An IoT-based sensor inspection system.

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***Abstract* — This paper proposes a sensor inspection system based on the Internet of Things. The system consists of three parts: hardware modules, software services, and interaction systems, including four core components such as sensor modules, cloud databases,front-end visualization platforms, and backend support systems. It aims to solve the high-efficiency and low-cost issues in industrial safety inspections and has important application prospects and future development potential. The system realizes an "sensing module monitoring——data cloud upload——manual online assessment——instrument problem diagnosis" intelligent factory inspection workflow.**

***Keywords:* industrial inspection, Internet of Things (IoT), Data Visualization**

I. INTRODUCTION

Currently, many industrial areas in China generally lack regular inspections and anomaly investigations, and some underground instrument pipe galleries have poor environmental conditions, making manual inspections difficult and posing significant safety risks. Safety issues in industrial inspections cannot be effectively addressed, resulting in frequent damage to related equipment, causing huge economic losses and even major safety accidents. The Tianjin Binhai New Area explosion on August 12th and the Yanhu community explosion in Shiyan, Hubei on June 13th are both ultimately caused by problems in the industrial inspection process, including irregular procedures, inadequate supervision, and ineffective implementation of regular inspections. On the contrary, enterprises do not pay attention to the inspection of industrial equipment, at least industrial equipment is always shut down, affecting production, and at least major accidents will occur, causing greater losses. [2] Therefore, the inspection of industrial equipment is very important [4].

This shows that as China's industry moves toward intelligence, an efficient and accurate sensor inspection system is needed.

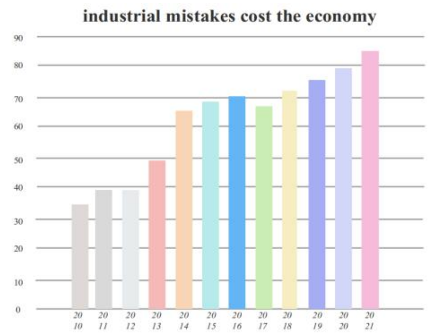

Fig. 6 Industrial accident loss economy in China

II. LITERATURE REVIEW

Aziz [1] conducted a review of WSNs for condition monitoring in industrial applications. The author also discussed the challenges, including power management, data processing, and security.

Hossain [2] reviewed the use of WSNs in various industrial applications. The study emphasized the need for reliable and robust communication protocols to ensure seamless data transmission in harsh industrial environments.

Aziz [3] conducted another review of WSNs for industrial applications, focusing on the challenges and opportunities associated with the technology.

Sahoo [4] surveyed the use of WSNs for industrial monitoring and control. The study highlighted the challenges associated with WSNs, including network topology design, data aggregation, and security.

Sahoo [5] conducted a review of WSNs for industrial automation, emphasizing the importance of reliable and robust communication protocols.

III. DESIGN METHODOLOGY

This project focuses on the establishment of a self-built Internet of Things (IoT) security inspection system as its core, and gradually constructs three components: hardware modules, software services, and interaction systems. The hardware materials and software platform used by the sensor are shown in Table 1.

Table. 1 The hardware materials and software platform

System	Material type	Specific model
Hardware System	Sensor Control Board	ESP32
	Temperature and Humidity Sensor	DHT11
	Ultrasonic Sensor	HC-SR04
	Gas Monitoring Sensor	MH-Z19B
	Sound Intensity Sensor	MAX4466
	GSM Module	SIM800L
Software System	Cloud Server	Alibaba Cloud ECS
	IoT Platform	Alibaba IoT Platform
	Video Streaming System	EZVIZ Cloud
	SMS Short Message Service	Alibaba Cloud SMS
	Backend Framework	Kitex
	Distributed System	Etcd
Interactive System	Local Database	Room
	Visualization Interface	Jetpack Compose
	Network Request Framework	Retrofit
	Web Components	ECharts

We aim to achieve a smart factory inspection workflow of "sensor module monitoring, data cloud uploading, manual online evaluation, and instrument problem diagnosis". The specific implementation and production process are shown in Figure 1.

