ISSN 2616-5910 Vol. 6, Issue 1: 71-78, DOI: 10.25236/AJALS.2025.060110

Design of a Digital Early Warning Platform for Intelligent Crop Pests and Diseases

Zhang Yaheng[a,*], Long Yanbin[b]

University of Science and Technology Liaoning, Anshan, Liaoning, China
[a]853323903@qq.com, [b]1034182681@qq.com
**Corresponding author*

Abstract: *With the advancement of agricultural modernization, accurate diagnosis and early warning of pests and diseases have become an important means to ensure food security. This paper designs an intelligent digital early warning platform for crop pests and diseases based on artificial intelligence and Internet of Things technology. Through front-end data collection, back-end intelligent analysis and expert knowledge base support, it realizes real-time monitoring, intelligent diagnosis and scientific early warning of pests and diseases. The system adopts a modular design, including situation visualization data panel, pest and disease detection and early warning management system, expert knowledge base and management platform, and system operation and maintenance management and configuration center. Experimental results show that the system can significantly improve the accuracy of pest and disease diagnosis and the timeliness of early warning, providing strong support for agricultural production.*

Keywords: *Crop Pests and Diseases; Intelligent Diagnosis; Early Warning System; Artificial Intelligence; Internet of Things*

1. Background

Crop pests and diseases are a long-term threat to agricultural production. Every year, food losses due to pests and diseases amount to 20%-40% of the world's total food production. According to statistics from the Food and Agriculture Organization of the United Nations (FAO), the global food losses due to pests and diseases in 2022 were about 1.2 billion tons, with the losses in Asia being particularly severe, accounting for more than 40% of the global total. Pests and diseases not only directly affect crop yields, but may also reduce crop quality, increase the use of pesticides, and damage the ecological environment[1].

Traditional pest control methods mainly rely on manual experience, and have problems such as low efficiency, slow response, narrow coverage, and delayed control. With the rapid development of the Internet of Things, big data, and artificial intelligence technologies, intelligent pest diagnosis and early warning systems have become an important direction for agricultural modernization. The system significantly improves the efficiency and accuracy of pest control through real-time data collection, intelligent analysis, scientific early warning, and decision support. Specifically, the system uses sensors and cameras to collect field environmental data and pest images, and combines deep learning algorithms (such as convolutional neural networks CNN) and expert knowledge bases to achieve accurate identification and classification of pests and diseases[2]. Based on historical data and environmental parameters, the system can predict the probability of pests and diseases, and automatically issue an early warning when the risk exceeds the threshold, providing agricultural managers with pest distribution heat maps, trend analysis, and prevention and control recommendations to help formulate scientific prevention and control strategies. The application of this system not only reduces food losses, but also reduces the use of pesticides, protects the ecological environment, and promotes the sustainable development of agriculture[3-4].

2. System architecture design

2.1 System Architecture Design

The system adopts a layered architecture design, which is divided into data acquisition layer, data

ISSN 2616-5910 Vol. 6, Issue 1: 71-78, DOI: 10.25236/AJALS.2025.060110

processing layer, application layer and user layer[5]. Each layer has a clear division of functions to ensure the efficient operation and scalability of the system. The overall framework structure of the system is shown in Figure 1.

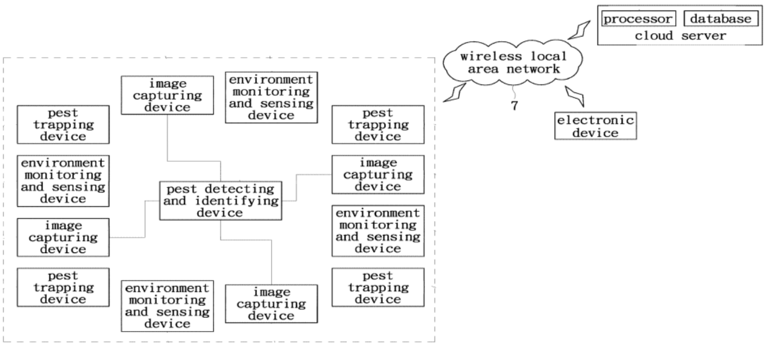

Figure 1 System architecture

2.1.1 Data Collection Layer

Function: Obtain field environmental data and pest images through sensors, cameras and other equipment. Equipment: Environmental sensors: Collect data such as temperature, humidity, light, soil moisture, etc. Cameras: Take images of crop leaves, fruits and other parts for pest identification. Drones: Used for pest monitoring of large areas of farmland, especially farmland in remote or complex terrain. Data transmission: The collected data is transmitted to the data processing layer through 4G/5G network or Wi-Fi[6-7].

