Intelligent Laboratory Management System Based on Loongson Chip

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Abstract: Traditional manual laboratory management is time-consuming and labor-intensive, while intelligent laboratory management systems can greatly improve the efficiency of laboratory management and are also an important condition for scientific and standardized management of school laboratories. The intelligent laboratory management system is an advanced network system with laboratory management and experimental management as its core. It can provide users with laboratory information, view laboratory personnel, laboratory management and other functions, and can recognize faces when wearing masks. Laboratories are important places for scientific research and teaching. This article takes Loongson 2k1000la as the core, STM32 as the lower computer development board, connects multiple sensors, uploads data to Alibaba Cloud Ubantu16 server, and can be controlled and synchronized through a mobile app. It can also be visualized in the cloud to build an intelligent laboratory management system. The system will mainly include the following three functions: temperature and humidity detection, fire prevention, RFID based device usage management, facial recognition attendance, and personnel information management. Through this system, management personnel can real-time monitor the situation of the laboratory, achieve intelligent management of the laboratory, and ensure the prevention of safety hazards. The combination of hardware platform and cloud server expands the functional scope of the system, while also reducing the computational burden of MCU, which conforms to the design principles of the Internet of Things and provides possibilities for realizing facial recognition, environmental comprehensive analysis, and data visualization services.

Keywords: Loongson; Intelligent Laboratory Management System; Environmental Monitoring; Face Recognition

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1 Introduction

1.1 Design Purpose

With the rapid development of technology, laboratories play an important role in scientific research and educational teaching. However, traditional laboratory management methods have some problems, such as inconvenient equipment management, inflexible resource scheduling, and incomplete security monitoring. To address these issues, intelligent laboratory management systems [1] have emerged. The intelligent laboratory management system utilizes the Internet of things technology [2] and artificial intelligence algorithms to achieve automated management of laboratory equipment [3] and intelligent scheduling of laboratory resources [4], thereby improving the efficiency and accuracy of laboratory management. Therefore, the laboratory management system is designed, which consists of the following functional modules: laboratory equipment management, laboratory resource reservation, laboratory personnel management, and laboratory safety monitoring [5].

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1.2 Application Fields

Intelligence is the ultimate goal and inevitable trend of intelligent laboratories, which includes informatization, digitization, and dataization. Therefore, the application of a qualified smart laboratory management system is not only about simply integrating enterprise data online, but also combining database based information technology with laboratory management need [6-9], helping laboratory staff greatly improve work efficiency. Currently, it is expected that this intelligent laboratory management system will be widely used in the following fields;

Scientific research and education sharing: The intelligent laboratory management [10] can be used in universities, research institutes and scientific research institutions to assist in the management of experimental equipment, resource sharing and experimental data management. Real-time laboratory data can be found on mobile app and webpage, including laboratory number, instrument usage, temperature and humidity. And can make an appointment to enter the room in advance, which can improve the efficiency of laboratory operation, the accuracy of data management and the safety of the laboratory.

Dangerous experimental laboratory: Safety is the most basic guarantee of everything. Therefore, the intelligent laboratory management system realizes real-time monitoring of the laboratory by installing cameras and sensors. The system can detect the temperature, humidity, gas concentration and other parameters in the laboratory, and set the threshold freely. Once an abnormal situation is found, the system will automatically give an alarm and take corresponding measures to ensure the safety of the laboratory and prevent the occurrence of laboratory safety accidents.

Important equipment laboratory: the intelligent laboratory management system can detect the actual running time of experimental instruments, evaluate the use of instruments and upload them to the system for analysis and calculation, and generate standardized and visual data, which is convenient for querying the actual use of equipment.

1.3 Main Technical Features

(1) Using the Loongson 2k1000la [11] development board as the lower computer motherboard, with a 32 microcontroller as the auxiliary board, and equipped with sensors such as K210 and RFID [12], laboratory entry and exit clock in, usage duration statistics, personnel count statistics, and other functions are implemented, and uploaded to the cloud for real-time access.

