ISSN: 2664-9640

Design of Intelligent Agriculture IoT Monitoring and Control System

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Abstract

With the rapid development of modern agriculture, traditional agriculture relies heavily on the input of pesticides and fertilizers, leading to increasingly serious problems of resource waste and environmental pollution. To address these challenges, the application of Internet of Things technology in agriculture has become particularly important. This article introduces a smart agriculture monitoring and control system based on the Internet of Things (SAIMCS), which integrates sensor technology, communication technology, and computer technology to achieve real-time monitoring and control of agricultural environmental parameters. The system is capable of real-time collection of soil moisture, temperature CO2 concentration and other environmental data are transmitted to the central control system through wireless networks for data analysis and decision-making, achieving automatic regulation of the agricultural environment. The experimental results indicate that, SAIMCS significantly improves agricultural production efficiency, reduces resource waste, and promotes sustainable development of agriculture.

Keywords

Intelligent Agriculture; IoT Monitoring; Agriculture Monitoring and Control System; Agricultural Environmental Parameters.

1. Introduction

Traditional agriculture relies heavily on the use of pesticides and fertilizers, which not only causes great waste of resources but also serious pollution to the environment. With the global emphasis on ecological environment protection and the promotion of sustainable development policies, traditional agriculture is facing severe challenges. In China, most agricultural production still relies mainly on manual experience for management, lacking systematic scientific guidance, resulting in low production efficiency and low resource utilization.

The development of facility agriculture technology provides new opportunities for the transformation of modern agriculture. In order to achieve a high level of facility agricultural production and optimize biological environment control, the progressiveness of information acquisition means is crucial. Wireless sensor networks, as a highly integrated modern information technology, provide a new technology for information acquisition and processing. Through a large number of low-energy and low-power intelligent sensor nodes, various environmental information can be collaboratively monitored, perceived, and collected in real-time, and processed and transmitted[1].

This article proposes a Smart Agriculture Internet of Things Monitoring and Control System (SAIMCS), aimed at achieving refined management and efficient control of various stages of agricultural production through IoT technology. During the planting preparation stage, the

ISSN: 2664-9640

system is able to collect real-time soil information through sensor networks to guide planting decisions. During the planting and cultivation stage, the system achieved control over temperature, humidity Real time monitoring and automatic control of environmental parameters such as CO2 to ensure crop growth under optimal environmental conditions[2]. During the crop growth stage, the system monitors the crop growth environment and nutrient status in real-time through sensors, and combines expert experience to regulate the environment and optimize the crop nutritional status. In the harvest stage, the system collects and provides feedback on the performance of agricultural products to improve the accuracy of harvest.

This system has demonstrated its enormous potential in improving production management efficiency, saving labor costs, and providing scientific data support in experiments[3]. SAIMCS is not only an important tool for achieving modernization of agricultural production, but also a key technology for promoting sustainable agricultural development.

2. System Design

2.1. Overall System Framework

SAIMCS adopts a B/S architecture, namely a browser/server architecture, aiming to achieve real-time monitoring, data analysis, and remote control of environmental parameters of farmland and greenhouses. The system is based on sensor networks and transmits data to the server for processing and storage through wireless communication technology. Users perform data queries, monitoring, and control operations through the browser. Simultaneously adopting a layered design, from top to bottom are the presentation layer, service layer, data layer, and perception layer.

The presentation layer, also known as the application layer, is the top-level of the system, mainly responsible for displaying the user interface, user interaction, and business logic processing. At this layer, users interact with the system through browsers or mobile applications, including login, monitoring data display, remote control, agricultural operations, agricultural material management, agricultural technology services, and other functions. Users access different functions through a browser[4].

Service layer: The service layer is the core layer of the system, responsible for functions such as data processing, business logic processing, and decision support. This layer mainly consists of backend services and business logic, responsible for processing requests from the application layer and calling the data provided by the data layer. After logical processing, the results are returned to the application layer.

Data layer: The data layer is the data storage and management layer of the system, responsible for storing various data generated by the system, including environmental data, monitoring data, agricultural inputs, agricultural data, user information, operation logs, etc. This layer uses MySQL database and related technologies for data storage and management, and provides interfaces for data reading and updating to the service layer[5]. This system adopts a separate database design scheme, which is divided into four major databases: basic business database, physical network database, shared database, and video monitoring database. Each library is isolated from each other and data serial communication is completed through service interfaces.

