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Design and Implementation of STM32 Microcontroller-based Smart Classroom System

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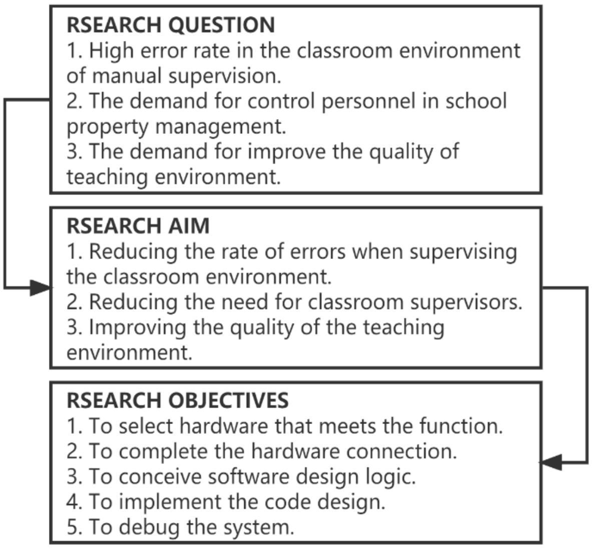
Abstract. Smart classroom is becoming a major trend in classroom construction. A smart classroom system with STM32 as the main control chip was designed. It could solve the problems of high error rate in the classroom environment of manual supervision, and satisfy the demand for personnel control in school property management and the quality of teaching environment improvement. Classroom environmental data was monitored using temperature and humidity sensors and light sensors, and displayed in real time through LCD screens. Electrical equipment such as air conditioners, curtains, lights and fans in the classroom were controlled by the master controller based on environmental data. The simulation test results showed that the system had a certain feasibility, and could accurately detect environment-related data and control equipment. The possible requirements of actual classroom intelligence were considered, and a smart classroom system design scheme with certain operability was proposed.

Keywords: STM32 microcontroller, smart classroom, control system.

1. Introduction

In 2008, IBM proposed the "Smart Plant"[1] strategy, which triggered a series of industrial revolutions. Later. Later, China proposed "sensing China"[2], and after the Internet of Things technology was officially listed in China's five emerging strategic industries. Smart campus reform based on Internet of Things technology has blossomed all over China. The classroom management of most colleges and universities is still in the situation of manual inspection and manual adjustment, and the demand for personnel deployed is large and inefficient at present [3-4]. As one of the most important components of the campus, classrooms also bear the responsibility of providing a place for teachers and students to learn knowledge, disseminate knowledge, and teach each other. Therefore, the transformation of classrooms was also particularly important in the process of intelligent reform of colleges and universities. Based on the above, the formulation of research question, aim and objectives was shown in Fig. 1.



RSEARCH QUESTION
1. High error rate in the classroom environment of manual supervision.
2. The demand for control personnel in school property management.
3. The demand for improve the quality of teaching environment.

RSEARCH AIM
1. Reducing the rate of errors when supervising the classroom environment.
2. Reducing the need for classroom supervisors.
3. Improving the quality of the teaching environment.

RSEARCH OBJECTIVES
1. To select hardware that meets the function.
2. To complete the hardware connection.
3. To conceive software design logic.
4. To implement the code design.
5. To debug the system.

Fig. 1: Formulation of research question, aim and objectives

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The structure of this paper was as follows:

- Overall system design
- Design of system hardware
- Design and analysis of system software
- System Simulation and Debugging
- Conclusion

A smart classroom system based on STM32 microcomputer was designed to solve the problems of high error rate in the classroom environment of manual supervision, the demand for control personnel in school property management, and the demand for improve the quality of teaching environment.

2. Overall System Design

2.1. System requirements design

According to the previous discuss, the system was designed to meet the following requirements:

- Monitoring the temperature and humidity of the classroom environment and intelligently regulate the ambient temperature and humidity to within the range of human comfort by controlling air conditioners, humidifiers, etc.
- Detecting the light intensity of the classroom environment and automatically turn on the lights when the ambient light intensity is below a certain value to protect students' eyesight.
- Entering the fire alarm mode when the ambient temperature is detected to be abnormally high.
- Intelligently controlling the opening and closing of curtains through stepper motors.

