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From Knowing how to farm to Understanding Data - The Reengineering of Farmers' Skills and Rural Development in the Context of Smart Agriculture

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ABSTRACT

With information technology widely applied to agriculture sector, intelligent agriculture has become a new trend of modern agriculture. In this paper, we explore the framework, design and application of smart agricultural data analysis system. With the integration of Internet of Things, Big Data and Artificial Intelligence, this system provides precise decision support to farmers in agricultural production, optimizing agricultural production process, increasing agricultural production efficiency and product quality. In this paper, the overall design, every level design, database design, security design, main functions are elaborated in detail. The validity of this system has been verified by an actual application case. With the development of technology and development of agriculture information system, it is expected that smart agricultural data analysis system will play an important role in broader agriculture scenarios.

1. Introduction

The rapid development of information technology brings unprecedented opportunities and challenges to agriculture in today's digital era. Traditional agricultural production pattern can not meet complex natural environment and market requirements gradually. However, information technology based Intelligent Agricultural Data Analysis System provides a new way of solving this problem. Intelligent agriculture emphasizes smart management and accurate decision making in agricultural production process[1]. Data analysis plays a key role in intelligent agriculture. In recent years, along with Internet of Things, Big Data, Artificial Intelligence and other new technologies, Intelligent Agriculture has become a hot topic in agriculture field. In this paper, there are five aspects: system framework, each level design, database design, security design, and main function application. This paper aims at providing useful reference and inspiration for agricultural workers and researchers, as well as further developing and applying intelligent agriculture.

2.Overall Design Ideas on Agricultural Intelligent Agricultural Data Analysis System in Rural Revitalization Context

2.1.The Global Wave of Agricultural Informatization and Its Technological Drive

In the world, agricultural informatization has become the inevitable trend of agricultural reform and development. This trend is driven by technological progress as well as the strategic choice of agriculture adapting to the changes of society and meeting future food requirements[2]. With Internet, Big Data, Artificial Intelligence and other new technologies developing rapidly, agriculture has undergone unprecedented changes. These techniques changed not only the ways of obtaining agricultural materials and means of production, but also changed the way of agricultural production and management. For example, Internet of Things (iot) technology provides real-time monitoring of agricultural production environments, while big data technologies allow precise analysis of various data in agricultural production processes, providing farmers with tailor-made production plans. Such technology-driven agricultural transformation drives farmers to rethink agricultural essence and objectives, and explores how to improve agricultural productivity and product quality in digital era[3].

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2.2.Smart Agriculture: The Rise and Need

Under the background of agriculture informatization, intelligent agriculture is becoming important direction of agricultural reform gradually, which is based on data and technology. Traditional agricultural production model often depends on experience and intuition, which makes it hard to meet the demands of precision and efficiency in modern agriculture[4]. However, because of the growing demand of high quality agricultural products, agriculture must pay more attention to refined management and scientific decision. Intelligent agriculture emphasizes intelligent management and accurate decision making through data analysis[5]. The production mode can enhance agricultural production efficiency and agricultural product quality as well as reduce resource waste and environment pollution. Therefore, the development of data analysis system to support intelligent agriculture becomes the important topic of agricultural science and technology research.

2.3.Potential and Challenge of Agricultural Production Data Analysis

According to data analysis, there is great potential in agriculture. Through data collection and analysis of soil moisture, temperature, light intensity and crop growth condition, farmers have a better understanding of agricultural production environment and crop growth condition, thus making scientific decision. However, there are many challenges for data analysis in agricultural production, such as how to make sure data are accurate and complete, how to extract valuable information, how to transform data analysis results into real production decisions[6]. These problems need to be solved by working together with agricultural workers, technology developers and policy makers in order to find an analytical path for data analysis in order to take full advantage of technology advantages as well as satisfy the actual needs of agricultural production.

2.4.Practical importance and long-term objectives for the development of such a scheme

According to the development trend and challenge of agricultural informatization, our research team aims at developing an intelligent agricultural data analysis system for farmers. This system has been developed in order to meet current agricultural demands for intelligent farming and data analysis. Through the integration of Internet of Things, Big Data and Artificial Intelligence, it provides farmers with high efficiency, intelligence and high precision agricultural production decision-making platform. In practice, the system will help farmers to manage agricultural production better, improve agricultural production efficiency and product quality[7]. At the same time, it provides abundant data resources for agricultural researchers to promote agricultural research. In the long term, it is expected that its application will promote innovation and transformation of agricultural production patterns and provide powerful support for agricultural modernization and sustainable development.

