Design and Implementation of Intelligent Warehouse Management System for Tobacco Raw Materials

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Abstract. In order to achieve the intelligent transformation of the existing inventory management system and supply chain system for tobacco raw materials, this research aims to establish digital twin models of the main storage facilities such as the tobacco turnover warehouse, direct material storage area, open-air stacking material storage yard, semi-finished product warehouse, and finished product warehouse in the digital information space. An intelligent warehouse management system for tobacco raw materials can be established, allowing the display of material movements for raw materials, auxiliary materials, semi-finished products, and finished products in a three-dimensional visualization environment. The intelligent warehouse management system designed in this paper enables real-time display of production information, such as basic records, positions, and statuses of physical objects in the tobacco raw materials storage site, thus improving the efficiency and accuracy of storage management in tobacco companies, optimizing the utilization of warehouse resources, and enhancing the quality and effectiveness of storage operations.

Keywords: tobacco raw materials; intelligent warehousing; digital information space; digital twin models

1 Introduction

1.1 Overview of Intelligent Warehouse Management System

Intelligent warehousing, as an indispensable part of industrial digitization, permeates through every level of the digital industry and has become an important component of intelligent logistics system construction [1]. As shown in Figure 1, compared to traditional warehousing, intelligent warehousing enhances land utilization efficiency, reduces labor costs, minimizes material waste, and decreases material picking error rates, elevating the level of warehouse automation and management. Meanwhile, intelligent

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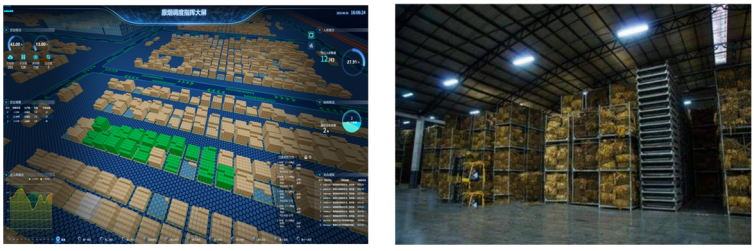
warehousing introduces software such as Warehouse Management System (WMS), enhancing overall management accuracy. Several specific advantages of the intelligent warehouse management system include:

Enhancing enterprise efficiency. The intelligent warehouse management system utilizes automation, data management, intelligent algorithms, human-machine cooperation, and real-time monitoring to enhance the efficiency and accuracy of warehouse operations, facilitating precise warehouse management and improving overall supply chain efficiency and competitiveness. This is specifically manifested in the following two points:

Enhancing material movement efficiency. The intelligent warehouse system automates material storage and retrieval through automated equipment, reducing manual operations and material handling time.

Enhancing enterprise management decision efficiency. The intelligent warehouse system provides real-time data and report analysis, translating data into useful reports and indicators to help management better understand warehouse operations.

(a) Traditional Warehouse Management



(b) Intelligent Warehouse Management

Fig. 1. Comparison between Traditional Warehouse Management and Intelligent Warehouse Management

Reduce Enterprise Management Costs. The intelligent warehouse management system can be integrated with automated equipment to achieve automated warehouse operations, reducing manual operations and human errors, thereby lowering labor costs and improving operational efficiency. Through real-time data and optimization algorithms, the system can monitor inventory levels, forecast demand, and supply chain information in real-time, helping businesses optimize inventory management, reduce inventory backlog and excess, and lower inventory costs and capital occupancy costs. Additionally, the system assists in resource scheduling and utilization rate improvement based on real-time demand and material priority, reducing resource wastage and, consequently, lowering management costs. By providing accurate data and report analysis functionality, the system helps management better understand warehouse operations and business conditions, avoiding cost losses due to erroneous decisions.