2.2. System framework design

As shown in Fig. 2, the software part of this smart classroom system could be divided into one main module, three sub-modules (screen display module, electrical equipment control module and environmental data monitoring module) and eight terminal modules (LCD module, LED module, button module, buzzer module, stepper motor module, relay module, temperature and humidity sensor module and photosensitive sensor module) according to the aforementioned functional description and hardware requirements of the smart classroom. The hardware part was composed of STM32 microprocessor, LCD screen, LED, KEY, BEEP, stepper motor, relay, DHT11 and photodiode. Classroom environment data is easier to know by teachers and students, through the data monitoring module to control the temperature and humidity sensor (DHT11) and light sensor (photodiode) real-time monitoring of the environment's temperature, humidity and light intensity, and with the screen display module to display the corresponding data of the environment on the LCD screen in real time. The work of lights, switches, curtains, fire alarms, air conditioners, fans and humidifiers were controlled by the microcontroller through the electrical equipment control module issued relevant instructions, when the environmental data monitoring module detected that the environmental data was above or below a certain threshold.

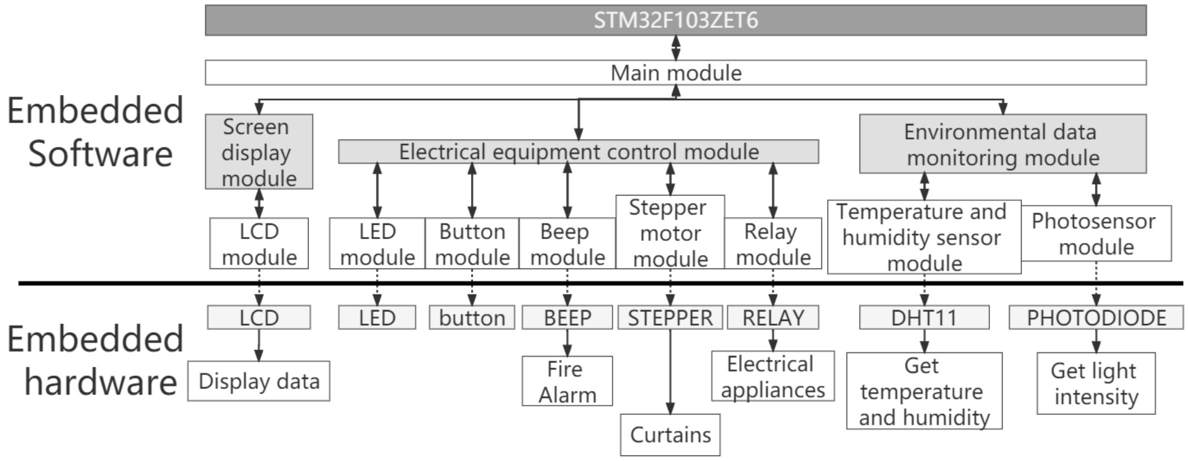


Fig. 2: Block diagram of the overall system structure

3. Design of System Hardware

The hardware design process starting with a minimal system [5] was as follows:

(1) Devices such as embedded processors and peripherals were selected according to the expected functions and usage environment conditions.

(2) The resources of the embedded processor were allocated based on the selected peripherals.

(3) The interfaces between the processor and the peripheral were designed.

3.1. STM32 microcontroller selection

The control core of this smart classroom system is the STM32F103ZET6, a low-end low-end 32-bit ARM microcontroller equipped with an ARM Cortex-M3 processor. The STM32F103ZET6 microcontroller has an embedded 8MHz RC oscillator with 512K bytes of flash program memory, up to 8 timers (3 x 16-bit timers, 1 x 16-bit with dead zone control and emergency braking, PWM advanced control timers for motor control, 2 watchdog timers and 1 system time timer) and up to 9 communication interfaces (2 I2C interfaces, 3 USART interfaces, 2 SPI interfaces, 1 CAN port and 1 USB 2.0 full-speed interface). Its core Cortex-M3 processor belongs to ARM's Cortex-M series, which is mainly for low-cost, low-power traditional single-chip microcomputer applications, such as industrial control, measuring instruments and medical equipment, etc., and can reach a working frequency of up to 72MHz, which is very in line with the cost considerations of large-scale intelligence in university classrooms, and can also meet the basic hardware needs of this project.