Perception layer: It is the infrastructure layer of the system, including hardware devices, network devices, various sensors, etc., responsible for implementing functions such as data collection, transmission, and device control. This layer provides various infrastructure support to ensure the normal operation of the system and accurate data collection[6].

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2.2. System Function Design

The Smart Agriculture Internet of Things Monitoring and Control System (SAIMCS) integrates multiple functional modules to fully support various aspects of agricultural production. The overall system functional design diagram is shown in Figure 1.

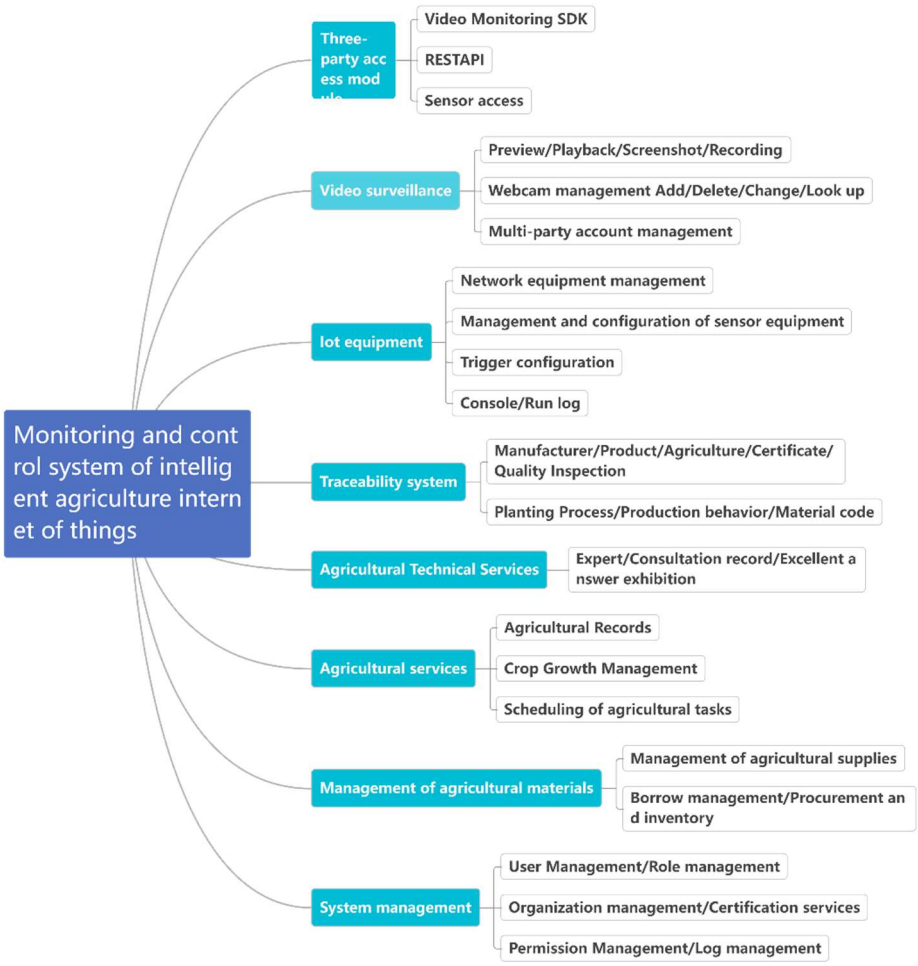

Figure 1. The overall system functional design diagram

(1) Third party access services

Function Description: The third-party access service aims to provide open interfaces to ensure system compatibility and scalability. By integrating with video surveillance SDKs, providing REST API services, and supporting sensor access, the system can seamlessly integrate with third-party services and applications[7].

Main functions:

Open API: Provides rich REST APIs, supports third-party application access, enables data sharing and functional expansion.

Video monitoring SDK integration: supports the integration of various video monitoring SDKs for unified management and calling.

Sensor access: Supports multiple sensor protocols (such as MQTT TCP, HTTP access, enabling data collection and device management.

(2) Video surveillance

Function Description: The video monitoring module provides real-time video monitoring of agricultural land, greenhouses, and other areas, ensuring the safety of agricultural production

ISSN: 2664-9640

and the convenience of management. At the same time, the module supports functions such as monitoring historical storage, remote playback, online monitoring screenshots, and online recording, which comply with national standard access requirements.

Main functions:

Real time video monitoring: View real-time monitoring footage of agricultural land and greenhouse areas to ensure production safety.

