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Development status and prospect of cold chain logistics of fruits, vegetables, and agricultural products based on intelligent technology

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Abstract: The cold chain in the production area of fruits and vegetables is the primary link to reduce product loss and improve product quality, but it is also a weak link. With the application of big data technology in cold chain logistics, intelligent devices, and technologies have become important carriers for improving the efficiency of cold chain logistics in fruit and vegetable production areas, extending the shelf life of fruits and vegetables, and reducing fruit and vegetable losses. They have many advantages in fruit and vegetable pre-cooling, sorting and packaging, testing, warehousing, transportation, and other aspects. This article summarizes the rapidly developing and widely used intelligent technologies at home and abroad in recent years, including automated guided vehicle intelligent handling based on electromagnetic or optical technology, intelligent sorting based on sensors, electronic optics, and other technologies, intelligent detection based on computer vision technology, intelligent transportation based on perspective imaging technology, etc. It analyses and studies the innovative research and achievements of various scholars in applying intelligent technology in fruit and vegetable cold chain storage, sorting, detection, transportation, and other links, and improves the efficiency of fruit and vegetable cold chain logistics. However, applying intelligent technology in fruit and vegetable cold chain logistics also faces many problems. The challenges of high cost, difficulty in technological integration, and talent shortages have limited the development of intelligent technology in the field of fruit and vegetable cold chains. To solve the current problems, it is proposed that costs be controlled through independent research and development, technological innovation, and other means to lower the entry threshold for small enterprises. Strengthen integrating intelligent technology and cold chain logistics systems to improve data security and system compatibility. At the same time, the government should introduce relevant policies, provide necessary financial support, and establish talent training mechanisms. Accelerate the development and improvement of intelligent technology standards in the field of cold chain logistics. Through technological innovation, cost control, talent cultivation, and policy guidance, we aim to promote the upgrading of the agricultural industry and provide ideas for improving the quality and efficiency of fruit and vegetable cold chain logistics.

Keywords: fruits and vegetables; cold chain logistics; automated guided vehicle intelligent handling; computer vision; spectral detection

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0 Introduction

In recent years, various cold chain logistics support policies have been introduced one after another, and the policy dividends have been released gradually. The state has successively launched the construction project of a three-level cold chain logistics node facility network, the short-board mending project for the construction of cold chain logistics facilities in the place of origin of agricultural products, and the project of improving quality, increasing efficiency, and reducing costs of modern logistics systems. Facing the new form and new requirements, in September 2022, the Ministry of Transportation and Communications (MOTC) issued the Technical Guidelines for Intelligent Refrigerated Container Terminal Equipment to promote the high-quality development of cold chain logistics and transportation [1]. In December 2022, the National Development and Reform Commission (NDRC) issued the '14th Five-Year Plan for the Development of Modern Logistics', which proposes to actively push forward the transformation of cold chain logistics through digitalization and intelligence, and this plan has been implemented. Digital and intelligent transformation: this plan is the first national plan in the field of modern logistics in China, which has a milestone significance [2]. The '14th Five-Year Plan' for promoting modernization of agriculture and rural areas also mentions that it is necessary to accelerate the construction and preservation of cold-chain logistics networks and to promote the deep integration of modern information technology such as the Internet of Things (IoT), big data, artificial intelligence, and other modern information technology with agricultural production and operation[3]. The Opinions of the Central Committee of the Communist Party of China and the State Council on the Complete and Accurate Comprehensive Implementation of the New Development Concept and Doing a Good Job in Carbon Peak and Carbon Neutral Work emphasize the role of intelligence and other emerging technologies for green and low-carbon industries[4]. The Outline of Strategic Planning for Expanding Domestic Demand (2022—2035) proposes a systematic layout of new information infrastructure and the development of an intensive and efficient modern logistics service system[5].

In 2022, the total demand for food cold chain logistics in China will be 330 million metric tonnes, of which the demand for vegetable cold chain logistics will reach 104 million metric tonnes and the demand for fruit cold chain logistics will reach 81.27 million metric tonnes, and the development of cold chain logistics will show a steady upward trend[6]. As the construction of cold chain facilities for fruit and vegetable products enters the stage of high-quality development, under the support of the above policies at all levels, the application of intelligent technology in the cold chain logistics of fruit and vegetable agricultural products at the origin has become increasingly widespread, which greatly improves the efficiency and quality of cold chain logistics. For example, through the Internet of Things (IoT) technology, the installation of sensors in warehouses and cold storage equipment and transport vehicles can monitor the temperature, humidity, and other key parameters of fruits and vegetables in real-time to ensure the quality of fruits and vegetables in the process of storage and transport. Intelligent temperature control systems and sensor technology enable precise control of the cold chain environment, reducing losses caused by human negligence. This paper focuses on the application status and development trend of several typical intelligent technologies and equipment in the cold chain logistics of fruits and vegetables.