1.2 Current Status of Intelligent Warehouse Management System

In today's globalized business environment, intelligent warehouse management systems integrate the latest technology and logistics operations to enhance a company's competitive advantage and improve the efficiency and accuracy of warehouse management [2]. The emergence of the Internet of Things and Radio Frequency Identification (RFID) technology has made automatic identification and traceability of goods possible, thereby improving the accuracy and efficiency of material management [3]. To address issues such as delayed or missed inventory checks, lengthy storage times, and poor standardization of item data in traditional logistics warehousing, experts have proposed IoT technologies based on 5G communication, optical wireless exchange, RFID, and other technologies to enhance data collection and efficiency of modern logistics warehousing while ensuring the safety of logistics goods tracking and warehouse environment management. For example, Lin et al. [4] has proposed the use of IoT technologies based on 5G communication, optical wireless exchange, and RFID to enhance data collection and material handling management efficiency in modern logistics warehousing, while ensuring the safety of logistics goods tracking and warehouse environment management. Zhao et al. [5] has utilized IoT+ technology and the UAP platform, and the Element-UI framework's layered design concept to establish an information intranet for intelligent warehouse systems, realizing an intelligent service-oriented warehousing system using digital control, radio frequency sensing, real-time perception, big data, and other technologies. Gao et al. [6] has designed an intelligent warehouse management system based on AGV to address poor information utilization and circulation in the process of warehousing logistics management, significantly improving warehouse management efficiency. The Dehong Cigarette Logistics Distribution Center has improved its cigarette warehousing management based on AI technology, endowing warehouse equipment with perception and recognition capabilities to enhance the precision of Dehong tobacco logistics warehousing management, further creating a digitized, information-based, and intelligent modern tobacco logistics enterprise [7]. Pan et al. [8] has proposed an intelligent warehouse management system based on big data technology and validated and evaluated the system, demonstrating its advantages in improving warehouse efficiency and reducing operational costs. Shang et

al. [9] has explored the application prospects of digital twin models in the design of intelligent tobacco warehouse management platforms, warehouse modeling, workflow modeling, and warehouse AR visualization systems, providing reference for the design of intelligent warehouse management systems. Zhang et al. [10] has combined 5G communication technology, AMS technology, and RFID technology to build an intelligent warehouse management system architecture based on "5G+ intelligent logistics equipment,".

Overall, the development of the intelligent warehouse industry shows a rapidly growing trend, with a compound annual growth rate of 15% from 2022 to 2027. It is estimated that the global warehouse automation market will reach a milestone of $100 billion by 2027. In 2023, the domestic warehouse automation market broke through 150 billion yuan, accounting for approximately 30% of the global market, with a compound annual growth rate of 21%, higher than the global growth rate. Relatively, China's intelligent warehouse development started late, with low penetration, but there is still a large market space in the future. As of 2021, China's digital economy penetration rate in the secondary industry was only 20%, whereas Germany and South Korea's penetration rates exceed 40%.

Compared to developed countries, China's industrial digitalization level still lags behind. According to statistics from the JD Logistics Research Institute, as of 2021, around 49.17% of companies in China have yet to use any intelligent warehousing equipment, and the penetration rate of currently used intelligent warehousing equipment is also relatively low. The highest penetration rate is 29.04% for AGV equipment, still less than 30%, while the lowest penetration rate is 11.88% for intelligent sorting equipment, indicating that there is still considerable market space. To promote the industrial digitalization process, China has successively introduced a series of top-level policies. In May 2015, the State Council issued "Made in China 2025", proposing the integration of information technology with manufacturing technology and the vigorous development of intelligent manufacturing, officially starting the digital transformation of China's industry. In March 2021, the State Council issued the "14th Five-Year Plan for National Economic and Social Development and the Long-Range Objectives Through the Year 2035", emphasizing the construction of intelligent manufacturing demonstration factories and the improvement of the intelligent manufacturing standard system. In December 2021, the Ministry of Industry and Information Technology and 8 other departments jointly issued the "14th Five-Year Plan for the Development of Intelligent Manufacturing", pointing out the need to comprehensively enhance China's level of intelligent manufacturing during the "14th Five-Year Plan" period.

2 Design of Intelligent Warehouse Management System for Original Tobacco

2.1 Architecture Design of Intelligent Warehouse Management System

As shown in Figure 2, the architecture of the original tobacco intelligent warehouse system mainly consists of two main components: the warehouse management system and warehouse hardware equipment.