(2) The system will automatically collect temperature, humidity, and smoke concentration data intermittently to prevent safety hazards such as fires in a timely manner. A mobile app has been developed for users to display the system's collection of laboratory temperature, humidity, personnel information, and item lending status. The motherboard will send the obtained data information to the mobile app through Bluetooth, and Bluetooth will enable transparent transmission function using serial communication. The upper computer APP is developed based on E4A for Android, with Bluetooth function, real-time display of laboratory personnel information, clock in, alarm status, etc. It can also be remotely controlled on the mobile phone, setting various environmental thresholds (including but not limited to temperature and humidity), and turning off and on alarm reminders.

(3) The addition, deletion, modification, and check-in of personnel information will be synchronized to the MySQL database. We used the Alibaba Cloud IoT platform and DataGear to visualize data, and connected it wirelessly to the Loongson development board, 32 [13], and corresponding sensors to receive real-time data and compare laboratory experiments horizontally and vertically.

(4) The motherboard sends the obtained data information to the mobile app through Bluetooth, and the Bluetooth enables transparent transmission function using serial communication. The upper computer APP is developed based on E4A Android and has Bluetooth function. It can display laboratory personnel information, clock in, alarm status, etc. in real time. It can also be remotely controlled on the mobile phone to set various environmental thresholds (including but not limited to temperature and humidity), turn off and on alarm reminders, add, delete, modify and clock in personnel information. The above personnel information will be synchronized to the MySQL database.

1.4 Key Performance Indicators

The key performance indicators of the intelligent laboratory management system include the following aspects:

Real time monitoring and control capability: The sys-

tem can monitor the equipment status, environmental parameters (such as temperature, humidity, gas concentration, etc.), and personnel entry and exit in the laboratory in real time, and can quickly take corresponding control measures. The response time of the system is less than 3 seconds to ensure the safety and normal operation of the laboratory.

(1) Accurate identity verification capability: The system uses facial recognition technology [14] for identity verification, which has high accuracy and robustness, and can accurately determine the identity of personnel entering the laboratory and compare it with personnel information in the database. The system's misidentification and omission rates are less than 1%, ensuring that only authorized personnel can enter the laboratory.

(2) Efficient security monitoring and early warning capabilities: The system is capable of real-time monitoring of security parameters within the laboratory, and can promptly issue alerts and notify administrators. The detection accuracy and warning accuracy of the system are greater than 98.5% to detect potential safety hazards in advance and prevent accidents from occurring.

(3) Data analysis and management capabilities: The system is capable of analyzing and managing data within the laboratory, including equipment usage, maintenance records, failure rates, etc. Capable of data storage and processing, able to provide statistical analysis reports and equipment maintenance recommendations, helping laboratory managers develop reasonable management strategies.

(4) Scalability and compatibility: The system should have good scalability and compatibility, be able to adapt to laboratories of different sizes and types, and be fully integrated with other management systems (such as laboratory information management systems, security monitoring systems, etc.) to achieve comprehensive laboratory management [15].

1.5 Main Innovation Points

(1) Application of internet of things technology: The intelligent laboratory management system utilizes internet of things technology [16] to connect devices, sensors, cameras, etc. in the laboratory to the network, achieving remote monitoring and control of devices [17]. Through IoT technology, laboratory managers can monitor the working status of laboratory equipment anytime and anywhere, detect abnormal situations in a timely manner, and take corresponding measures to improve the efficiency and accuracy of laboratory management.

(2) Facial recognition identity verification: The intelligent laboratory management system uses facial recognition technology for identity verification, real-time identification of personnel entering the laboratory, and comparison with personnel information in the database to determine their identity and permissions. Compared to traditional access control systems, facial recognition identity verification is more secure and convenient, which can effectively prevent illegal personnel from entering the laboratory and ensure the safety of the laboratory.

(3) Intelligent security monitoring and warning: The intelligent laboratory management system achieves real-time monitoring of the laboratory by installing cameras and sensors. The system can detect parameters such as temperature, humidity, and gas concentration in the laboratory. Once an abnormal situation is detected, the system will automatically issue an alarm and take corresponding measures. In addition, the system can also use artificial intelligence algorithms [18] to analyze and predict safety data in the laboratory, detect potential safety hazards in advance, and effectively prevent accidents from occurring.