2.1.2 Data processing layer

Function: Responsible for data cleaning, storage and analysis. Data cleaning: Remove invalid data, duplicate data and noise data to ensure data quality. Data storage: Use relational databases (such as MySQL) to store structured data (such as user information, pest and disease types), and use NoSQL databases (such as MongoDB) to store unstructured data (such as pest and disease images) [8].

Data analysis: Use deep learning models (such as CNN) to identify pest and disease images, and combine historical data and environmental parameters to predict pests and diseases.

2.1.3 Application layer

Function: Provides pest and disease diagnosis, early warning and management functions. Pest and disease diagnosis: By uploading pest and disease images, the system automatically identifies the pest and disease type and provides prevention and control suggestions. Pest and disease early warning: Based on environmental data and historical records, predict the probability of pest and disease occurrence and issue an early warning when the risk exceeds the threshold. Management function: Supports pest and disease information entry, knowledge base management, user authority management and system configuration[9-10].

2.1.4 User Layer

Function: Interact with the system through the Web or mobile terminals. Web terminal: Provides a management interface for administrators and experts, supporting data visualization, pest and disease diagnosis and knowledge base management. Mobile terminal: Provides a simple interface for farmers, supporting pest and disease image upload, early warning information reception and prevention and control advice query.

2.2 Front-end page design

The front-end page adopts responsive design and supports multi-terminal access, ensuring that users can get a good experience on different devices. The main functional modules include:

2.2.1 Data visualization panel

Function: Display the distribution and trend of pests and diseases through charts and maps.

Heat map: shows the distribution of pests and diseases in the field, and the depth of color indicates the severity of the pests and diseases.

ISSN 2616-5910 Vol. 6, Issue 1: 71-78, DOI: 10.25236/AJALS.2025.060110

Line chart: shows the changing trend of the frequency and severity of pests and diseases.

Environmental monitoring: Display changes in environmental parameters such as temperature, humidity, and light.

2.2.2 Pest and disease diagnosis interface

Function: Provides functions of uploading pictures and real-time diagnosis.

Image upload: Users upload pest and disease images through cameras or photo galleries.

Real-time diagnosis: The system automatically identifies the type of pests and diseases and provides prevention and control suggestions.

History: Save the user's diagnostic records and support query and comparison.

2.2.3 Early warning information push

Function: Notify users via email, SMS or APP.

Warning level: divided into three levels of warning: low, medium and high according to the severity of pests and diseases.

Push content: including pest and disease type, location, severity and prevention and control recommendations.

2.2.4 System Settings

Function: Support user rights management and parameter configuration.

Permission management: Set access rights for different user roles, such as administrators, experts, and farmers.

Parameter configuration: Configure system parameters such as warning thresholds and notification methods.

2.3 Backend Business Design

The backend adopts microservice architecture and modular design to ensure high scalability and maintainability of the system. The main modules include:

2.3.1 Data collection services

Function: Communicate with sensors and cameras to collect environmental data and pest and disease images.

Communication protocol: Support MQTT, HTTP and other protocols to ensure the stability and security of data transmission.

Data caching: Use Redis to cache high-frequency access data to improve system response speed.

2.3.2 Data storage service

Function: Store structured and unstructured data.

Relational database: MySQL is used to store structured data such as user information, pest types, and diagnostic records.

NoSQL database: MongoDB is used to store pest and disease images and sensor raw data.

Data backup: Back up the database regularly to ensure data security.

2.3.3 Analytical Services

Function: Identify and predict pests and diseases based on deep learning models.

Model training: Use PyTorch or TensorFlow framework to train CNN models to identify pest and disease types.

Prediction algorithm: Combine historical data and environmental parameters to predict the probability of pests and diseases.

Model optimization: Update the model regularly to improve recognition accuracy.

ISSN 2616-5910 Vol. 6, Issue 1: 71-78, DOI: 10.25236/AJALS.2025.060110

2.3.4 Notification Service

Function: Send warning information through API calls to third-party platforms.

Notification method: support email, SMS and APP push.

Notification template: Preset warning templates of different levels to ensure that the information is clear and easy to understand.