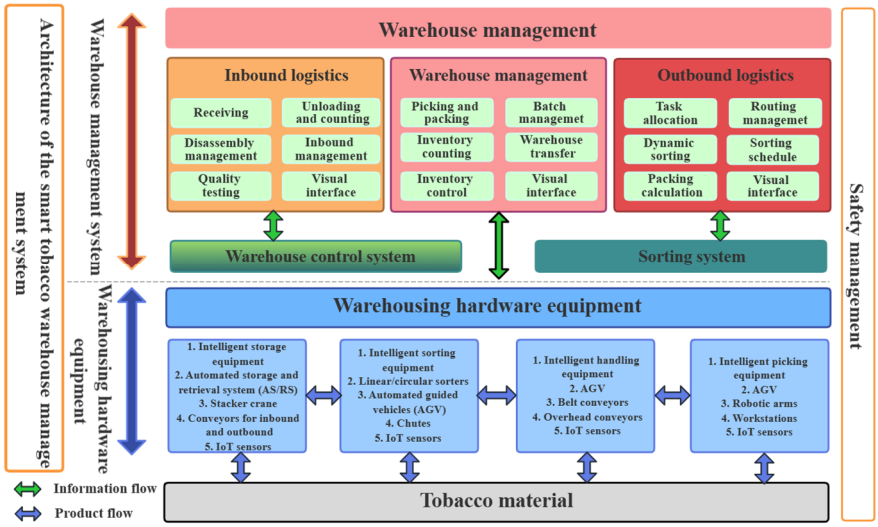


Fig. 2. Architecture of the original tobacco intelligent warehouse system

Through the various associated databases, IoT applications, business and information flow engines of the original tobacco, it automatically connects the personnel, goods, business, and time information chain of the entire process of on-the-way transportation, reporting, entry, unloading, sampling, storage, inspection, and outbound operation, achieving the unified presentation of the physical basic records, location, status, trends, and real-time presentation of the tobacco storage on-site.

2.2 Design of Temperature and Humidity Monitoring Function

The internal temperature of the tobacco stack can easily rise, leading to mold and causing significant economic losses. Monitoring the internal temperature of the tobacco stack is an important daily task in tobacco warehousing management. According to the requirements of temperature and humidity monitoring in the tobacco stack and the layout characteristics of the internal structure of the tobacco stack, this paper analyzes and designs an intelligent temperature and humidity detection module as shown in Figure 3, to achieve 24-hour real-time automatic monitoring of multi-point temperature and humidity inside the tobacco fermentation stack.

After the temperature and humidity sensors collect the relevant data, they use a serial communication interface to send the sensor data to the sub-node module. The sub-node transfers the data to the LoRa gateway through an internal protocol, and the LoRa gateway processes the data locally and transmits the processed data to the backend management system through serial communication. The backend management system transmits the data to the cloud server via the internet for remote data storage and analysis. Upon receiving the data, the cloud server can further process, analyze, and present the data. The specific information transmission process is shown in Figure 4.