Monitoring history storage: Store monitoring videos and support playback of historical monitoring images at any time.

Remote playback: View past video surveillance records through the remote playback function.

Online screenshots and recordings: Real time screenshots and recordings of monitoring footage, saving important monitoring information.

National standard access: supports access to monitoring equipment according to national standards, achieving standardized management.

(3) IoT equipment

Function description: The IoT device management module is responsible for managing and controlling various IoT devices and sensors, ensuring the accuracy of data collection and the normal operation of the devices. Support MQTT TCP and HTTP protocols are used to access devices, and indicator trigger modules are provided for threshold warning setting, real-time operation console for remote control of devices, and data collection.

Main functions:

Device management: Manage and monitor all connected IoT devices and sensors.

Protocol support: Supports MQTT Multiple protocols such as TCP and HTTP ensure the flexibility of device access.

Indicator Trigger: Configure and manage indicator triggers to achieve threshold warning and real-time alarm.

Remote control: Provides a real-time control console that supports remote control and operation of devices.

Communication logs: Record and manage device communication logs for easy anomaly tracking and troubleshooting.

(4) Traceability system

Function Description: The crop traceability system provides traceability functionality throughout the entire process from planting to harvesting, ensuring food safety and controllable quality. The system is equipped with a agricultural service module, providing full process management of agricultural product traceability, including supplier, product, agricultural product, authorization certificate, quality inspection report, planting process, production behavior, and material code management processes.

Main functions:

Planting records: Record the entire process information of crops from planting to harvesting.

Supply chain management: Manage supplier information and the circulation process of agricultural products.

Authorization certificate: Manage authorization certificates and quality inspection reports related to agricultural products.

Production behavior tracking: Track and record the production behavior and process of crops.

Material code management: Generate and manage material codes to achieve traceability and query of agricultural products.

(5) Agricultural technology services

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Function description: The agricultural technology service module provides agricultural technology guidance and consulting services, helping farmers to scientifically plant and manage. Support expert online Q&A, and farmers can communicate with experts online for inquiries. At the same time, provide a database of basic technical experts to help improve the productivity of agricultural machinery and increase the ability of breeding and breeding technology.

Main functions:

Online Q&A: Support farmers to communicate with experts online for technical Q&A and consultation.

Expert database: Provides an agricultural technology expert database to help farmers obtain professional technical support.

Technical document library: stores and manages various agricultural technical documents and materials.

(6) Agricultural services

Function description: The agricultural service module records and manages agricultural activity information, improving the efficiency and standardization of agricultural management. Provide auxiliary functions such as recording agricultural activities of farmers, managing and recording crop growth, automated agricultural task scheduling, and agricultural reminders to assist farmers in production.

Main functions:

Activity record: Record the agricultural activities of farmers and form a complete agricultural record.

Growth management: Manage the growth status and stage records of crops.

Task scheduling: Automated scheduling of agricultural tasks, optimizing agricultural arrangements and execution.

Agricultural reminder: Provides a reminder function for agricultural activities to help farmers carry out agricultural operations in a timely manner.

(7) Agricultural input system

Function Description: The agricultural input system provides agricultural input management and services, ensuring efficient and standardized agricultural input supply. This mainly includes functions such as agricultural input supply management, agricultural input sharing, agricultural input borrowing, and inventory management.

Main functions:

Supply Management: Manage agricultural supply channels and supplier information.

Agricultural input sharing: Realize the sharing and allocation of agricultural input resources, and improve the utilization rate of agricultural inputs.

Borrowing Management: Provides functions for borrowing and returning agricultural inputs.

Inventory management: Real time management of agricultural inputs inventory to ensure the stability of agricultural inputs supply.

(8) System Management

Function Description: The system management module provides basic support services for system operation, including user management, permission management, log management, etc., to ensure the security and stability of the system.

Main functions:

User management: Manage system user information and user roles.

Permission management: Configure and manage system permissions to ensure system security and data confidentiality.

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Log management: Record system operation logs and operation logs for easy system maintenance and troubleshooting.

3. Database Design

The data layer of the Smart Agriculture IoT Monitoring and Control System (SAIMCS) adopts a separate database design scheme, which is divided into four modules: basic business database, IoT database, shared database, and video monitoring database. Each database is isolated from each other and data serial communication is completed through service interfaces.