Notification record: record the warning information sent, support query and statistics.

Through the above design, the system can realize real-time monitoring, intelligent diagnosis and scientific early warning of pests and diseases, and provide comprehensive technical support for agricultural production.

2.3.5 Database Design

The system database uses a hybrid storage of MySQL and MongoDB to meet the storage requirements of structured and unstructured data. MySQL is used to store structured data, such as user information, pest types, diagnosis records, etc.; MongoDB is used to store unstructured data, such as pest images and sensor raw data. The following is the main table structure design:

3. Database Design

3.1 Database Architecture

The system uses a hybrid storage architecture of MySQL and MongoDB to ensure efficient storage and query of data. MySQL is used to store structured data and supports complex queries and transaction processing; MongoDB is used to store unstructured data and supports flexible data formats and efficient data retrieval.

3.2 Table structure design

3.2.1 User Table (MySQL)

The user table stores the basic information and permission information of system users, and supports user authentication and permission management.

Table 1 User Storage

Field Name	Data Types	describe
user_id	INT	User ID (primary key, auto-increment)
username	VARCHAR(50)	username
password	VARCHAR(100)	Password (encrypted storage)
role	VARCHAR(20)	User role (administrator)
email	VARCHAR(100)	Email
phone	VARCHAR(20)	phone number
created_at	DATETIME	Creation time
updated_at	DATETIME	Update time

3.2.2 Pest and disease information table (MySQL)

The pest information table stores detailed information about pests and diseases, including types, symptom descriptions, and control methods, and supports the management and query of the pest and disease knowledge base.

Table 2 Pest and disease information

Field Name	Data Types	describe
pest_id	INT	Pest and disease ID (primary key, auto-increment)
pest_name	VARCHAR(100)	Name of pests and diseases
pest_type	VARCHAR(50)	Pest type (disease/pest)
symptom_desc	TEXT	Symptom description
prevention_method	TEXT	Prevention and treatment methods
image_url	VARCHAR(255)	Pest and disease reference image URL
created_at	DATETIME	Creation time
updated_at	DATETIME	Update time

ISSN 2616-5910 Vol. 6, Issue 1: 71-78, DOI: 10.25236/AJALS.2025.060110

3.2.3 Test record table (MySQL)

The detection record table stores detailed records of pest and disease detection, including detection time, detection results, related images and treatment suggestions, and supports the query and analysis of pest and disease diagnosis history.

Table 3 Test record

Field Name	Data Types	describe
record_id	INT	Detection record ID (primary key, auto-increment)
user_id	INT	User ID (foreign key)
pest_id	INT	Pest ID (foreign key)
detection_time	DATETIME	Detection time
detection_result	TEXT	Test results
image_path	VARCHAR(255)	Detecting image paths
handling_suggestion	TEXT	Suggestions
status	VARCHAR(20)	Processing status (unprocessed/processed)
created_at	DATETIME	Creation time
updated_at	DATETIME	Update time

3.2.4 Sensor Data Table (MySQL)

The sensor data table stores environmental data collected by sensors, including temperature, humidity, light, etc., and supports query and analysis of environmental data.

Table 4 Sensor Data Table

Field Name	Data Types	describe
sensor_id	INT	Sensor ID (primary key, auto-increment)
sensor_name	VARCHAR(50)	Sensor Name
location	VARCHAR(100)	Sensor location
temperature	DECIMAL(5,2)	Temperature (unit: Celsius)
humidity	DECIMAL(5,2)	Humidity (unit: percentage)
light_intensity	DECIMAL(8,2)	Light intensity (unit: lux)
soil_moisture	DECIMAL(5,2)	Soil moisture (unit: percentage)
collection_time	DATETIME	Data collection time
created_at	DATETIME	Creation time
updated_at	DATETIME	Update time

3.2.5 Pest and disease image table (MongoDB)

The pest and disease image table stores pest and disease images and related metadata, supporting efficient storage and retrieval of images.