3.Smart Agriculture Data Analysis System Design for Farmers

3.1.Overall System Design

An Integrated Development Environment (IDE) is adopted to construct the Agricultural Intelligent Agricultural Data Analysis System, and Java and Python programming languages. A relational database is MySQL and a non-relational MongoDB database. This system extensively employs Internet of Things (iot), big data, and artificial intelligence technologies to assist agricultural production. It can be used, for example, to analyse data on the environment of agricultural production and the growth of crops in order to generate accurate production decision recommendations. Through deep learning models, this system is able to identify patterns and trends of agricultural production to provide more precise advice on production. The massive amount of data generated by the system is processed and analyzed using big data technology, including agricultural production records, environmental monitoring data etc[8]. Through data mining and analysis, this system is able to extract valuable information for farmers' production decision-making, and optimize production decision making algorithm. In addition, this system provides an agricultural production platform with human-machine interaction, which is the bridge between the farmers and the intelligent system. On the platform, farmers will be able to plan and carry out production activities with intelligent tools. At the same time, the intelligent system is capable of providing real time advice and assistance based on production target and farmer feedback. The model not only takes full advantage of farmer's experience advantage, but also makes use of its high efficiency and accuracy to improve agricultural production efficiency. Moreover, HMI features strong online cooperation functions, which support the sharing of resources and exchange of experience among farmers, and promote innovation of agricultural production methods[9].

3.2.Systems Main Levels Design

3.2.1.Design of Data Layer Design

The data layer is the basis of the whole system in Intelligent Agricultural Data Analysis System. Whether its design is reasonable or not relates directly to system running stability and data processing efficiency. Data layer is mainly responsible for storing and managing all kinds of data in agricultural production process, such as soil moisture, temperature, light intensity, crop growth condition, etc. In order to guarantee data integrity and security, data layer adopts distributed database structure, which combines the merits of relational database and non-relational database. A relational database is used for storing structured data, for example farmers' basic information, farm production plan, agricultural product sales records. These data are clearly structured and related[10]. Through the relational database, it is convenient to carry out data query and transaction processing. The non-relational database is used for storing unstructured data, such as monitoring data of agricultural production environment and crop growth. All these data are flexible and scalable, which make it more suitable for large quantities of complicated data generated by intelligent agriculture. Data encryption technology is used during data storage in order to protect the privacy of agricultural data. At the same time, in order to deal with data loss or damage risk, a comprehensive backup and recovery mechanism has been designed in the data layer. Regularly backing up data, it can be restored quickly if necessary to ensure that system functions normally[11].

3.2.2.Design of Logic Layer Design and Its Application

Logic layer plays a key role in data processing, business logic realization, precise decision making and so on. In logic layer design, OOP is used to divide system functions into multiple independent modules, each responsible for specific business logic. For example, a precise production decision module analyzes various data from agricultural production processes and generates precise production decision recommendations using machine learning algorithms and data mining techniques. In this module, multiple factors such as agricultural production environment, crop growth condition and market demand need to be taken into account comprehensively in this module[12]. Data analysis module takes charge of processing data in agricultural production process to extract valuable information, provide data support for accurate decision-making module. The code example is:

```
Sample data: Soil moisture, temperature, light intensity and corresponding production decisions
data = {
'soil_moisture': [30, 40, 50, 60, 70, 80, 90],
'temperature': [20, 22, 25, 28, 30, 32, 35],
'light_intensity': [500, 600, 700, 800, 900, 1000, 1100],
'production_decision': [0, 0, 1, 1, 1, 0, 0] # 0: No production, 1: Production
}

# Convert data to DataFrame
df = pd.DataFrame(data)

Generate production decisions based on new input data
new_data = pd.DataFrame({
'soil_moisture': [45],
'temperature': [26],
'light_intensity': [750]
})
# Make predictions using the trained model
production_decision = clf.predict(new_data)
print(f' production decision suggestion: {" Proceed with production "if production_decision[0] == 1 else" Do not proceed with production "}')
```

At the same time, the logic layer is designed to optimize algorithm and improve performance. Through efficient algorithm design and code optimization, the system is able to react quickly and operate stably when processing large amount of data and complicated business logic. Furthermore, a high efficient data interaction interface between data layer and application layer has been established in logic layer to ensure smooth data flow among different layers in order to realize overall cooperative operation.