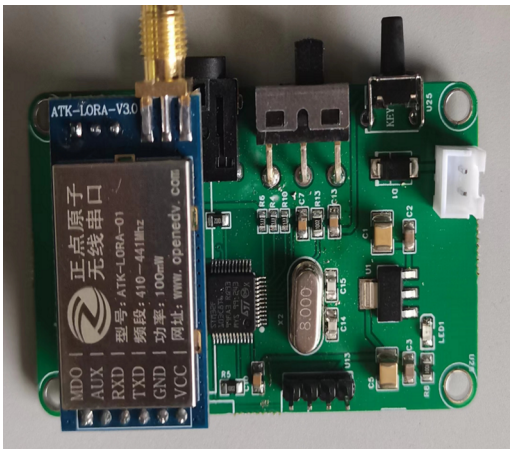


Fig. 3. Temperature and Humidity Detection Module

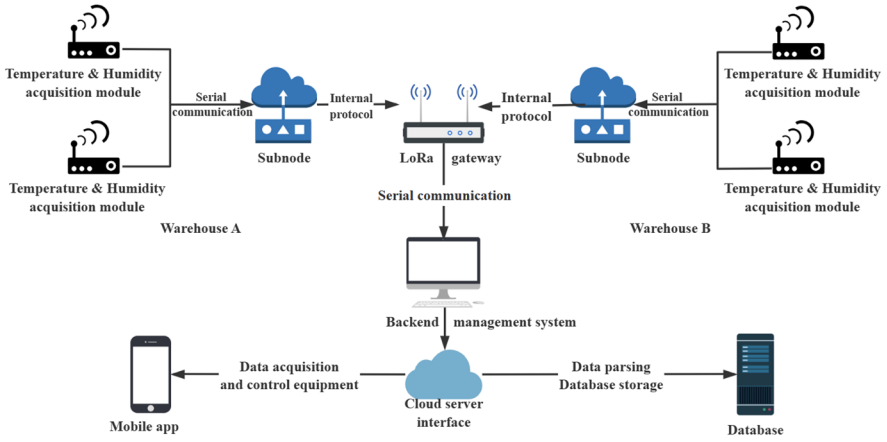


Fig. 4. Temperature and Humidity Information Transmission and Processing Flowchart

2.3 Design of Digital Twin Model for Intelligent Warehouse Management

The main objective of the design of the smart storage digital twin model for original tobacco is to utilize digital technology and IoT devices to achieve intelligent management and optimization of the original tobacco storage process, with its structural design as shown in Figure 5.

The design of the smart storage digital twin model for original tobacco can help tobacco storage enterprises achieve intelligent management and optimization, improve operational efficiency and tobacco quality, and reduce losses and risks. Additionally, the model can provide data support and references for decision-making in the storage process, assisting enterprises in strategic planning and business decisions.

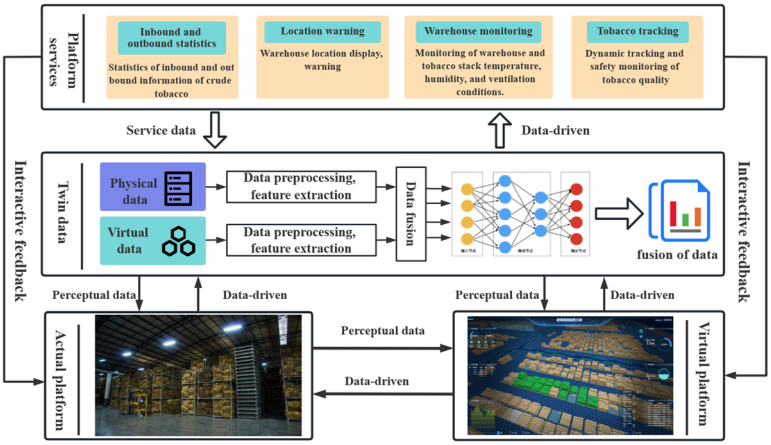


Fig. 5. Structure diagram of the smart storage digital twin model for original tobacco

2.4 Data security management

Data security protection involves a number of aspects, including third-party authentication systems and intranet network security support. Third-party authentication systems prevent unauthorized access and data leakage by ensuring that only authorized users can access data resources through authentication and authorization management. Strong authentication mechanisms, such as multi-factor authentication and single sign-on, improve data security. In addition, intranet network security support includes measures such as network firewalls, intrusion detection systems and data encryption. These security measures work in tandem to build a data security protection system that protects sensitive data from leakage, tampering or unauthorized access. The specific data security management process is shown in Figure 6.

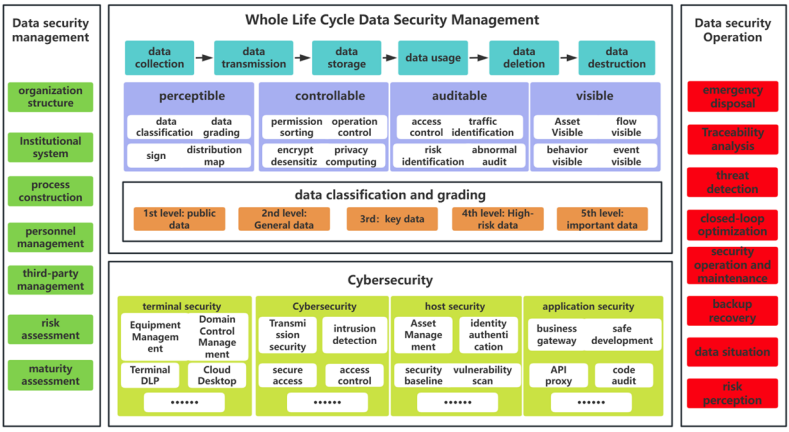


Fig. 6. Structure diagram of the smart storage digital twin model for original tobacco