(4) Data analysis and management: The intelligent laboratory management system can automatically track the usage of laboratory equipment and provide recommendations for equipment maintenance and updates [19]. By analyzing laboratory data, the system can discover information such as equipment usage and failure rates, helping laboratory managers develop reasonable equipment maintenance plans and improve equipment utilization and lifespan.

2 System Composition and Function Description

2.1 Overall Introduction

2.1.1 Overall Function Description

The intelligent laboratory management system is main-

ly divided into three categories: security management, equipment management, and personnel management.

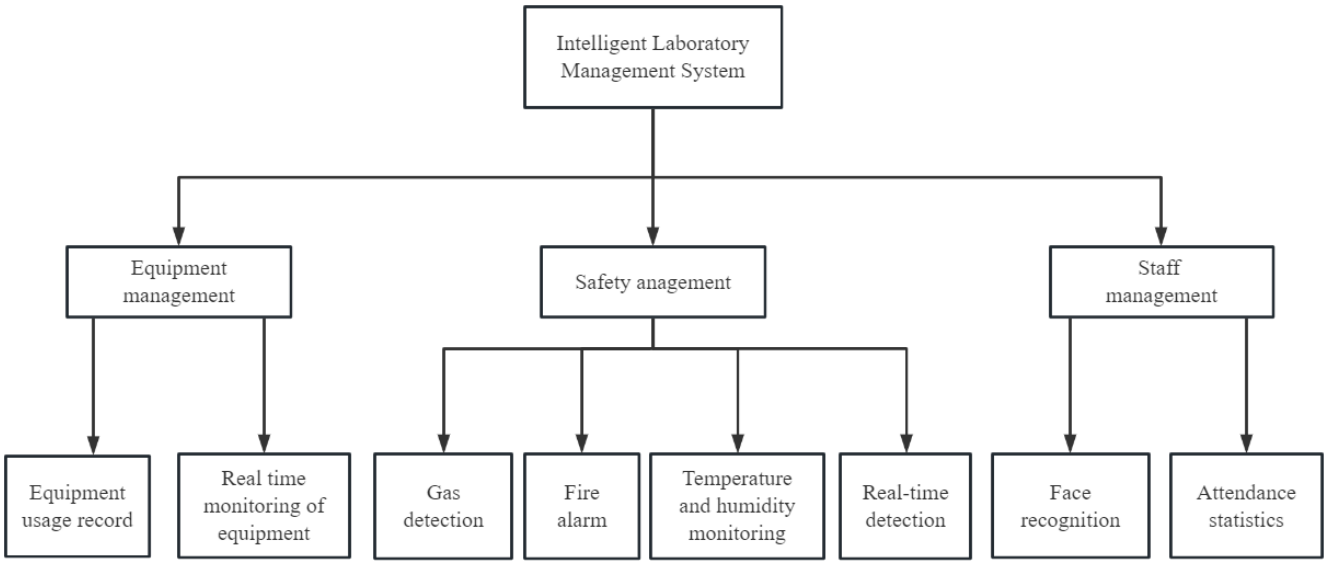

Figure 1 The intelligent laboratory management system

(1) Equipment management

Intelligent laboratory equipment management mainly includes remote monitoring, maintenance, and updates of equipment. In order to achieve remote monitoring of equipment, IoT technology can be used to connect laboratory equipment to the network, enabling real-time monitoring and control of the equipment. Through sensors and intelligent algorithms, the system can monitor the working status of equipment in real time, such as temperature, humidity, pressure, etc. Once the equipment malfunctions, the system will promptly issue an alarm and take corresponding measures. In addition, the system can automatically track the usage of equipment and provide recommendations for equipment maintenance and updates.

(2) Personnel management

Intelligent laboratory personnel management mainly involves the identification and permission management of laboratory personnel. In order to achieve personnel management in intelligent laboratories, facial recognition based identity verification technology can be used. By installing cameras at the laboratory access control point, the system can identify personnel entering the laboratory in real time and compare their identity and permissions with the personnel information in the database. At the same time, the system can also record the entry and exit time and behavior of personnel for subsequent data analysis and management.