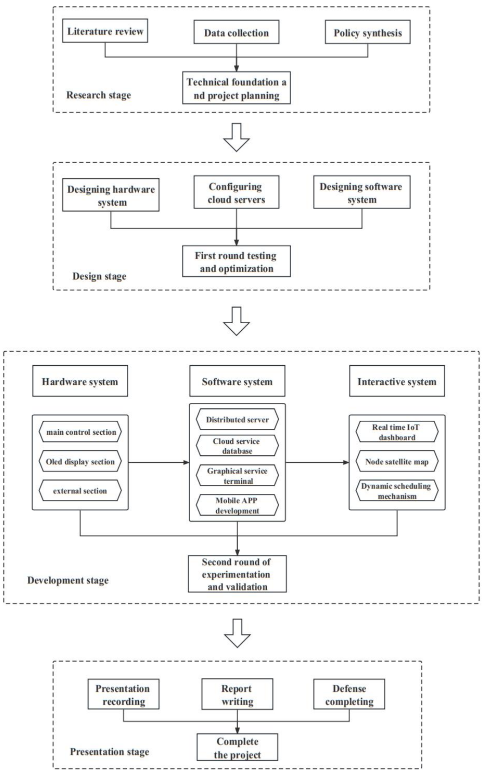

Fig. 1 Overall development process diagram

The system consists of three major components: hardware modules, software services, and interaction systems, mainly including five core components: sensor modules, cloud databases, front-end visualization platforms, and back-end support systems. It aims to solve the industry's demand for efficient and cost-effective industrial safety inspections and has significant application prospects and development potential. Firstly, the system collects industrial indicators such as temperature, humidity, or content through sensor modules in the field, and then transmits it in JSON format to the cloud database for storage and visualization on the web dashboard, which is monitored by workers and fed back to manual online evaluation for instrument status diagnosis. Ultimately, it achieves a smart factory inspection workflow of "sensing module monitoring—data cloud upload—manual online assessment—instrument problem diagnosis".

3.1 Hardware Design

3.1.1 Power Management Section

The IP5306 sensor power management chip is selected as the power management unit. The power management circuit can be used for charging and battery supply management, including single-cell lithium battery charging, direct current 5V input power supply, and 4-LED power display. Additionally, it can communicate with the microprocessor via the I2C interface, enabling automatic charging, battery power detection, and system maintenance functionalities.The schematic diagram of the charging circuit designed by us is shown in Figure 2.

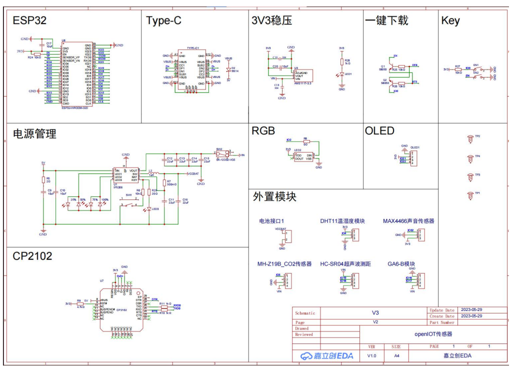

Fig. 2 Circuit design schematic

3.1.2 Main control section

The ESP32 system-on-chip (SoC), designed and developed by Espressif, is selected as the main control chip and IoT communication module. It is a low-power and highperformance SoC with an integrated wireless module that supports both Wi-Fi and Bluetooth communication technology.

The ESP32 can perform low-power background tasks, has rich resources and flexible communication methods. In particular, the ESP32's built-in wireless module supports Wi-Fi, and we use the ESP32 as a sensor for ADC acquisition and iot communication The circuit boards in Figures 3 and 4 are designed as a Sensor for ADC acquisition and IOT communication.