3.1. Basic Business Database

The basic business database is the core part of the data layer of the Smart Agriculture Internet of Things Monitoring and Control System (SAIMCS), responsible for storing and managing various business data generated by the system, including user information, role information, data dictionary, authorization information, agricultural records, agricultural input information, system logs, etc. The design goal of this database is to ensure the integrity, consistency, and efficient access of data, and to support the implementation and expansion of business logic.

3.2. Internet of Things Database

The IoT database is an important component of the data layer of the Smart Agriculture IoT Monitoring and Control System (SAIMCS), mainly responsible for storing and managing data from various IoT devices and sensors, such as temperature, humidity, soil humidity, soil temperature, carbon dioxide concentration, illumination, and other data information. The design goal of this database is to ensure the real-time and accuracy of sensor data, as well as the efficiency of equipment management, to support the intelligent and refined management of agricultural production. This library is mainly responsible for data collection and storage, device management, data collection logs, alarm and event management, historical data storage, and query functions. Real time monitoring and intelligent management of agricultural production environment have been achieved through the management of sensor data and device information. Data processing and analysis provide users with scientific decision-making basis. The alarm and event management module helps users respond to abnormal situations in a timely manner. The historical data storage and query module supports long-term data analysis and trend prediction, providing strong data support for the development of smart agriculture.

Table 1. Sensor Configuration Information Table (iot_sensor)

AttributeName	Data Type	Length	Data meaning
id	bigint	20	Primary key
sensor_name	varchar	64	name
sensor_dname	varchar	32	Storage Field Name
sensor_unit	varchar	32	unit
sensor_address	int	4	Register Address
sensor_len	tinyint	4	Register occupation length
sensor_decimal	tinyint	4	Decimal places
sensor_format	varchar	255	Collection formula
sensor_plc	varchar	32	PLC configuration address
sensor_status	varchar	32	state

ISSN: 2664-9640

Table 2. Networking Device Configuration Table (iot.net_devices)

AttributeName	Data Type	Length	Data Meaning
id	bigint	20	Primary key
dev_sn	varchar	32	Device SN
farm_id	bigint	20	farm
land_id	bigint	20	massif
dev_imei	varchar	15	Equipment IMEI
dev_iccid	varchar	20	Binding card number
dev_type	varchar	32	Equipment types
dev_online	varchar	16	Device online status: online, offline, default offline
dev_relay_status	varchar	16	Electronic relay
relay_run_time	varchar	1024	Relay time interval
dev_model	varchar	32	Equipment model
dev_parent_id	bigint	20	Superior node ID, if present, defaults to 0
dev_group	varchar	32	Group information, if needed
dev_address	varchar	255	Device Location Description
dev_lng	varchar	20	longitude
dev_lat	varchar	20	latitude
dev_altitude	varchar	255	altitude
dev_at_pwd	varchar	32	AT command password
plant_type	varchar	64	raise crops
dev_active_time	timestamp	0	Device activation time

3.3. Shared Database

The shared database is responsible for storing and managing the data that is open and shared within the system. These data include sensor data, monitoring data, geographic information, standard information, agricultural technology data, etc., to achieve data exchange and sharing. The mutual isolation between libraries ensures the security and reliability of data, ensuring that the system operates efficiently while providing scientific data support and technical guidance for agricultural production.

3.4. Video Surveillance Database

The video surveillance database is mainly responsible for storing and managing various video surveillance data generated in the system. The design goal of this database is to ensure efficient storage, fast retrieval, and secure management of video data to support real-time monitoring and historical retrospective analysis of agricultural production areas. This library mainly provides functions such as video capture logs, operation logs, video recording, historical video recording, and exception recording.

4. System Functions and Implementation

4.1. Development Environment Setup

Building a stable and efficient development environment is crucial. This environment should include high-performance servers and development workstations, using Ubuntu CentOS or Windows operating system, equipped with Visual Studio Code IntelliJ IDEA and other integrated development tools, using Java Python, JavaScript, and their corresponding development frameworks such as Spring Boot. The database management system adopts MySQL, and version control uses Git and its hosting platform Gitee. Choose Docker containerization tool, configure Jenkins for continuous integration and deployment tools, and test tools include JUnit and Selenium. By selecting and configuring these components

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reasonably, it is possible to ensure efficient collaboration and compatibility among various modules of the system, improve development efficiency, and ensure stable operation and maintenance of the system.