(3) Security management

Intelligent laboratory safety management mainly involves laboratory safety monitoring and early warning. In order to achieve safety monitoring of the laboratory, cameras and sensors can be installed to achieve real-time monitoring of the laboratory. The system can detect parameters such as temperature, humidity, and gas concentration in the laboratory. Once an abnormal situation is detected, the system will automatically issue an alarm and take corresponding measures to ensure the safety of the laboratory. In addition, the system can also utilize artificial intelligence algorithms to analyze and predict safety data in the laboratory, in order to detect potential safety hazards in advance.

2.1.2 Hardware Platform Introduction

Mainly controlled by the Loongson 2k series, it communicates with the upper computer through wireless connection and serial communication, connects multiple modules (DHT11, RFID, etc.) to achieve human-computer interaction, completes temperature and humidity collection, clock in and sign in, and uploads real-time data to the cloud to monitor laboratory environment data and laboratory personnel clock in situation. Regional nodes are connected to RFID readers to achieve intelligent clock in control and monitor laboratory temperature and humidity data. By adding an infrared temperature probe, it can detect the body temperature of personnel and send real-time data to the cloud and mobile app. The motherboard will send the obtained temperature, humidity, smoke concentration, and RFID recognition

data to the mobile app via Bluetooth. At the same time, it is equipped with a camera module to recognize masks during the epidemic.

2.1.3 Software Platform Introduction (E4A, MySQL, and Alibaba Cloud)

(1) The APP is developed based on E4A for Android, with Bluetooth function, real-time display of laboratory personnel information, clock in, alarm status, etc. It can also be remotely controlled on the mobile phone, set various environmental thresholds (including but not limited to temperature and humidity), turn off and on alarm reminders, add, delete, modify and clock in personnel information. The above personnel information will be synchronized to the MySQL database.

(2) The cloud database provided by Alibaba Cloud is a stable, reliable, and scalable online database service. Based on the Feitian distributed system and high-performance storage with full SSD disks, it supports MySQL, SQL Server, PostgreSQL, and PPAS (highly compatible with Oracle) engines. By default, it deploys a primary backup architecture and provides a complete solution for disaster recovery, backup, recovery, monitoring, migration, and other aspects, completely solving the troubles of database operation and maintenance.

2.2 Introduction to Each Module

2.2.1 Development Board

Loongson 2k10001a is a high-performance processor introduced by China Loongson Company, which adopts advanced 8-layer metal interconnection technology and has high integration. Its main frequency can reach 1.5GHz, supports superscalar technology, and can execute multiple instructions at the same time, which improves the processing efficiency. The processor also has multi-core design, supports multi-thread parallel execution, and can better meet the needs of multi-task processing.

Loongson 2k10001a also has strong floating-point computing capabilities and provides a variety of peripheral interfaces, including USB PCI, Ethernet and other technologies can meet the needs of different application fields.

Loongson 2k10001a has also done a good job in power consumption control, adopting dynamic voltage frequency regulation technology to dynamically adjust power consumption and performance according to different load conditions, in order to achieve better energy balance.

The STM32 microcontroller is widely used in the field of embedded systems, including industrial automation, consumer electronics, automotive electronics, and various other applications.

STM32 has high performance and low power consumption characteristics, as well as rich peripheral interfaces, including universal input/output ports, serial communication interfaces, timers, etc.

STM32 also provides a comprehensive development tool and software ecosystem, including a free integrated development environment (IDE), debugging tools, software libraries, etc. It also supports multiple communication protocols and interface standards, such as CAN, SPI, I2C, etc., providing a wider range of connectivity and communication capabilities.