Table 5 Pest and disease image

Field Name	Data Types	describe
_id	ObjectId	Image ID (MongoDB primary key)
user_id	INT	User ID
pest_id	INT	Pest and Disease ID
image_data	Binary	Image data
image_metadata	JSON	Image metadata (such as shooting time and location)
detection_result	String	Test results
created_at	DateTime	Creation time

3.2.6 Sensor raw data table (MongoDB)

Table 6 Sensor raw data

Field Name	Data Types	describe
_id	ObjectId	Data ID (MongoDB primary key)
sensor_id	INT	Sensor ID
location	String	Sensor location
temperature	Double	Temperature (unit: Celsius)

ISSN 2616-5910 Vol. 6, Issue 1: 71-78, DOI: 10.25236/AJALS.2025.060110

humidity	Double	Humidity (unit: percentage)
light_intensity	Double	Light intensity (unit: lux)
soil_moisture	Double	Soil moisture (unit: percentage)
collection_time	DateTime	Data collection time
created_at	DateTime	Creation time

The sensor raw data table stores the raw data collected by the sensor and supports efficient storage and query of large-scale data.

3.3 Database relationship diagram

The system database relationship diagram is shown below:

```
User table
│
├── Pest and disease information table (PestInfo)
│  └── Detection Record Table (DetectionRecord)
│  └── Pest and disease image table (PestImage) [MongoDB]
│
└── Sensor Data Table (SensorData)
    └── Sensor Raw Data Table (SensorRawData) [MongoDB]
```

The system can efficiently store and manage structured and unstructured data, supporting the real-time and accuracy of pest and disease diagnosis and early warning.

4. System function modules

4.1 Situation Visualization Data Panel

In the morning, farmer Lao Zhang opened the intelligent digital early warning platform for crop pests and diseases as usual. What caught his eye was the situation visualization data panel, which was like a "clairvoyant" in the fields, allowing Lao Zhang to grasp the real-time situation of the farmland without leaving his home. On the pest distribution heat map, areas of different colors represent different degrees of pest and disease occurrence. Lao Zhang noticed that the southeast corner of his corn field showed a striking red color, which meant that the pests and diseases there were more serious. He felt nervous and immediately decided to go to the area for a field inspection. On the trend line chart, Lao Zhang saw that the frequency of corn borers had been on the rise in the past week, which made him more convinced that action was needed. At the same time, environmental data monitoring showed that the humidity in the fields was high recently, providing suitable conditions for the breeding of pests and diseases.

The situation visualization data panel displays the real-time situation of pests and diseases through charts and maps. The main functions include:

Pest and disease distribution heat map: shows the distribution of pests and diseases in the field.

Pest and disease trend line chart: shows the changing trend of the frequency and severity of pests and diseases.

Environmental data monitoring: Display changes in environmental parameters such as temperature, humidity, and light.

4.2 Pest and disease detection and early warning management system

When Lao Zhang arrived at the field, he found wormholes on some corn leaves. He quickly took out his mobile phone, opened the pest detection and early warning management system in the system, took several photos of the damaged leaves and uploaded them. The deep learning model in the background of the system quickly started to analyze the images. After just a few seconds, the system responded: corn borer was detected, and the severity was medium. At the same time, based on

ISSN 2616-5910 Vol. 6, Issue 1: 71-78, DOI: 10.25236/AJALS.2025.060110

historical data and current environmental parameters, the system predicted that the probability of corn borer occurrence will further increase in the next three days. While Lao Zhang was still thinking about countermeasures, his mobile phone received an early warning message: "The risk of corn borer occurrence in the southeast corner of your corn field is high. It is recommended to take preventive measures as soon as possible." This early warning message was like timely rain, allowing Lao Zhang to immediately prepare pesticides and spray equipment to carry out targeted prevention and control in areas with serious pests and diseases. The historical early warning displays all historical early warning information and the details of the early warning content are shown.

The pest and disease detection and early warning management system is the core module of the system, and its main functions include:

Pest and disease image recognition: Uploaded pest and disease images are identified through deep learning models (such as CNN).

Pest and disease prediction: Based on historical data and environmental parameters, predict the probability of occurrence of pests and diseases.

Early warning information push: When the risk of pests and diseases exceeds the threshold, early warning information will be automatically sent to users.

4.3 Expert Knowledge Base and Management Platform

While preparing for prevention and control, Zhang suddenly remembered that he had seen methods for preventing and controlling corn borers in the system's expert knowledge base and management platform. He opened the system again, entered the knowledge base, and searched for "corn borer prevention and control". The system immediately displayed a number of relevant information, including chemical control, biological control, and agricultural control. After reading carefully, Zhang decided to use biological control methods and bought a batch of trichogrammatid bee cards to place in the fields to achieve the effect of using insects to control insects. The system will also regularly update the knowledge base content and share the latest research results and prevention and control experience with users. Experts will also share their insights and suggestions on the platform to provide farmers with more comprehensive and professional guidance.