1 The main application of intelligent technology in the field of fruit and vegetable cold chain

The main application scenarios are shown in Figure 1. The main functions and advantages and disadvantages are shown in Table 1.

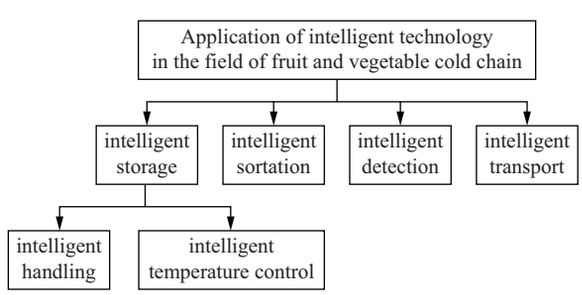


Figure 1 Application scenarios of intelligent technology in the field of fruit and vegetable cold chain

Intelligent technology is more and more widely used in the cold chain logistics of fruit and vegetable origins, which provides strong support for improving the efficiency and quality of fruit and vegetable cold chain logistics.

Table 1 The main functions and advantages and disadvantages of intelligent technology in the field of fruit and vegetable cold chain

Application scenario	Intelligent technology	Key function	Dominance	Inferior
Intelligent warehousing	1)Intelligent temperature control: temperature and humidity sensors, Internet of Things, big data and other technologies 2) AGV intelligent handling: electromagnetic navigation technology, two-dimensional code navigation technology, laser navigation technology, vision navigation technology	1) Intelligent temperature control: real-time monitoring and precise control of temperature and humidity to ensure that fruits and vegetables are stored and transported in a suitable environment 2) Intelligent handling: realise autonomous navigation and obstacle avoidance, improve handling efficiency and reduce manpower cost	1) Improving freshness and reducing energy costs 2)Improve handling efficiency and accuracy, reduce manual errors 3) Reduce labour intensity and improve working environment	1) Large initial investment 2) High technical threshold 3) The existence of data security risks
Intelligent sorting	Sensor and electro-optical technology, computer vision technology, Internet of Things, PLC automatic control technology, etc.	Fast and accurate sorting and grading of fruits and vegetables	Improve sorting speed and accuracy and reduce manual intervention	1) Highly technically demanding 2) Requires regular maintenance and calibration to ensure accuracy
Intelligent detection	Computer vision technology, near-infrared spectroscopy technology, acoustic properties application technology, electronic nose (tongue) technology, electric and magnetic properties application technology, X-ray and laser application technology, and so on	1) Non-contact, non-destructive testing of fruits and vegetables 2) Determine quality indicators such as sugar content and acidity as well as freshness and ripeness	Enables rapid, non-destructive testing to protect the integrity of fruit and vegetables	Equipment is costly and requires specialised personnel to operate and maintain; some detection techniques may be affected by environmental factors
Intelligent transport	GPS, Internet of Things and big data technology, perspective imaging technology, radioactive on-line detection technology, electromagnetic wave application technology, and so on	1) Real-time monitoring of the position, speed, temperature, humidity and other parameters of transport vehicles, and can automatically adjust and optimise transport routes and speed 2) Intelligent application of highway green channel to reduce clearance time	1) Improve transport efficiency 2) Reduce wastage and waste during transport	1) High investment 2) High dependence on network and data transmission

The main application scenarios include: (1) Intelligent warehousing. Intelligent temperature control in the storage link is the basic requirement. Temperature and humidity sensors are set up in each link of the cold chain to monitor the temperature and humidity in the environment in real-time and accurately regulate them according to the preset conditions, to ensure that fruits and vegetables are stored and transported in a suitable environment. Intelligent handling is one of the typical examples of the use of intelligent technology in the storage link. Based on electromagnetic or optical technology, an automatic

guided vehicle (AGV) can move autonomously in cold storage and logistics centers to complete the cargo handling task. (2) Intelligent sorting Intelligent sorting systems based on sensors, electro-optical, and other technologies can quickly and accurately identify and classify different kinds of fruits and vegetables, improve sorting efficiency, and reduce manual errors. (3) Intelligent detection. An intelligent detection system based on computer vision technology can detect the appearance, color, size, and other parameters of fruits and vegetables in real-time, identify unqualified fruits and vegetables, and improve the level of quality control. (4) Intelligent transportation. An intelligent green pass system based on perspective imaging technology can detect the inside of fruits and vegetables without destroying the packaging, ensuring the quality of fruits and vegetables while speeding up customs clearance. This technology plays an important role in fruit and vegetable exports and cross-border transport.