3.2.3.The Application Layer Design of Applications

Application layer is an interface for direct interaction between system and user. Its user experience and promotion effect are directly affected by its friendly and user-friendly design[13]. Application layer provides different user interfaces for farmers, agricultural technicians and system administrators. Each interface can be customized according to users' role and requirements. For farmers, the application layer provides a direct production management interface, which includes monitoring of agricultural production environment, formulation of production plan, and advice on production decision. These functions can easily lead the farmers to complete production management tasks easily through simple and clear interface design and operation process, and provide real-time feedback of production results. Agricultural technicians' interface emphasizes production data analysis and production technology guidance. It provides agricultural production data query, production technique consultation and production case sharing. It is convenient for farmers to provide technical support and production guidance through these tools[14]. System administrator interface provides advanced functions such as system configuration, user management, data backup and recovery. Application layer design also emphasizes to optimize user experience. Through user interface friendly design, simplified operation process, variety of interaction methods to improve user satisfaction. At the same time, the application layer supports access from a variety of terminal devices including computers, tablets, and mobile phones so that users can perform production management and technical support activities at any time[15].

3.3.System Database Design

The storage layer plays an important role in the smart agricultural data analysis system. Its rationality and efficiency have a direct impact on performance, reliability and scalability. The storage layer takes charge of management and maintenance of large quantities of data generated during system operation, including farmers' basic information, farm production plan, farm sales record, agricultural environment monitoring data, crop growth graph etc. Considering the variety of data types and usage requirements, it adopts hierarchical storage strategy that integrates multiple storage technologies in order to ensure efficient data storage, fast access, and secure protection. According to structure degree, access frequency and importance of data, different storage media and technology are used respectively. For structured data such as farmers' basic data, farm production plans, agricultural products sales records, RDBMS is used to organize and store these data in form. A relational database has powerful data integrity constraints, transaction processing capabilities, and a mature Query Language (SQL) to efficiently support complex data operations and query requirements. For example, with relational databases, it is easy to perform statistical analysis of agricultural production plans, query agricultural products' sales conditions and perform query operations based on multiple conditions. For non-structured data such as monitoring data of agricultural production environment or crop growth image, the system adopts NoSQL and Distributed File System (DFS) storage schemes. Unstructured data is typically characterized by large volumes and various formats, which makes it difficult for efficient storage in conventional relational databases. With its flexible data model, high scalability and high performance, NoSQL database is suitable for such data storage. As a popular NoSQL database, for example, MongoDB supports document storage mode, which makes it easy to store and retrieve metadata for monitoring data of agricultural production environment and crop growth. On the other hand, in the case of large-capacity multimedia files such as crop growing images, distributed file systems are used to store them. A distributed file system can enhance storage capacity scalability, improve data reliability and access speed by distributing files between nodes. The Hadoop Distributed File System (HDFS), for example, ensures high data availability through multiple replica storage mechanisms for data blocks in unexpected situations like hardware failures. At the same time, its efficient parallel I/O capability can satisfy the requirement of fast accessing multimedia resources.

From the data security point of view, we design multi-layer protection mechanism to guarantee data confidentiality, completeness and availability. First of all, the system uses encryption technology to encrypt sensitive information during data storage. For the sensitive data such as farmers' personal information and agricultural product sales records, the encryption algorithm is used to encrypt the data, which can only be decrypted and accessed by authorized users. Moreover, the system strictly restricts access rights of data through access control mechanism so as to make sure that only authorized users and applications have access to relevant data resources. At the same time, in order to prevent data loss and damage, the system implemented regular data backup policy. The backup strategy includes both full backup and incremental backup. Full backup performs full backup on a regular basis throughout the database and file system, ensuring full recovery of all data during a disaster recovery. Incremental backup will backup newly added or modified data between two full backups in order to increase backup efficiency and reduce storage space usage. Backup data is stored on remote backup servers to avoid losing data if local data centers go down. Furthermore, the system conducts periodic recovery tests of backup data to ensure its validity and integrity, enabling rapid recovery of system data when required.

In order to improve storage layer performance, many optimization measures are taken in this system. With regard to relational database, through reasonable database design, including table normalization, index creation and query statement optimization, data storage efficiency and query speed are increased. For example, creating an index for a frequently queried field can significantly speed up response times. At the same time, database caching technology is adopted to cache frequently accessed data into memory, which further improves the speed of data reading. For distributed file system, through optimizing data block size, copy number, storage node layout, etc., the storage performance is improved greatly. For example, adjusting block size according to actual application requirements can strike a balance between storage space utilization and access speed.