4.2. Video Monitoring Module

The video surveillance module plays a crucial role in the Smart Agriculture Internet of Things Monitoring and Control System (SAIMCS), designed and implemented to provide comprehensive, real-time, and efficient monitoring and management functions for agricultural production areas. This module includes camera management, real-time preview, monitoring data storage, historical monitoring playback, online screenshot and recording, and supports national standard access. The camera management function allows users to register and configure camera devices, monitor camera status in real-time, and ensure the normal operation of the devices. The real-time preview function provides high-definition and low latency video streaming playback, supporting simultaneous preview of multiple video streams, making it convenient for users to monitor the situation in areas such as farmland and greenhouses in real time. The monitoring data storage function adopts efficient video compression algorithms and distributed storage architecture to ensure the security, reliability, and easy access of video data. The historical monitoring playback function supports retrieving and playing historical videos by time period and camera position, helping users analyze crop growth and environmental changes. The online screenshot and recording function allows users to capture and record surveillance videos in real time, saving critical moments of footage. The system is also fully compatible with national standard protocols, ensuring seamless integration with various monitoring devices and systems. Through these functions, the video monitoring module can effectively improve the efficiency and accuracy of agricultural production management, ensuring the safety and stable operation of agricultural production.

4.3. IoT Equipment Modules

The IoT device module plays a crucial role in the Smart Agriculture IoT Monitoring and Control System (SAIMCS), and its functional design and implementation aim to manage and control various IoT devices, ensuring the accuracy of data collection and the normal operation of the devices. This module includes device management, indicator triggers, remote control communication logs, operating console, and supports MQTT Multiple protocols such as TCP and HTTP are used to meet the communication needs of different devices.

4.4. Traceability System

The agricultural product traceability system in the Smart Agriculture Internet of Things Monitoring and Control System (SAIMCS) covers multiple management processes, including supplier management, product management, agricultural product management, authorization certificate management, quality inspection report management, planting process management, production behavior management, and material code management. Among them, supplier management includes supplier information entry, supplier relationship management, and supplier evaluation; Product management includes product information entry, product traceability code generation, and product archive management; Agricultural product management includes monitoring the growth of agricultural products, collecting and managing agricultural products, and managing the entry and exit of agricultural products; Authorization certificate management includes certificate issuance and certificate inquiry; Quality inspection report management includes the input of quality inspection information and the generation of quality inspection reports; Planting process management includes planting plan management and planting environment monitoring; Production behavior management includes production record management and production process tracking; Material code management includes material code generation and material code association. These functions achieve data

ISSN: 2664-9640

traceability and management through information technology, combined with IoT technology to monitor production environment and process data in real-time, providing strong support for agricultural product quality and safety, and improving the transparency and controllability of the production process.

4.5. Agricultural Technology Services and Agricultural Services Module

The agricultural technology services and agricultural management module plays a key role in the SAIMCS system, aiming to provide efficient and professional agricultural technology support and agricultural management services for farmers. The system integrates a series of functions, including but not limited to online Q&A, expert library, technical document library, planting sharing, agricultural activity recording, growth management, task scheduling, agricultural prompts, etc., providing farmers with a comprehensive intelligent solution for agricultural production. Through online Q&A and expert libraries, users can quickly obtain solutions and suggestions from experts in the agricultural field, while the technical document library provides users with rich agricultural technology materials and practical information. The planting sharing function promotes experience sharing and technical exchange among farmers, making agricultural production more collaborative and interactive. Agricultural activity recording and growth management, through data collection and analysis, help farmers scientifically manage the planting process, achieving precision and optimization of agricultural production. Task scheduling and agricultural reminders provide good guidance and assistance in practical operations, making agricultural activity arrangements more reasonable and efficient. In summary, the comprehensive functional design and implementation of agricultural technology services and agricultural modules have effectively improved the management level and production efficiency of agricultural production, injecting strong impetus and wisdom into the sustainable development of agriculture.

4.6. Agricultural Input System

The agricultural input system, as one of the key components of the Smart Agriculture Internet of Things Monitoring and Control System (SAIMCS), undertakes the important task of agricultural input management in agricultural production. Its functional design covers multiple key functions such as agricultural input statistics and analysis, agricultural input display, agricultural input sharing and reporting, agricultural input application, and collection record management. Through statistical analysis of agricultural inputs, the system not only summarizes data, but also deeply analyzes the inventory, use, and consumption of various agricultural inputs, providing reasonable decision-making support for farmers; The display function of agricultural inputs provides farmers with a convenient way to search and choose agricultural inputs; The sharing and reporting of agricultural inputs promotes the sharing and rational utilization of agricultural inputs resources; The function of applying for agricultural inputs ensures that farmers can obtain the necessary agricultural inputs in a timely manner; The management function of receiving records ensures transparency and standardization in the use of agricultural inputs. In summary, the agricultural input system provides comprehensive and efficient management services for agricultural production, provides solid support for intelligent management and decision-making of agricultural production, and promotes the sustainable development and efficiency improvement of agricultural production.