3 Implementation of Intelligent Warehouse Management System for Original Tobacco

As shown in Figure 7, the smart storage management system for original tobacco includes main modules such as unloading management, periodic inspection, warehouse management, and storage records. The system has established basic databases such as the original tobacco palletizing parameters database, original tobacco unloading inspection (quality, quantity, weight) database, daily status trend monitoring of the original tobacco palletizing area (temperature, humidity, mold, water stains, puncture, etc.) database, original tobacco outbound recommendation database, and location management database.

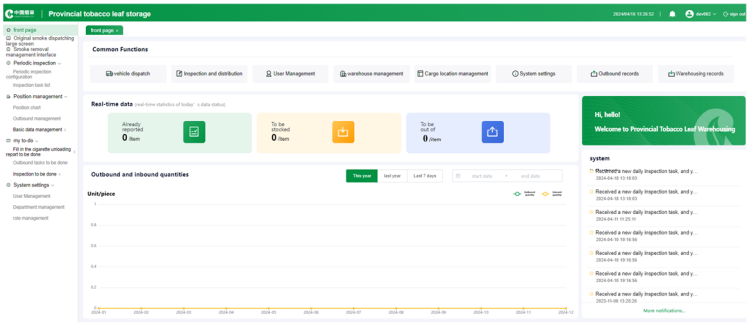


Fig. 7. Main interface of the smart storage management system for original tobacco.

3.1 Management of Tobacco Inbound and Outbound

Through the establishment of the inbound and outbound management modules, a scientific management system and standardized operating procedures are established to ensure the effective guarantee of the quality and quantity of the original tobacco, achieve full life cycle management of the original tobacco, improve the efficiency of inbound and outbound operations, and enhance the quality control level. Some system interfaces for the inbound and outbound management of original tobacco are shown in Figures 8.

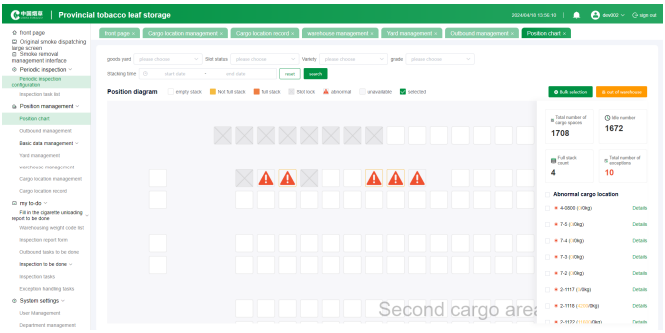


Fig. 8. Warehouse management query interface

3.2 Tobacco Pile Temperature and Humidity Monitoring System

The quality and preservation of tobacco leaves are closely related to the temperature and humidity of the storage environment. Monitoring the temperature of tobacco piles is a crucial aspect of the tobacco storage process. The establishment of a temperature and humidity monitoring system is of great significance for ensuring the quality of the tobacco and reducing losses. It can help companies to promptly identify and address potential issues, thereby improving the storage efficiency and quality of the tobacco. The interface of the tobacco pile temperature monitoring system is shown in Figure 9.