2.2.2 RFID Module (RC522)

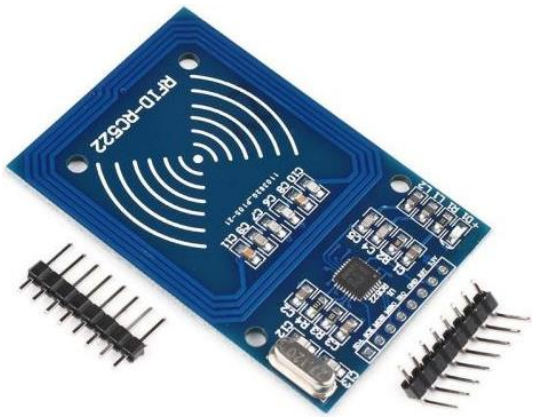

Figure 2 The RC522 module

The RC522 module is an RFID (Radio Frequency Identification) reader module based on 13.56MHz radio frequency technology. The RC522 module uses a highly integrated RF front-end and data processing module, with the ability to quickly read and write tag data.

Here are some of the main features and functions of the RC522 module:

RF communication frequency: The RC522 module operates on the 13.56MHz RF communication frequency, which complies with the ISO/IEC 14443A/MIFAME standard.

Supports multiple RF cards: The RC522 module can read and write ISO/IEC 14443A RF cards, including MIFARE Classic 1K, MIFARE Classic 4K, and MIFARE

Ultralight.

SPI interface: The RC522 module communicates with the main controller (such as Arduino) through the SPI (Serial Peripheral Interface) interface, simplifying the connection and data transmission with the microcontroller.

High speed read and write: The RC522 module has a fast data transmission speed and can achieve high-speed read and write operations on RF cards.

Built in security features: The RC522 module supports encryption and decryption functions for RF cards, enabling secure storage and transmission of data.

Low power design: The RC522 module adopts a low-power design, suitable for use in battery powered applications.

Rich development resources: The RC522 module has many open source libraries and sample codes available for developers to quickly start using the module.

By using the RC522 module, various applications based on radio frequency identification technology can be built, such as access control systems, smart card readers, item tracking systems, etc. It is widely used in fields such as the Internet of Things, security verification, and identity recognition.

2.2.3 Temperature and Humidity Se-nsing Module (DHT11)

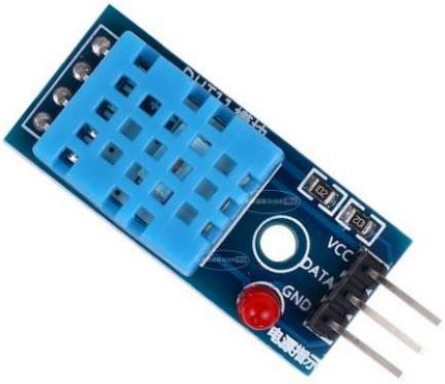

Figure 3 The DHT11 module

DHT11 is a digital temperature and humidity sensor, which is a single wire sensor that can monitor the temperature and humidity of the environment in real time and output the data in the form of digital signals. Here are some characteristics of DHT11:

(1) Easy to use: DHT11 is easy to use, just connect the data cable to read temperature and humidity.

(2) Wide temperature and humidity measurement range: The temperature measurement range of DHT11 is 0℃ -50℃, and the humidity measurement range is 20% - 90%.

(3) Highly accurate: The temperature and humidity measurement accuracy of DHT11 is relatively high, with a temperature accuracy of ±2 degrees Celsius and a humidity accuracy of ±5%.

(4) Good stability: DHT11 adopts dedicated digital module acquisition technology, has good anti-interference ability, and high stability.

(5) Digital output: The temperature and humidity data of DHT11 is output in the form of digital signals, which are transmitted through a single wire and are very convenient for integration into various applications.

2.2.4 Smoke Concentration Module (MQ2)

Figure 4 The MQ2 module

MQ2 is a gas sensitive sensor that can detect the presence of various combustible gases and convert the detected gas concentration into an analog voltage output. Here are some characteristics of MQ2 sensors:

(1) Multiple gas detection: MQ2 can detect various combustible gases, including liquefied gas, methane, smoke, etc.

(2) High sensitivity: MQ2 has high sensitivity and can detect the presence of combustible gases at low concentrations.

(3) Highly stable: The MQ2 sensor uses special gas sensitive materials and circuit design, which has good stability and long lifespan.

