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Application and challenge of big data technology in agricultural mechanization supply chain

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Abstract: *With the continuous improvement of agricultural mechanization level, the role of supply chain management in agricultural production is becoming increasingly significant. The article aims to explore the application of big data technology in agricultural mechanization supply chain and the challenges it faces. Through remote sensing technology, Internet of Things technology, data mining, and machine learning methods, remote monitoring and intelligent management of agricultural machinery and equipment can be achieved, as well as information management of agricultural product production and circulation links, further optimizing resource allocation and enhancing the quality and market competitiveness of agricultural products. Research has found that big data technology can significantly improve the overall efficiency and response speed of agricultural mechanization supply chains, supporting agricultural producers to make more scientific and reasonable decisions. However, challenges such as data security, data quality, and data privacy also arise. To address these challenges, the article proposes implementing multi-layer encryption and access control, adopting advanced data cleaning techniques and verification mechanisms, and implementing strict data classification and anonymization processing strategies.*

Keywords: *Big data technology; Mechanization; Supply chain; data security*

1. Introduction

The agricultural mechanization supply chain is critical to agricultural production, directly impacting the level of modernization and farmers' incomes. As economic and technological development accelerates, traditional supply chain management models face challenges such as information asymmetry, inefficient resource allocation, and low coordination, impeding further optimization. Big data technology emerges as a solution, leveraging its powerful data processing capabilities to enable remote monitoring, improve efficiency, and lower maintenance costs in agricultural mechanization[1]. Additionally, big data facilitates the digitization of agricultural product production and sales, optimizing resource use and enhancing the competitiveness of agricultural products.

2. Relevant Technologies

Big data technologies in agriculture are developing rapidly to support precision agriculture, increase crop yields, optimize resource utilization and so on. The following are several big data technologies closely related to the agricultural field.

2.1 Remote Sensing Technology

Remote sensing technology is a technique that can obtain information about target objects without direct contact, mainly by analyzing the data collected by sensors on satellites or aircraft. These sensors are capable of capturing electromagnetic radiation in different wavebands ranging from visible light to infrared light and microwaves, thus enabling the analysis of the physical, chemical and biological properties of the Earth's surface [2]. The types of sensors used in remote sensing technology include passive sensors and active sensors. Passive sensors rely on the sun as a light source and capture the energy of sunlight reflected by the surface of objects. Active sensors have their own transmitting sources and can emit electromagnetic waves and receive their reflected signals, with radar being a typical example. In addition, remote sensing technology also involves concepts such as spectral resolution, spatial resolution and temporal resolution. Spectral resolution refers to the ability of a sensor to

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distinguish different wavelengths. By analyzing these characteristics, different substances on the Earth's surface can be identified and classified. Spatial resolution defines the size of the ground area that a pixel in a remote sensing image can represent, which directly affects the fineness of the image. Remote sensing images with high spatial resolution can provide more detailed observations of the Earth's surface. Temporal resolution refers to the frequency at which remote sensing satellites revisit the same location. High temporal resolution means that changes on the Earth's surface can be monitored more frequently, which is especially important for rapidly changing phenomena.

2.2 Internet of Things

The Internet of Things (IoT) technology enables intelligent communication and automated interaction between objects by connecting physical objects to the Internet. Based on various sensors, devices, network communication technologies and data processing capabilities, the IoT technology constructs a network of intelligent systems covering a wide range of fields. Sensors are the perception layer of the IoT and are responsible for collecting data on the environment or the status of devices. Depending on the need to monitor different parameters, sensors can be highly diverse, including various physical and chemical sensors such as those for temperature, humidity, light, pressure, and acceleration. The precision and response speed of these sensors directly affect the performance of the IoT system. Communication among IoT devices relies on wireless technologies to achieve data transmission and the issuance of instructions. Common communication technologies include Wi-Fi, which is suitable for short-distance data transmission with relatively large bandwidth; Bluetooth, which is mainly used for short-distance communication between devices; and LoRaWAN, a long-distance, low-power wireless transmission technology that is suitable for application scenarios where a small amount of data is collected in a vast area, such as environmental monitoring [3]. The focus of the IoT technology lies not only in collecting data but also, more importantly, in how to process and utilize this data. After being collected, the data is usually sent to cloud platforms or local servers for storage, management and analysis. By utilizing data analysis and machine learning algorithms, useful information can be mined from vast amounts of data and trends can be predicted, thus supporting smarter decision-making and automated control.

2.3 Data Mining

Data mining is a process of extracting implicit, previously unknown but potentially useful information and knowledge from large amounts of incomplete, noisy and fuzzy data. Data mining also plays a crucial role in the current agricultural mechanization supply chain. It helps people predict data changes, and at the same time, it can reveal the potential factors that affect the demand for agricultural machinery and predict inventory losses, etc. [4]. Data mining also plays a key role in supplier selection, management, logistics and distribution. For example, the demand forecasting and inventory management cases of John Deere Company and Han Deel Company are all closely related to data mining.

