tag{3}$$

The formula for temperature calculation is:

$$Tempreture\,(^{0}C) = \frac{175.72 \times \mathrm{Code}_{\mathrm{temp}}}{65535} - 46.85 \tag{4}$$

The final temperature calculation formula:

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$$Temperature(^{0}C) = (Raw_{temp} + Offset_{temp}) \times Scale_{temp} \div 1000 \tag{5}$$

Similarly, the formula for humidity calculation can be obtained:

$$Humidity(\%RH) = (Raw_{hum} + Offset_{hum}) \times Scale_{hum} \div 1000 \tag{6}$$

Create a thread to read the information from the device file, perform calculations to obtain temperature, humidity, and light intensity, then transmit the information to the main thread using signal parameters.

3.2.4. Equipment Control Design

Control the lights, fan, and buzzer through the UI interface buttons. The lights mainly consist of three LEDs - Led1, Led2, Led3 - for on and off control. The buzzer design involves sound events and tone events, with a tone value of 1000 and a duration of 1 second for sounding. To turn off the buzzer, set all values to 0.

3.2.5. Weather Forcast Design

After connecting to WIFI, retrieve information from the internet using the get method to obtain data in JSON format. Parse this data and set the parsed data on the UI interface.Define a request handler using the QNetworkAccessManager class; define an operation request using the QNetworkRequest class. QNetworkAccessManager *manager;

QNetworkRequest quest;

QNetworkAccessManageri,it is used to coordinate network operations, specifically to handle QNetworkRequest requests. QNetworkRequest is part of the Network Access API and holds the necessary information for sending a request over the network. It contains a URL and additional information that can be used to modify the request. After sending the request, a network reply signal will be received. Simply use QJsonDocument to parse the JSON data and obtain the information.

3.2.6. Baidu Cloud Interaction Design

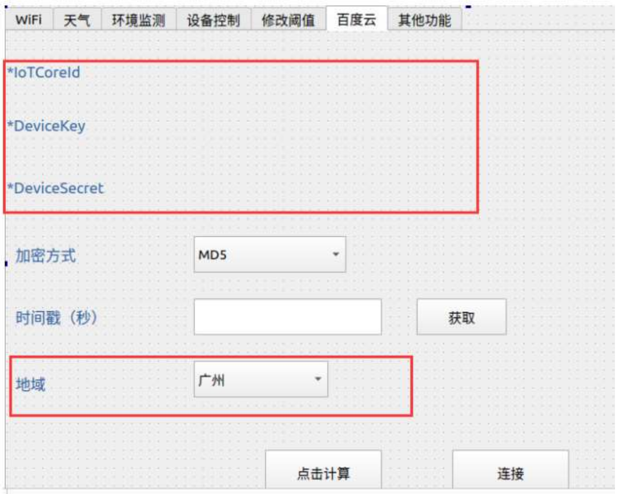

Figure 6. Baidu Cloud Interaction Interface

When creating a device on Baidu Cloud, the IoTCoreId, DeviceKey, and DeviceSecret (triplet) entered on the UI interface are combined to generate an address and username. The password is calculated using the MD5 encryption algorithm. Clicking the calculate button copies the calculated result to a member variable for ease of use during connection. Upon successful connection, a timer is started to automatically publish the collected temperature, humidity, and

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light intensity to a specified topic every 5 seconds. Additionally, the device subscribes to a topic for cloud-based device control. When the user publishes JSON data to the cloud, the development board receives and responds to the forwarded JSON data by controlling the states of the LED lights, fan, and buzzer based on the message content. The LED lights are controlled based on the values of led1, led2, and led3. For example, {"led1",1} will turn on led1 when received by the development board. The interface for Baidu Cloud interaction is shown in the image below.

4. System Testing

4.1. System Development Environment Setup

Linux is chosen as the operating system, arm-Linux-gcc-4.3.2 is selected as the cross-compiler, and testing is conducted on a virtual machine with Ubuntu installed.

4.2. Network Connection

Open the wlan0 interface, start the wpa_supplicant process, scan for nearby wireless networks, add a network connection, set the username and password, and then establish the connection. The target board will automatically assign an IP address. Finally, install u-boot on the development board and set the ipaddr and serverip. Download the uImage image file on the development board. In the final test, ensure that the connection is established, the image is downloaded to the board, and the network communication is successful.