(4) High precision: MQ2 can provide accurate gas concentration measurement results with high measurement accuracy.

(5) Quick response: The MQ2 sensor has a fast response speed and can detect gas changes and output results in a short period of time.

2.2.5 WiFi Module (ESP8266)

Figure 5 The ESP8266 module

The ESP8266 is a low-cost and low-power WiFi module, which integrates the microcontroller and WiFi functions, and can be used as the core of the single-chip system to realize wireless connection with the Internet. The following are the main features of ESP8266:

(1) Low power consumption: The ESP8266 has excellent power management capabilities and is suitable for battery powered applications.

(2) Integrated WiFi: ESP8266 supports 802.11b/g/n wireless standard, can connect to wireless network, and realize communication with the Internet.

(3) Powerful processing capability: The ESP8266 module integrates a 32-bit Tensilica processor internally, which can run advanced applications.

(4) Rich peripheral interfaces: The ESP8266 module provides multiple General Purpose Input/Output (GPIO) pins for interaction with sensors, actuators, and other external devices.

(5) Programmable: Developers can use C/C++language and Arduino integrated development environment (IDE) to program the ESP8266 module.

2.2.6 Bluetooth Module (HC-05)

HC-05 is a classic Bluetooth module commonly used for wireless serial communication. The following are the main features of the HC-05 module:

(1) Bluetooth communication: HC-05 supports Bluetooth 2.0 specification and can communicate with other Bluetooth devices such as smartphones, tablets, and computers.

(2) Serial communication: The HC-05 module communicates with the main controller (such as a microcontroller) through a serial port (UART) interface to achieve wireless data transmission.

(3) Master slave mode: HC-05 can switch between master mode and slave mode. In main mode, it can actively connect to other Bluetooth devices; In slave mode, it waits for other devices to actively connect.

(4) Transparent transmission mode: HC-05 supports transparent transmission mode, which can wirelessly transmit serial data through Bluetooth, making serial communication between two devices wireless.

(5) Pairing and Encryption: The HC-05 module supports simple pairing (PIN code) and data encryption, providing a certain degree of security.

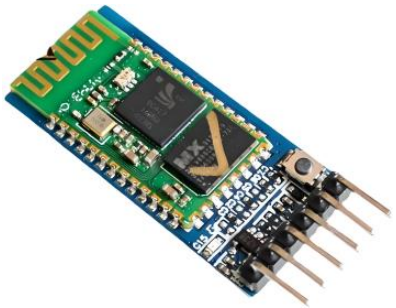

Figure 6 The HC-05 module

2.2.7 Camera Module (K210)

Figure 7 The K210 module

The K210 is a low-power, high-performance AI chip, which adopts a unique architecture and design to meet the needs of edge computing, IoT devices and other fields for efficient AI processing. The following are the main features of the K210 chip:

(1) AI processing unit: The K210 chip has a dedicated AI processing unit built in, which can efficiently perform common machine learning and deep learning tasks such as image recognition, object detection, and language processing.

(2) Multimedia processing capability: The K210 chip supports hardware accelerated image processing and audio processing functions, which can quickly process image and audio data.

(3) Rich peripheral interfaces: The K210 chip provides multiple peripheral interfaces, including GPIO, SPI, I2C, etc., for easy communication and interaction with other devices.

(4) Dual core processor: The K210 chip is equipped with two RISV architecture processing cores, one of which is the Dual Core and the other is the Assistant Core. This dual core design can fully utilize the processing power of the chip.

(5) Low power design: The K210 chip adopts advanced power management technology and has excellent power efficiency, making it suitable for applications with high power consumption requirements such as mobile devices and IoT devices.

3 Completion Status and Performance Parameters

3.1 Function Display

This article will showcase and evaluate the performance of three functions: fire prevention in laboratory environment, attendance information of laboratory personnel, and usage status of laboratory equipment.

3.1.1 Environmental Monitoring

The system will automatically collect temperature, humidity, and smoke concentration data intermittently to prevent safety hazards such as fires in a timely manner. The AAP data interface of the mobile phone is shown in the following figure.