The implementation of the intelligent service data visualization system is shown in Figure 2.

ISSN: 2664-9640

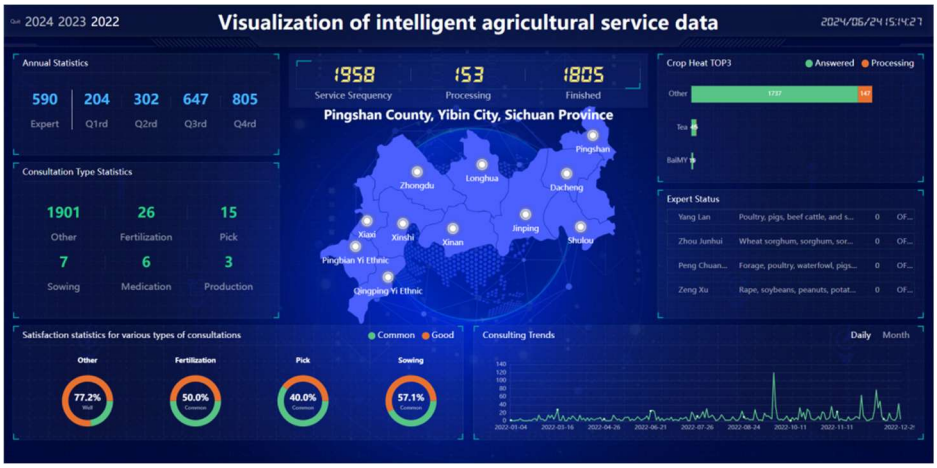

Figure 2. The implementation of the intelligent service data visualization system

The implementation of the visualization function for agricultural product traceability data is shown in Figure 3.

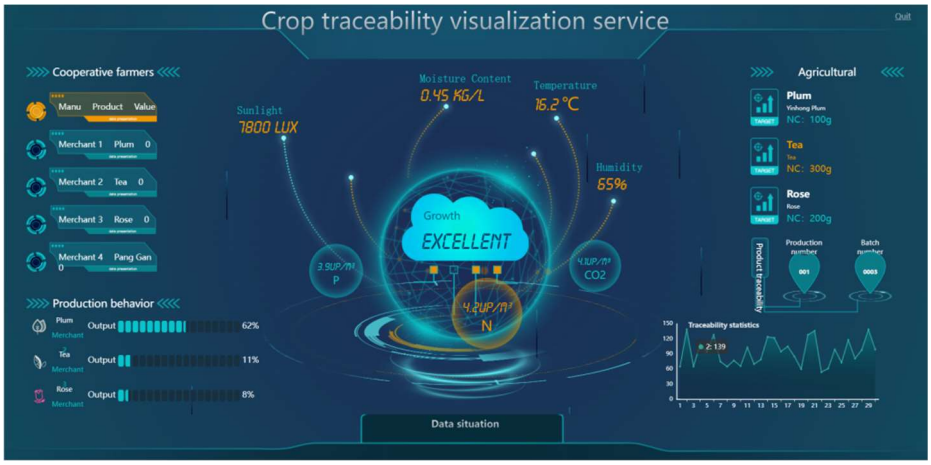

Figure 3. The visualization function for agricultural product traceability data

5. Conclusion

The smart agriculture IoT monitoring and control system designed and implemented in this article has achieved precise management and efficient control of various stages of agricultural production. It can collect soil information in real time through sensor networks, guide planting decisions, and achieve temperature, humidity Real time monitoring and automatic control of environmental parameters such as CO2 to ensure crop growth under optimal environmental conditions. At the same time, combining expert experience to regulate the environment and optimize the nutritional status of crops. It has good application prospects in improving production management efficiency, saving labor costs, and providing scientific data support.

Acknowledgments

Funding: This research was supported by the Key R & D projects of Sichuan Provincial Department of science and technology (NO, 2021YFG0029) , and in part by the Yibin University Science and Technology Program (NO. 2022YY09) and the Yibin Science and Technology Program(NO. 2022NY012).

ISSN: 2664-9640

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