3.2. Environmental data monitoring module

As shown in Fig. 2, the environmental data monitoring module was mainly composed of temperature and humidity sensors and light-sensitive sensors, which was used to detect the temperature, humidity and light intensity of the environment.

DHT11 was selected to sense ambient temperature and humidity. DHT11 is an integrated humidity and temperature sensor with a calibrated digital signal output. It uses a dedicated digital module acquisition technology and temperature and humidity sensing technology, with high sensitivity, fast response time, good stability, small size and low power consumption, suitable for the system's environment. The encapsulation mode of DHT11 is 4-pin single-row package, which is convenient to connect. Pin 1 is connected to 3.3v-5v power supply, pin 2 is connected to corresponding data communication interface for data transmission to STM32 single chip microcomputer, pin 3 is suspended, pin 4 is grounded or negative power supply pole [6].

A photodiode was selected to monitor the ambient light intensity. When the photodiode is exposed to illumination, the saturated reverse leakage current increases greatly, and a photocurrent that changes with the incident light intensity is formed. The current in the circuit changes with the light intensity, and the ADC is used to read the change in the photodiode voltage to obtain the change in ambient light, and the resulting light intensity is displayed on the LCD [7].

3.3. Electrical equipment control module

The module was mainly composed of LED module, button module, buzzer module, stepper motor module and relay module, corresponding to the lights, buttons, fire alarms, curtains, air conditionings, fans and humidifiers and other electrical terminals. When the microcontroller receives the data sent by the sensors and makes certain judgments, it will issue relevant commands to control the operation of the relevant electrical devices.

3.4. Screen display module

LCD liquid crystal display was used to display temperature, humidity and light intensity data of classroom environment. LCD liquid crystal display was composed of two parallel glass substrates sandwiched by a liquid crystal box in the middle. The basic colours such as red, green and blue were formed by passing white light through the colours filter and controlling the current to control the light transmission of each pixel to control the colour of the pixel. It was a display mode with better brightness, better visibility, lower power consumption, mature technology and lowest cost [8].

3.5. System hardware physical diagram

The hardware connection diagram of this system was shown in Fig. 3. The USB data line was used by the CH340 conversion chip for program programming and power supply for the development board and various peripherals. The photodiode was connected to PE8, the relay was connected to PB7, the IN1, IN2, IN3 and IN4 of the stepper motor was connected to PB5, PB6, PB9 and PB8 respectively, and the relay was used as a switch with an external diode to simulate the relevant electrical devices.

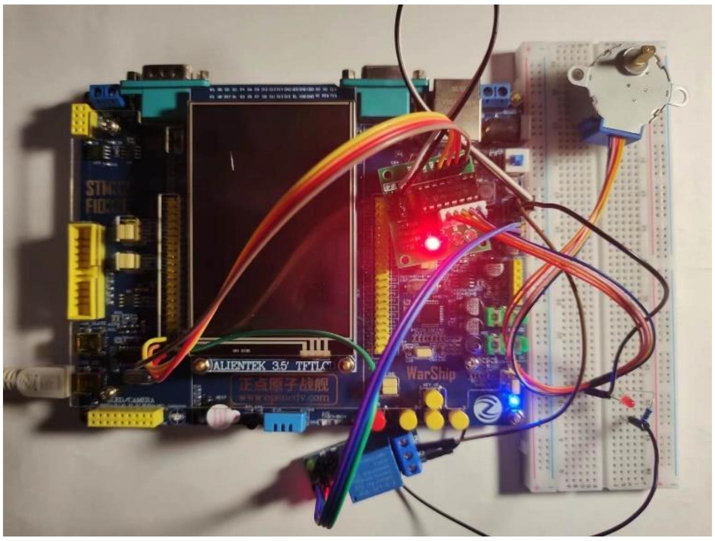


Fig. 3: Physical diagram of the system hardware

4. Design and Analysis of System Software

4.1. Introduction to the software design environment

MDK is the best development tool for ARM processors, especially for Cortex M core processors, and is backward compatible with MDK4 and MDK3, etc. It enhances the support for Cortex-M microcontroller development, provides flexible and easy-to-use Middleware, and unleashes the power of the microcontroller to provide a wide range of peripherals, so compared to It is more suitable for this system based on STM32F103ZET6 series microcontrollers than other software. The development was also done on ARM's Keil-MKD5[9].