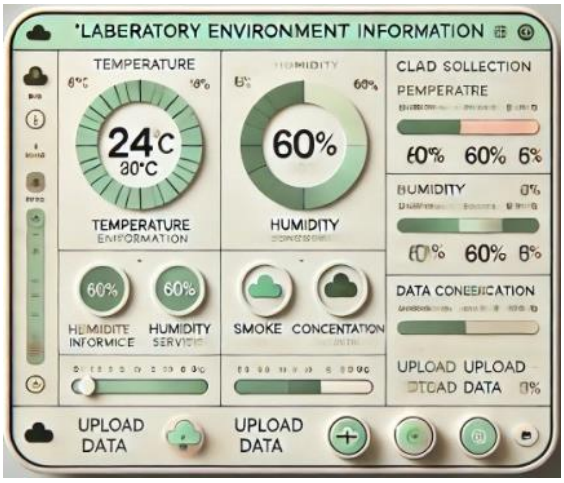

Figure 8 Laboratory environment information

3.1.2 Personnel Management

When someone is detected approaching and identified as a laboratory personnel, the door lock will automatically open and a voice "welcome" announcement will be made. At the same time, laboratory personnel can also use RFID to clock in and check in. The system will record the check-in time of this person, and the mobile interface is displayed as shown in the following figure.

In order to facilitate the management of personnel information, functions such as personnel check-in analysis and personnel information modification are provided for backend operators. The function menu bar is shown in the following figure.

Figure 9 Personnel information

3.1.3 Equipment Management

In order to unify the management of laboratory equipment, the system uses a one person one card swiping method to complete the use of experimental equipment. The system will automatically record the personnel who use the equipment and the time of use and end. In order to facilitate the management of devices, this system provides operations such as adding and modifying devices. The mobile interface is shown in the following figure.

Figure 10 The management of devices

3.2 Performance Parameters

Table 1 Performance Parameters

Project	Development board response time	APP response time	Server response time
Temperature and humidity detection	<1s	<1s	<1.5s
Smoke detection	<1s	<1s	<1.5s
Face recognition	<2s	<1s	<1.5s
Attendance clock in	<1s	<1s	<1.5s
Equipment Usage Record	<1s	<1s	<1.5s

3.3 Front End Interface

This system uses Alibaba Cloud IoT platform and DataGear for data visualization display.

In order to make all data in the system globally accessible, this design adopts the DataGear platform for data visualization development, which presents all data intuitively and clearly, and automatically refreshes the data in real-time, as shown in the following figure.

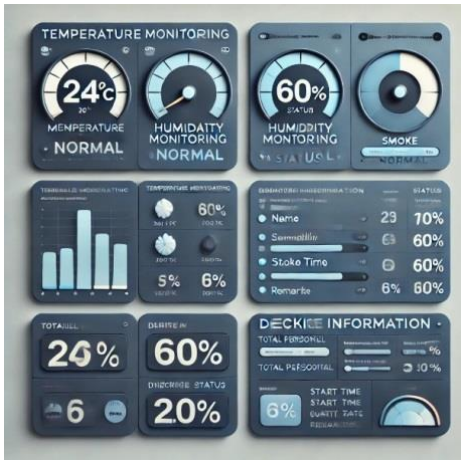

Figure 11 DataGear Data

4 Summary

Facial recognition technology requires improved efficiency and an expanded database to enhance resource richness. Sensor sensitivity also needs upgrading, and future plans include acquiring more cost-effective sensors for performance comparisons. High energy consumption across modules poses challenges, particularly as laboratory areas expand, significantly increasing costs. The Internet of Things (IoT) and cloud computing are pivotal to the evolution of smart laboratories, enabling unified management of software and hardware, intelligent course scheduling, and enhanced information security. Smart labs represent the future of experimental teaching, fostering interaction, sharing, and collaboration while providing a secure and efficient learning environment. As cloud platform-based teaching in universities continues to develop, future research will focus on leveraging machine learning to analyze backend data, offering more targeted teaching services. The system design involved the Loongson development board, environmental detection modules, and microcontrollers, and we deeply appreciate the resources and training provided by the Loongson team.

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