2.4 Machine Learning

Machine learning is an interdisciplinary field that focuses on how computers can simulate or implement human learning behaviors to acquire new knowledge or skills and reorganize the existing knowledge structures so as to continuously improve their own performance. Machine learning can be applied to the risk identification and analysis of the global agricultural machinery supply chain and can play an important role in the supply chain of agricultural equipment and mechanization. At present, machine learning has been applied in the field of agricultural production and has achieved remarkable progress, such as predicting the production factors of crops, monitoring and warning of agricultural pests and diseases, detecting the quality of agricultural products and tracing their origins, and providing decision support for automated operations. Machine learning has improved the production efficiency of agriculture, enhanced the quality of agricultural products, increased the utilization rate of resources, and strengthened the ability to resist risks.

3. Application of Big Data Technology in the Agricultural Mechanization Supply China

3.1 Data Collection and Analysis

Data collection and analysis involve the collection of basic data such as soil conditions, climate

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changes, crop growth status, and agricultural machinery usage, as well as in-depth analysis of these data in order to extract valuable information for agricultural production. The successful implementation of this process relies on the application of a series of advanced technologies, including the Internet of Things, remote sensing, data analysis, and machine learning. The Internet of Things technology deploys various sensors in farmland, such as soil temperature, humidity, and pH sensors, to collect key data on agricultural production in real time. These data are then transmitted to a central database for monitoring the crop growth environment and adjusting agricultural mechanization operations. Precise soil humidity data can guide the start or stop of the irrigation system and precisely control the amount of irrigation water used, thus avoiding the waste of water resources. Remote sensing technology, which includes satellite images and images taken by unmanned aerial vehicles (UAVs), provides a more comprehensive view of crop growth. By analyzing these images, agricultural producers can identify areas where crops are growing poorly, adjust fertilization or irrigation strategies in a timely manner, and also monitor pest and disease situations and control the spread of pests ctsand diseases. In terms of data analysis, applying machine learning algorithms can analyze the large amounts of collected data, identify the patterns and trends of crop growth, and the impact of environmental factors on crop growth. These analysis results can help agricultural producers optimize planting plans and improve the efficiency and sustainability of agricultural production. Meanwhile, by analyzing market data, including consumer demand and price trends, agricultural producers can better formulate crop planting and marketing strategies and enhance the market competitiveness of agricultural product.

3.2 Decision Support System

The Decision Support System (DSS), by leveraging the integrated application of big data technology in the agricultural mechanization supply chain, provides a powerful analytical tool to assist agricultural producers in making more scientific and rational decisions [5]. The DSS integrates a large number of data resources, such as real-time and historical data obtained from the data collection and analysis stage, as well as external market and environmental data. It consists of three core modules: data management, model management, and knowledge management. The task of the data management module is to ensure the quality and availability of data, including data collection, cleaning, integration, and storage. Through effective data management, the DSS can guarantee that the data used in the decision-making process is accurate and reliable. The model management module provides a series of analytical tools and models, including statistical analysis models, prediction models, optimization models, etc. These models can conduct in-depth analysis of the data and identify potential changing trends. For example, based on historical yield data and weather forecasts, a prediction model can be used to forecast future crop yields, thereby guiding the formulation of planting plans [6]. The knowledge management module offers decision-making suggestions based on agricultural expertise and historical experience. This knowledge helps to interpret the analysis results of the models and provides more intuitive decision support. When faced with the threat of pests and diseases, the knowledge management module provides strategies and suggestions that have been successful in dealing with similar situations in history. Through the collaborative work of these three modules, the DSS can provide comprehensive and accurate decision support for agricultural production, helping producers optimize operation plans, improve resource utilization efficiency, and enhance the adaptability of agricultural production to market and environmental changes [7].

4. Challenges in the Application of Big Data Technology in the Agricultural Mechanization Supply Chain

4.1 Data Security

With the development of technology, the amount of agricultural data has increased dramatically, including crop growth data, soil and climate conditions, and agricultural machinery operation data. The security of such data is related to the stability and reliability of the entire supply chain. Data security challenges mainly stem from the following aspects.

(1) External attacks: As agricultural supply chains rely more and more on network technologies, such as Internet of Things devices and cloud computing platforms, they have become potential targets for hacker attacks. These attacks include denial-of-service (DoS) attacks, data theft, malware infections, etc., aiming to steal or destroy critical agricultural data.

(2) Internal threats: The inadvertent operations or malicious behaviors of internal users may also lead

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to data leakage or loss. Employees may accidentally expose sensitive data to unauthorized third parties due to a lack of necessary data security knowledge.

(3) Data transmission risks: In the supply chain, data needs to be transmitted among different participants and systems. During the transmission process, data may be intercepted or tampered with. This risk is particularly prominent especially in unencrypted data transmission [8].