4.2. Overall software design analysis

The structure of the software part of this system was relatively simple. By modularizing the functional partitions, each module was completed independently and integrated to realize the overall system software, and the overall design flow chart was shown in Fig. 4. Initialization of system service programs, initialization of subroutines of individual functional modules and initialization of interrupt service programs were included.

The environmental data monitoring module started working, monitoring the temperature, humidity, and light intensity of the classroom environment when the system was powered on, a one-second delay to cross the unstable state and completed a series of initializations. The temperature and humidity were got directly from the digital sensor DHT11 by the microcontroller. The light intensity was acquired according to the voltage value of the photoresistor converted by the ADC. Environmental data such as temperature, humidity and light intensity of the classroom were displayed in real time on TFTLCD, when the data was obtained by the microcontroller and sent to the LCD screen display module.

The environmental data obtained at the same time was judged by the microcontroller. Lights and curtains were opened and delayed for 2min to wait for the next monitoring of light intensity data, avoiding frequent lights on and off when the light intensity of the classroom environment fell below a certain threshold. The relay was turned on, the humidifier was powered on, the ambient humidity data rose, and the delay was 20min to wait for the next judgment of the humidity data, when the ambient humidity of the classroom was below a certain threshold. The humidifier was turned off and waited for the next data to judge if the ambient humidity in the classroom reached the threshold standard. Relays were driven to turn on the classroom air conditioner to lower the ambient temperature, when the classroom ambient temperature exceeded the first threshold. Local light flashing and buzzer alarms were turned on when the classroom ambient temperature exceeds the second threshold. The air conditioner was turned off if the ambient temperature fell below the first threshold.

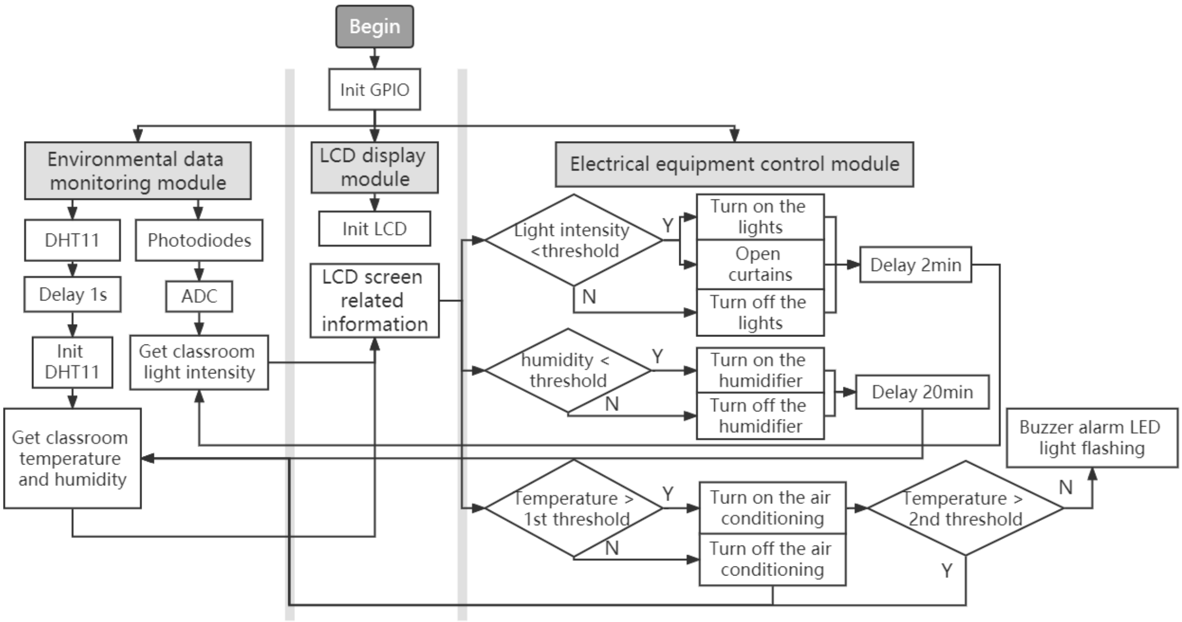
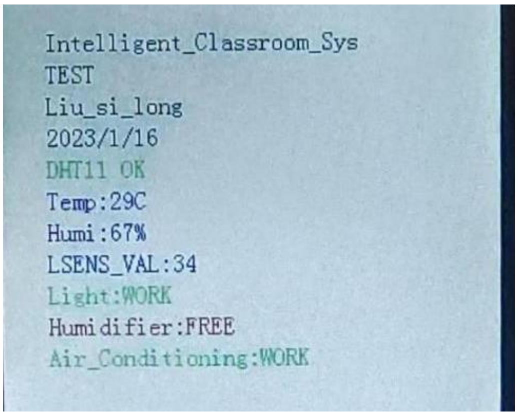