4.3. Access Control System

After entering the UI interface of the access control system, you need to first trigger the photoelectric switch. By using a card to test the photoelectric switch on the expansion board, it will trigger the login page to pop up, as shown in the following image:

Figure 7. Access Control Test Image

The login interface is as shown in the following image:

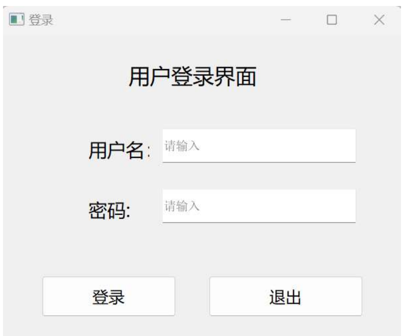

Figure 8. User Login Interface

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4.4. Data Acquisition and Detection

4.4.1. Data Acquisition Testing

Clicking on "environment monitoring," as shown in the following image, we can cover the sensor that detects ambient light and observe the changes in the light intensity information. Additionally, by placing a finger on the temperature and humidity sensor, we can observe changes in temperature and humidity, as shown in the following image:

Figure 9. Environmental Monitoring Interface

Figure 10. Environmental Monitoring Change Interface

4.4.2. Detection Testing

Clicking on the "modify monitoring threshold" module, you can see the interface for modifying the threshold values, as shown in the following image:

Figure 11. Threshold Modification Interface

The LED light section on the left is divided into 1st level illumination, 2nd level illumination, and 3rd level illumination. When the ambient light sensor detects light intensity, the

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corresponding threshold value will be used to turn on the lights. The fan start temperature on the upper right, for example, the threshold value set in the image is 28 degrees. When the temperature detected by the temperature and humidity sensor reaches 28 degrees, the fan will automatically start to simulate cooling. When we cover the ambient light with our finger and touch the temperature and humidity sensor, all the lights will be fully on, and the fan will start. As shown in the following imag:

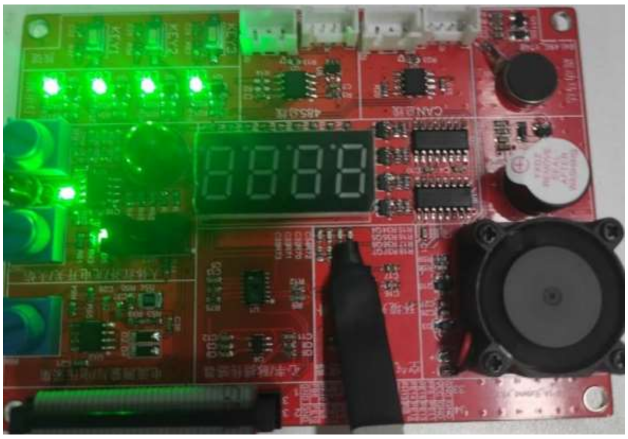

Figure 12. Physical Display

4.5. Equipment Control Testing

You can see three components. Clicking on the LED light section, when we select "on," you can see the corresponding lights on the expansion board. For example: if we set all three lights to "on." As shown in the following image:

Figure 13. Device Control Interface

You can see the corresponding lights lit up on the expansion board, as shown in the following image:

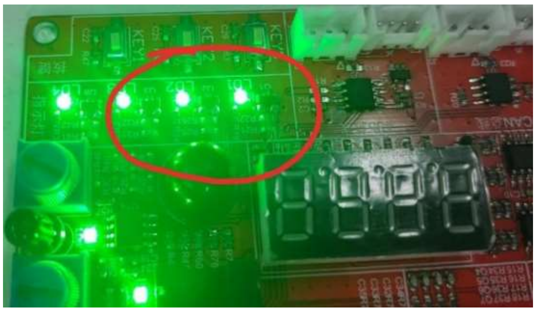

Figure 14. Physical Display

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4.6. Weather Forecast Testing

First, connect the development board to the Wi-Fi module to establish a network connection. Then click on the weather forecast module, select the city you want to know about, as shown in the following image:

Figure 15. Cities's choice

The following image shows the various indicators of the current city:

Figure 16. Select City Indicators

4.7. Baidu Cloud Interaction Testing

You need to connect to Wi-Fi first, then click on the Baidu Cloud connection module. First, you need to obtain a timestamp, then click on "calculate" to get the information you want to connect to. Finally, click on "connect" to achieve Baidu Cloud interaction.

Figure 17. Baidu Interaction Interface

5. Conclusion

This design is based on ARM for indoor smart home design, using the stm32mp1a core chip for development and design. The database is used to store resident information, and resident password verification is used for unlocking; data collection, detection, and weather forecast

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retrieval all require network support, as well as algorithm support for message push. In addition, device control is implemented on the UI interface for controlling lights, fans, and buzzers. This implementation also has some shortcomings, such as adding monitoring and peephole monitoring, which would be more in line with the "smart" concept. Monitoring can achieve real-time detection, and the peephole can identify incoming visitors, making it more secure and reliable.

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