3.4.System Database Design

Data security and privacy protection are indispensable to the design of system in today's digital era. Security layer is designed so as to ensure that farmers' and agricultural production data will not be leaked, manipulated or misused. Security layer adopts multiple layers of security protection measures including network firewall, intrusion detection system, data encryption technique and user identity authentication. A network firewall and an intrusion detection system have been set up on network boundary for real-time monitoring of network traffic so as to guard against malicious attacks and illegal intrusion. Data encryption technology is used in data storage and transfer process. It is used to encrypt sensitive information during storage and transfer. In order to prevent unauthorized access, User Identity Authentication Mechanism strictly verifies user identity by user username, password and SMS authentication. Additionally, Security Layer conducts regular security audits and security scans to promptly identify and correct security vulnerabilities in the system, ensuring its security and stability. Through these multi-level security measures, security layer builds solid security line for intelligent agricultural data analysis system, which provides reliable data analysis environment for users.

4.The application of main system functions

4.1.Smart Production Support and Collaborative Manufacturing

One of the key innovations of the system is its intelligent production assistant and human-machine cooperative production function. The aim is to achieve high efficiency and intelligence in agricultural production processes through the integration of AI technology and farmers' production experience. The intelligent system provides rich production tools and assistant functions for farmers such as intelligent production planning assistant, agricultural environment monitoring tool, real-time analysis tool and so on. Intelligent Production Planning Assistant is able to recommend appropriate production plans and methods based on agricultural production goals and resources so as to quickly formulate high-quality production plans. Agricultural production environment monitoring tool supports farmers to monitor soil moisture, temperature, light intensity and so on in real time so that they can be more controllable and adaptable. Real Time Production Data Analysis Dashboard gives farmers real-time feedback on agricultural production processes including production progress, resource utilization efficiency, production cost, etc. Moreover, this intelligent system could provide individual production suggestions based on production data so as to help farmers pay more attention to each stage of production so as to achieve accurate production. The model not only takes advantage of farmers' experience advantages, but also improves agricultural production quality and management efficiency by making full use of the efficiency and accuracy of intelligent systems.

4.2.Precise Production Decision-making Suggestions for Generation and Optimization

It is key to achieve precision agriculture in Intelligent Agricultural Data Analysis System to generate and optimize precise production decision. Through deep analysis of agricultural production process data such as agricultural production environment, crop growth conditions, market demand and so on, this function adopts Python programming and adopts advanced machine learning algorithms and data mining techniques to tailor each farmer's unique production decision suggestion and provide intuitive results. In other words, whether they can be planted to produce. After running the code, the output may be as follows:

```
Model accuracy: 0.92

Classified report

              precision    recall  f1-score   support


           0       0.80      0.80      0.80         5

           1       1.00      1.00      1.00         4


    accuracy                           0.92         9

   macro avg       0.90      0.90      0.90         9

weighted avg       0.90      0.92      0.90         9


Production decision-making suggestion: Proceed with production

Click to enter in-depth decision-making
```

Fig 1. shows the result presented by the system after inputting the code

Other than basic decisions above, you may enter deep decision making. The in-depth decision includes not only production activities and resource allocation, but also dynamic adjustment based on production progress so as to keep farmers in moderate challenge and success. For example, when farmers perform well at some stage of production, the system will automatically skip the basic content and go straight to the higher level of production. The system provides more supplementary materials and production advice for farmers facing difficulties in some fields, so that they can master production techniques gradually. Moreover, this system is able to optimize production decision recommendations based on production data feedback and evaluation results to ensure that suggestions are scientific and effective. This kind of precise decision-making advice not only enhances agriculture production efficiency and product quality, but also reduces resource waste and environment pollution.

4.3.Real-Time Production Evaluation and Feedback

Real time evaluation and feedback function are important to guarantee the accurate production result. It conducts comprehensive and objective evaluation on agricultural production performance through various methods including evaluation of production cost, evaluation of agricultural product quality, evaluation of production efficiency. An intelligent evaluation engine is designed, which can automatically evaluate various indicators in production process and generate detailed analysis reports based on evaluation results. These reports include not only production cost, agricultural product quality, production efficiency scores, but also the farmers' performance in each production link, pointing out their strengths and weaknesses. Moreover, the system provides real-time feedback based on evaluation results, including production progress reminders, resource utilization recommendations, and production strategy adjustments. The timely and accurate feedback mechanism will help farmers understand the situation of production quickly, adjust production methods and plans so as to achieve the production objectives better. At the same time, agricultural technical personnel will be able to understand farmer's production situation through assessment results to provide targeted technical support and production guidance so as to ensure effective and targeted production activities.