Fig. 4: The overall design flow chart of the software part

5. System Simulation and Debugging

The electrical equipment control module of this system was composed of lights, curtains, humidifiers, air conditioners and buzzers. LEDs were used instead of lights, stepper motors simulated the opening and closing of curtains, and the connection between LEDs and relays simulated the working and resting states of humidifiers and air conditioners through the lighting of LEDs in the system simulation and debugging. The microcontroller could run offline at this time.

The microcomputer was connected to the computer through USB, and then powered on, the hex file is programmed into the microcomputer through the serial assistant, when the written program was compiled on and the hex file was generated. DHT11 readiness, temperature, humidity, light intensity, lamps, air conditioner, humidifier, etc. could be seen on the TFTLCD screen when the programming was completed and waited for one second. The font was red, when the sensor was not initialized or when the electrical device was idle. The font was green when sensor initialization was complete or when electrical equipment was in the working state. The system effect was shown in Fig. 5.



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Intelligent_Classroom_Sys
TEST
Liu_si_long
2023/1/16
DHT11 OK
Temp:29C
Humi:67%
LSENS_VAL:34
Light:WORK
Humidifier:FREE
Air_Conditioning:WORK
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Fig. 5: System effect display

6. Conclusion

The design of the smart classroom system was implemented on the basis of STM32 microcontroller, through various sensor modules, LCD screen display modules and a series of electrical equipment terminals, with Keil-MDK5 as the development platform. Environmental data could be detected by the system through sensing devices. The work and fire alarm of related electrical equipment could be controlled by the system with certain data indicators.

The simulation test results showed that the system had a certain feasibility, and could accurately detect environment-related data and control equipment and could solve the problems of high error rate in the classroom environment of manual supervision, the demand for control personnel in school property management, and the demand for improve the quality of teaching environment.

This system could be used for the intelligent transformation of major universities and primary and secondary schools, which could effectively improve the comfort of the teaching environment, reduced the burden of teaching and supervision, reduced the cost of personnel consumption in the inspection classroom, and considered the possible requirements of the actual classroom intelligence. In summary, a design scheme of smart classroom system with operable, scalable and certain commercial value was proposed. The goals of the intended design were met.

7. Acknowledgements

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8. References

[1] P. Yang, YX. Yao, BB. Shi, et al. A review of research on smart campus construction [J]. *Modern Educational Technology*,2019,29(01):18-24.

[2] FF. Du. Experimental application of Internet of things technology in the construction of university wisdom campus [J]. *Shandong Industrial Technology*,2016,208(02):132.

[3] Donny Soh Cheng Lock, Indriyati Atmosukarto, Arthur Loo Wee Yeong, et al. Improving Operational Processes for COVID-19 Ready Smart Campus[J]. *Journal of Advances in Information Technology*,2022,13(06):597-603.

[4] Thanh-Hiep Nguyen, Duy-Nhat Tran, Doan-Linh Vo, et al. AI-Powered University: Design and Deployment of Robot Assistant for Smart Universities[J]. *Journal of Advances in Information Technology*,2022,13(01):78-84.

[5] YH. Wang, XK. Sun, ZC. Shi, et al. Embedded system principles and applications: STM32F103 series microcontrollers based on ARM CortexM3 core [M]. *Beijing: Tsinghua University Press*,2016: 60-61.

[6] Temperature and Humidity Module DHT11 Product Manual [EB/OL]. http///www.aosong.com.

[7] ZH. Liu. Photodiodes in physics[J]. *Family Life Guide*,2018(09):70.

[8] YP. Wang. Correlation analysis of TFT-LCD and OLED of display technology[J]. *Electronic World*,2021,623(17):13-14.

[9] Arm Limited. MDK-Middleware [EB/OL]. https://www2.keil.com/mdk5/middleware.