Technical complexity and update lag: The technologies and equipment used in the agricultural supply chain may come from different suppliers, and their security performance and update frequencies vary. Some obsolete devices or software may have known security vulnerabilities and become weak links in security management.

4.2 Data Quality

The issue of data quality is another major challenge for big data in the agricultural mechanization supply chain. Data quality problems directly affect the accuracy of data analysis and the effectiveness of decision-making. Data inconsistency and duplication are among the main problems. Since data is collected from diverse sources, including sensors, manual input, and historical records, data formats and standards may vary, resulting in inconsistencies during the integration and analysis processes. Data duplication is also a common problem, which may lead to a waste of resources and biases in analysis results. Incomplete data is also a common issue. Data missing may be caused by equipment failures, network problems or human negligence, which will affect the comprehensiveness and accuracy of analysis. Moreover, the timeliness and accuracy of data are particularly important for agricultural production. Delayed data may render decisions ineffective and have an adverse impact on agricultural production [9]. Errors are prone to occur during the data collection and entry processes, and coupled with the limitations on the accuracy of equipment, data may be inaccurate, which in turn may lead to incorrect analysis results and wrong decisions.

4.3 Data Privacy

Data privacy is of the utmost importance in every industry and is also an issue worthy of attention for every enterprise in the agricultural mechanization supply chain. Data privacy concerns not only individuals but also enterprises. If security measures are not in place, for individuals, their personal privacy may be obtained by lawbreakers and used for illegal acts such as telephone fraud. For enterprises, since agricultural manufacturers may need to share production plan data with component suppliers so that the suppliers can deliver goods in a timely manner, if the transmission process is not encrypted or secure transmission protocols are not adopted, the data may be stolen or tampered with. This will not only disclose the enterprise's trade secrets but also may affect the quality of agricultural machinery products and the normal operation of the supply chain. What this brings to the enterprise may not only be economic losses but also may cause the enterprise to lose its market credibility.

5. Solution

5.1 Implement multi-layer encryption and access control.

Data encryption is the process of converting plaintext data into ciphertext data through encryption algorithms. Data encryption includes encryption at the transport layer, the storage layer, and the application layer. Information such as the personal information of farmers, agricultural sales data, the trade secrets of suppliers and the profits they have obtained all belong to private data, and encryption is used to prevent such data from being illegally accessed. Access control is a security mechanism that restricts access to resources, aiming to ensure that only authorized users or systems can access specific data and resources. For the agricultural mechanization supply chain, access control can prevent internal personnel from illegally accessing and misusing data. In this way, the loss and leakage of data can be effectively prevented.

5.2 Implement advanced data cleaning techniques and verification mechanisms.

In the agricultural mechanization supply chain, data comes from a wide variety of sources, and the quality of data varies. Data cleaning can improve the quality of data, thus providing a solid foundation for subsequent data analysis, mining and decision-making. Data cleaning techniques include techniques for

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handling missing values, techniques for handling outliers, and techniques for dealing with data consistency. All of these can play an important role in the processing of the agricultural mechanization supply chain. The purpose of data validation is to ensure the accuracy, completeness and reliability of data. The principles include the authenticity, legality and timeliness of data. It includes syntax validation, logical validation, cross-validation and so on. The aim of data validation is to ensure the authenticity and reliability of data, reduce risks, maintain data integrity, ensure business compliance, enhance data credibility and promote trust among partners.

5.3 Implement strict data classification and anonymization processing.

The application of data classification in the agricultural mechanization supply chain mainly involves strictly classifying agricultural machinery sales data, customer information, supplier data, production process data and so on. Doing so is conducive to better managing and protecting data. The classification can be carried out according to data content, sensitivity level, purpose of use and the like. Data anonymization is a method that makes personal identity information or other sensitive information in data unidentifiable through technical processing. In the agricultural mechanization supply chain, as a large amount of personal information and commercial confidential data are involved, anonymization can effectively protect the privacy of data subjects and the trade secrets of enterprises while ensuring the availability of data. Commonly used methods for anonymization include data generalization, data desensitization and pseudonymization. Strict data classification and anonymization are helpful for protecting data security and privacy, improving the efficiency of data management and utilization, as well as for compliance and risk management.

6. Conclusion

Currently, the application of big data technology in the agricultural mechanization supply chain has gradually become a key means to improve efficiency and responsiveness. By integrating and analyzing a large amount of data from various links such as production, supply, and distribution, the agricultural mechanization supply chain can predict demand more accurately, optimize inventory management, and enhance the efficiency and sustainability of agricultural production. However, the realization of these applications faces numerous challenges. The security requirements for data collection demand efficient and compatible technical equipment and systems. Data quality is crucial to the reliability of analysis results, and advanced algorithms and processing techniques are needed to ensure it. To address these challenges, it is necessary to formulate reasonable data management strategies, adopt advanced security technologies, and at the same time promote cooperation among policymakers, industry associations, and enterprises to jointly build a secure, efficient, and sustainable big data platform for the agricultural mechanization supply chain.

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