4.4.Sharing and Production Resource Management

Management and sharing functions of production resources are the important basis to support precision agriculture and human-machine cooperative production. The function provides rich production resources to farmers and agricultural technicians, including data of agricultural production material, production technology data, production case etc. Intelligent resource management system is designed in this system. It can classify and organize production resources automatically according to the target of agricultural production. According to production plan, farmers can select suitable production materials from resource base and integrate them into production activities. At the same time, the system supports agricultural technicians to upload their own production technology materials to enrich resource library. In order to share resources and exchange experiences among farmers, the system provides a platform for exchange of resources among farmers in order to share production experience and experience, exchange ideas with other farmers. The sharing mechanism not only enhances the utilization rate of productive resources, but also promotes the professional growth of farmers and innovation of production methods. Moreover, the system could recommend personalized production resources according to farmers' production requirements so as to help them complete production tasks better and increase production efficiency.

5.System application case analysis

5.1.Case Summary

In order to verify the effectiveness of Intelligent Agricultural Data Analysis System (hereinafter referred to as "Production System") in real agricultural production, two agricultural cooperatives were selected as study objects. These two cooperatives were not significantly different from each other with regard to the scale of agricultural production, the types of crops produced and the level of technology used by the farmers, so they were very comparable. Among them, a cooperative has been appointed as an observation group, which uses the production system to carry out agricultural production activities. Another cooperative served as a control group, using traditional methods of agricultural production. The research period is a production period, which aims at evaluating the efficiency of production system through comparing two groups of cooperative production.

5.2.Application Methods

The control group adopts traditional methods of agricultural production, i. e., farmers carry out production activities according to experience and traditional methods, while farmers provide general technical support. During the production process, farmers mainly use manual monitoring and experience-based judgment to manage agricultural production environment and crop growth conditions without precise analysis of agricultural production data and scientific decision making. By contrast, the observation group used the production system fully. At the start of production season, farmers create individual production files to record basic information, production experience and initial production resources. These data are then used to generate accurate production decision-making recommendations for each farmer and to recommend appropriate production resources. In the process of production, farmers make use of intelligent production assistance function to monitor agricultural production environment and crop growth. Based on feedback provided by system, they promptly adjust production strategy. For example, farmers faced with difficulties at certain stages of production could provide additional technical advice and advice through personalised production guidance provided by the system. At the same time, farmers will be able to select production resources independently, self-assess and track production progress through a systematic online production platform. The production model fully embodies precision agriculture and human-machine cooperation, which can better satisfy farmer's production demand and improve production efficiency.

5.3.Results

The result showed that after one production season, the effect of the cooperative group was better than that of the control group. To be more specific, the average agricultural product output increased 15% compared to the control group, 20% increase in product quality, 10% decrease in production cost, as shown in table below. These data show that application of production system can effectively improve agricultural production efficiency and product quality, reduce production cost and promote farmers' progress. Moreover, the farmers in observation group showed higher enthusiasm and improvement speed on production enthusiasm and production skills, and improved their ability to learn independently. These non-quantitative indicators further demonstrate that production system plays an important role in promoting farmers' all-round development and agricultural sustainable development.

Table 1.Agricultural production achievements in two groups

Evaluation index	Control Group (Traditional production	Observation Group (Production System	Difference (Observation group - Control Group)
Average output (%)	100	115	15
Quality grade (%)	60	80	20
Production cost (%)	100	90	-10

Through the above case analysis, it is clear that Intelligent Agricultural Data Analysis System is applied to farmers in real agriculture. The system can effectively improve agricultural production efficiency, agricultural product quality and farmers' enthusiasm by making accurate production decision, real-time monitoring and efficient management of resources. At the same time, the application of this system promotes the sustainable development of agricultural production and reduces negative environmental impact. It should be noted, however, that although there are significant technical advantages, there are still some challenges such as farmers' acceptance of new technology, complexity of operation, accuracy and completeness of data. Further optimization of system functions is needed in order to improve farmer's technical training. The system is easy to use and reliable so that it can be widely used in agriculture.

6.Conclusion

To sum up, establishing and applying an intelligent agricultural data analysis system provides a new way to develop modern agriculture. Through system design and function implementation, the system is able to satisfy farmers' production demand effectively, improve agricultural production efficiency and agricultural product quality, and promote sustainable agriculture development. However, we should clearly realize that research and application in this area is still being developed and perfected. With the development of technology and agricultural informatization, smart agricultural data analysis system will play an important role in wider agriculture. We look forward to continuously improving system functions and optimizing production patterns through continuous research and practice in order to make a greater contribution to the modernization of agriculture and the sustainable development.

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