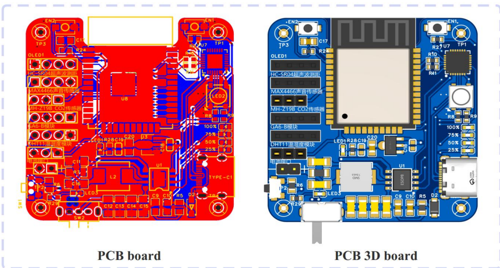

Fig. 3 Sensor printed circuit board

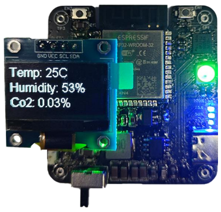

Fig. 4 The sensor physical diagram

3.1.3 Shell design section

In order to protect the main control board of the sensor and facilitate installation and maintenance, we designed a customized enclosure based on the size and shape of the sensor. The enclosure is made of durable polymer material, which is lightweight, and corrosion-resistant. Suitable openings are also left for interfacing with the OLED screen and external modules.

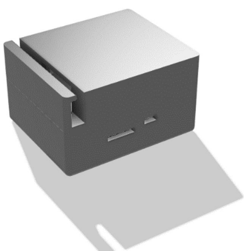

Fig. 5 3D rendering of the shell

3.2 Software Services

3.2.1 Integration with IoT modules

The collected data is transmitted in JSON format to the cloud server. In the event of abnormal data in the device, it is provided to the workers through a website to verify if the instrument is operating normally.

3.2.2 Real-time instrument platform

Considering the need for factory equipment maintenance workers to have a user-friendly graphical interface for real-time data monitoring, this project has developed a well-designed, natural and interactive visual control panel that helps administrators understand the data visible within their domain, as shown in Figure 6.

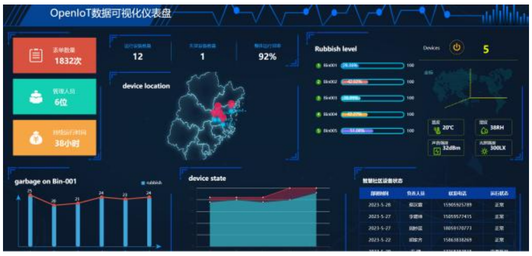

Fig. 6 Data visualization page of the system

3.2.3 Sensor operation modes

The ESP32 is used to interrupt and detect the external sensor module's operating state and transmit the operating information to the cloud. As shown in Table 1, the sensor displays its operating mode on the main control board through RGB color changes.

.Table. 1 Sensor operating mode

Mode	Light Status
Normal operation	RGB green
Network connecting	RGB blue
Network exception	RGB red
Module exception	RGB red blink
Battery(100%)	4 LED lights on
Battery(75% to 100%)	3 LED lights on
Battery(50% to 75%)	2 LED lights on
Battery(25% to 50%)	1 LED lights on
Low battery	4 LED lights off
Charging mode	LED blink

3.3 Interactive System

In the interactive part, to build a user-friendly system interaction mode, this project defines a graphical dashboard for IoT hardware based on the Echarts framework. Through a series of chart styles, the data is presented to relevant personnel in a more intuitive way, striving to create a convenient and efficient user experience. Figure 7 shows the interface of the visual dashboard and back-end interaction interface

(1) Real-time data update:

Sensors establish WebSocket long connections with the client and server, and the server updates the information on the client management panel through message issuance, realizing low-latency and high-concurrency data display functions.

(2) Satellite map display:

This system uses a satellite map display to provide precise location information for IoT module nodes, presenting the location status of various IoT nodes and sensors clearly. This facilitates factory managers designated nodes in the shortest possible time.