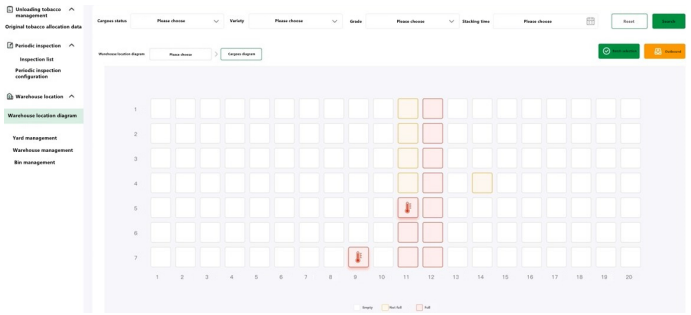


Fig. 9. Temperature monitoring interface

3.3 Digital Twin Model of Intelligent Warehouse Management

By utilizing digital technology and IoT devices, a smart tobacco warehouse management model is constructed to simulate and monitor the actual tobacco storage process using digital twin technology. This enhances the intelligence level of tobacco warehouse management, optimizes management processes, improves efficiency, and enhances cost control capabilities while ensuring the quality and safety of the tobacco. The digital twin interface of the smart tobacco warehouse management system is partially shown in Figure 10.

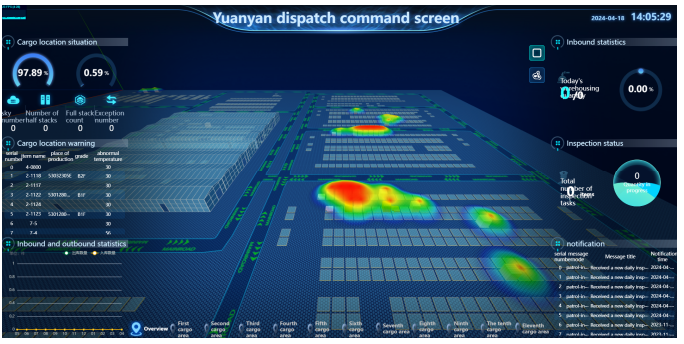


Fig. 10. Digital twin interface display

4 Conclusion

The raw tobacco intelligent warehouse management system realizes real-time monitoring and intelligent decision-making of the tobacco warehousing process, and plays an active role in improving logistics efficiency, optimizing inbound and outbound warehouse management, and monitoring the quality of raw tobacco, etc. At the same time, the establishment of the tobacco intelligent warehousing digital twin model enables the management personnel to more accurately understand the real-time state of the tobacco storage environment, discover potential problems in a timely manner, and be able to adjust and optimize the warehousing strategy intelligently according to the model prediction. Intelligent adjustment and optimization of storage strategies, improving storage efficiency and guaranteeing the quality of tobacco, providing stronger support for the development and upgrading of the tobacco warehousing industry.

Acknowledgements

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References

1. Yi, B. Development and Prospects of Intelligent Warehousing in China[C]//China Storage and Distribution Association. 2022 Report on the Development of China's Storage and Distribution Industry. 2022:84-99.
2. Zhang, N., Hou, Z., & Wan, Y. Analysis of Intelligent Warehouse Logistics Management System[J]. Information Systems Engineering, 2023(07):24-27.
3. Zhong, X. Y. Design of an Intelligent Warehouse Management System Based on the Internet of Things[J]. Information Recording Materials, 2023, 24(08):86-88.
4. Lin, Q. X. Research on Smart Logistics and Warehouse Management Based on the Internet of Things Technology[J]. Logistics Engineering and Management, 2023, 45(09):69-71.
5. Zhao, Y. J., Li, P. F., & Li, P. Y. Research and Application of Smart Warehouse System Platform Based on Internet of Things + Technology[J]. Automation and Instrumentation, 2023(07):126-128+133.
6. Gao, P. Design and Implementation of an Intelligent Warehouse Management System Based on AGV[J]. Electronic Components and Information Technology, 2021, 5(07):189-190+194.
7. He, B., Tang, L., & Zhou, J. Research on the Smart Tobacco Logistics and Warehousing System in Dehong [J]. China Storage and Transportation, 2022(08):103-104.
8. Pan, X. L. Research on Intelligent Warehousing Management Based on Big Data Technology[J]. China Navigation Weekly, 2023(20):63-65.
9. Shang, L. X., Li, C. F., & Sang, T. Application of Digital Twin Model in Intelligent Tobacco Warehousing[J]. Digital Technology and Applications, 2022, 40(02):75-77.
10. Zhang, Z. Z., & Su, J. Design of Intelligent Warehouse Management System based on "5G+ Smart Logistics Equipment"[J]. Journal of Qingdao University (Natural Science Edition), 2023, 36(02):58-63.