The expert knowledge base stores knowledge and experience on pest control, supports system intelligent diagnosis and user query. The main functions include:

Knowledge base management: supports the entry, editing and deletion of pest and disease information.

Knowledge retrieval: Provide keyword search function to quickly locate relevant pest and disease information.

Knowledge graph: Build a relationship graph between pests and diseases and their control methods to support complex queries.

4.4 System Operation and Maintenance Management and Configuration Center

While farmers are using the system normally, the staff of the system operation and maintenance management and configuration center are also silently guarding the stable operation of the system. They always pay attention to the system log records, and once an abnormal situation is found, they will immediately investigate and repair it. At the same time, they will optimize the configuration of system parameters according to user feedback and actual needs. For example, according to the characteristics of pests and diseases in Lao Zhang's area, the operation and maintenance personnel adjusted the warning threshold to make it more in line with local actual conditions. They also regularly review and adjust user permissions to ensure that only authorized users can access sensitive data and functions. Through the collaborative work of the four major functional modules of the situation visualization data panel, pest and disease detection and warning management system, expert knowledge base and management platform, and system operation and maintenance management and configuration center, the intelligent crop pest and disease digital warning platform provides farmers with a comprehensive, accurate and timely pest and disease control solution to protect the healthy growth of crops.

The system operation and configuration center is responsible for the daily maintenance and parameter configuration of the system. The main functions include:

ISSN 2616-5910 Vol. 6, Issue 1: 71-78, DOI: 10.25236/AJALS.2025.060110

User rights management: Supports configuration of user roles and rights.

System log record: record system operation status and user operation log.

Parameter configuration: supports the configuration of warning thresholds, notification methods and other parameters.

5. Conclusion

The intelligent digital early warning platform for crop diseases and insect pests designed in this paper combines the Internet of Things, big data and artificial intelligence technologies to achieve real-time monitoring, intelligent diagnosis and scientific early warning of diseases and insect pests. The system adopts a modular design and has good scalability and maintainability. The experimental results show that the system can significantly improve the accuracy of disease and insect pest diagnosis and the timeliness of early warning, providing strong support for agricultural production. In the future, the system performance will be further optimized, more sensors and edge computing technologies will be introduced, and the intelligence level and real-time performance of the system will be improved.

References

[1] Zhou Heng, Liao Xiang, Li Jingtie. Research on the design of automatic identification system of crop diseases and insect pests based on drones. Guangxi Agricultural Mechanization, 2024(05).

[2] Cai Guoqing, Wu Jianjun, Zhu Yuhua, Zhen Tong, Li Zhihui, Lian Yimeng. Research progress on crop pest and disease detection based on convolutional neural network. Shandong Agricultural Sciences, 2024(11).

[3] Niu Panting, Zhang Baolin, Pan Lijie, Guo Jianpeng, Li Ruixin. Research progress on crop diseases and insect pests based on deep learning. Journal of Inner Mongolia Normal University (Natural Science Chinese Edition), 2024(01).

[4] Tan Zhifeng, He Zhilei, Zhang Lei, Miao Juan. A review of the application of deep learning technology in crop pest and disease identification. Hebei Agriculture, 2024(01).

[5] Deng Yun, Feng Qiyao, Niu Zhaowen, Kang Yanping. Fine-grained classification of crop pests and diseases based on progressive generative adversarial networks. Chinese Journal of Agricultural Mechanization, 2024(03).

[6] Wu Lili. Practical technology for identifying crop diseases and insect pests. Agricultural Engineering Technology, 2024(23).

[7] Chang Ruiyang, Yang Haibin. Research on crop pest and disease identification based on convolutional neural network. Wireless Internet Technology, 2023(02).

[8] Dong Yuzhou, Li Bingxu, Li Xu, Liu Shuai, Chu Xuhong. Crop pest and disease detection system based on visual classification. Modern Agriculture, 2022(07).

[9] Dong Wenhu, Zhao Ruixue. Research on the construction of knowledge graph and question-answering system for crop diseases and pests. Northeast Agricultural Science, 2025(01).

[10] Zou Taochun, Wang Qin, Liu Qinli, Xu Huan. Current status and countermeasures of green control of crop diseases and insect pests in Xingwen County. Sichuan Agriculture and Agricultural Machinery, 2025(01).