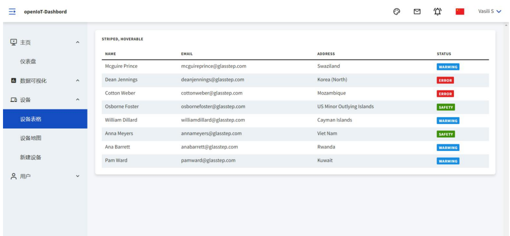

Fig. 7 Back-end interaction interface

IV. EXPERIMENT SETTING AND DATA ANALYSIS

Experimental equipment: accessories box (like Figure 8), sensor module, air conditioning system, cloud database, front-end visualization platform, back-end support system. The experimental steps are as follows:

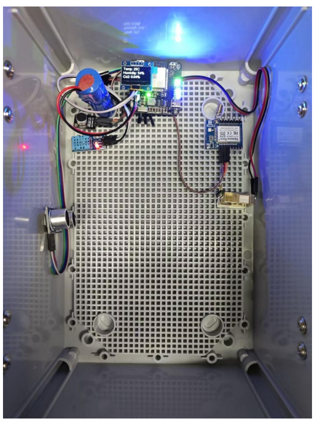

Fig. 8 Accessories box

1. Install sensor modules in the accessories box to simulate an industrial production environment.

2. Start the sensor modules and collect the data of industrial indicators such as temperature, humidity and CO_2 concentration.

3. Transmit the collected data through the cloud database to the front-end visualization platform and display it on the dashboard.

4. During the experiment, use simulated abnormal situations such as air conditioning control and fire alarm to observe whether the sensor system can timely detect and send alarm information to management personnel.

5. Figure 9 and Table 2 show the collected experimental data. Evaluate the experimental data, including error, accuracy, stability and real-time performance,.

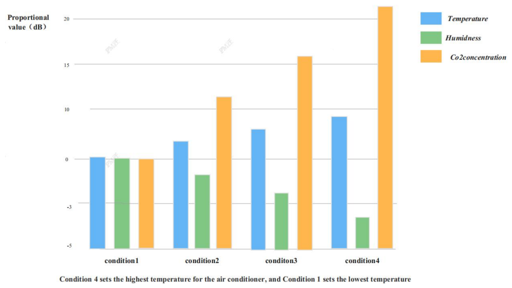

Fig. 9 Data acquisition in different conditions

Table.2 The error between the collected data and the real data

Condition	Temperature(℃)	Humidess(%)	Co2(%)
25℃/49%/0.4%	25	49.1	0.38
75℃/39%/5%	73	37.4	4.96
103℃/32%/1%	106	31.6	1.24
196℃/22%/2%	201	22.1	2.17
error	2.7%	2.7%	5.6%

Through the experiment, we verified the stability and reliability of the system. The experimental data show that the system can operate stably and process large amounts of data, while accurately and in real-time monitoring and collecting industrial indicator data. The system can also timely detect abnormal situations and send alarm information to the management personnel. In simulated abnormal situations such as air conditioning failure and fire, the system can detect and send alarm information to the management personnel in a timely manner, ensuring the safety of the production environment. At the same time, the stability and reliability of the system have also been verified.

V. CONCLUSION AND FUTURE WORK

In this paper, a sensor system based on IoT was successfully implemented using various hardware, advanced cloud servers, and a graphical user interface. The system utilized multiple sensor modules such as ultrasonic sensors, gas monitoring sensors, and sound intensity sensors to monitor and collect real-time data on the status of industrial equipment. Moreover, the system stored and displayed collected data through a cloud database and a front-end visualization platform, which helped companies optimize their production processes and enhance production efficiency. The experimental results demonstrated that the system can accurately and in real-time monitor and collect industrial indicators' data, and promptly discover abnormal situations to send alarms to management personnel. Furthermore, the system's stability was also verified.

In the future, we will further improve the system's functionality and performance, including:

1. Introducing more sensor modules, such as laser sensors, pressure sensors, etc., to expand the system's monitoring range and accuracy.

2. Optimizing the system's data processing and transmission methods to improve data's real-timeity and accuracy.

3. Introducing machine learning and artificial intelligence technology to analyze and predict the collected data to increase the system's level of intelligence.

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