1.1 Intelligent warehousing

The application of intelligent warehousing systems in fruit and vegetable cold storage, including automatic temperature control systems, automatic handling equipment, and so on. Improve the efficiency of warehouse management, reduce labor costs, and provide real-time monitoring of environmental changes in fruits and vegetables in the storage process of temperature and humidity control to ensure the freshness and quality of fruits and vegetables.

Warehousing link is a typical intelligent application of intelligent handling technology. Automated guided vehicle is intelligent handling technology based on electromagnetic or optical technology, able to move autonomously in the cold storage and logistics center. The development of the field of fruit and vegetable cold chain logistics has been experienced from the initial application to the gradual maturation of the process. Early AGV systems were mainly used in industrial manufacturing, and in the 1950s, the United States began to use AGV systems in warehouses. From the 1960s to the 1990s, Japan introduced AGV from the United States after the rapid development of a wide range of uses. With the advancement of technology and the increase in demand for cold chain logistics, AGVs have been introduced into the cold chain logistics of fruits and vegetables and are used for automatic handling in cold storage and production lines by carrying sensors and positioning systems[7].

With the development of the Internet of Things, artificial intelligence, and sensor technology, the navigation and control technology of the AGV system has been improved, which can not only accurately identify and automatically carry fruit and vegetable products but also achieve automatic obstacle avoidance and other functions. Developing from traditional electromagnetic and 2D navigation to laser and vision navigation, many scholars have carried out research and innovation and proposed optimization and improvement solutions to further improve overall logistics and transportation efficiency. The traditional electromagnetic and two-dimensional code navigation technology is mature and has low technical difficulty, but it requires construction on the ground and the addition of ground markings, and once the storage layout is changed, it needs to be reconstructed, which is costly and inflexible. WANG et al. [8] found that electromagnetic navigation had its own accuracy problems before and after the AGV installed RFID sensors. The use of RFID, this automatic identification technology, improved the electromagnetic navigation accuracy and ensured the stable operation of the AGV. Laser and visual navigation, as trackless navigation, can freely adjust the path according to the changes in the storage area and can cope with temporary transport tasks. In the different aspects of fruit and vegetable cold chain logistics, logistics can better adapt to the changes in demand and improve the flexibility and adaptability of the AGV. However, it also faces various problems. For the problem of low handling efficiency, ZHENG[9] research proposed a control system with a Bluetooth function. When the robot encounters a fault and cannot automatically follow the path, the robot′s travel path can be controlled and optimized by the Bluetooth controller App, and the correct rate reaches 100% when the distance is within 12 m (Figure 2). Aiming at the disadvantage of the high price of single-use LIDAR and the low accuracy of single-use vision maps, LI[10] proposed to integrate the two technologies of laser and vision navigation for positioning and map building and determined that the average value of deviation of the

distance between the actual arrival point of the AGV and the set target point was 5.67 cm with good accuracy, to achieve the advantages of laser navigation and vision navigation complementing each other and to reduce the cost while improving autonomy and intelligent level. However, the application landscape for this technology is simple, and to increase accuracy in large-scale and complicated contexts, collaboration with other technologies like GPS and 5G will be required.



Figure 2 Bluetooth control of warehousing and logistics handling robot

In recent years, the application of AGV intelligent handling technology in fruit and vegetable cold chain logistics has gradually scaled up, and more and more cold chain warehouses and logistics centers have introduced AGV systems. Compared with the traditional manual handling method, the transport efficiency of AGV is significantly improved. Its precise positioning and uniform speed control can reduce the vibration and damage of the goods, which not only reduces the manpower cost but also reduces the man-made damage of fruits and vegetables in the process of handling and further protects the freshness and quality of fruits and vegetables in cold chain logistics.

1.2 Intelligent sorting

Early sorting technology mainly relies on artificial and simple mechanical equipment, low efficiency, and large errors. With the development of sensor technology and electro-optical technology, semi-automatic sorting was initially realized. With the progress of computer technology and image processing technology, the sorting system began to integrate sensors and electro-optical technology, through the detection of the appearance of fruits and vegetables, color and size, and other characteristics, to achieve a higher accuracy of automatic sorting. In recent years, the application of artificial intelligence and big data technology has made the intelligent sorting system capable of more complex data analysis and decision-making, improving the accuracy and efficiency of sorting and promoting the intelligent development of fruit and vegetable cold chain logistics.

GAO et al. [11] used kinematics to develop a picking and sorting robot (Figure 3) that can grasp strips and spherical fruits and vegetables, used motion simulation and other software to analyze and optimize, and designed a sorting robot to grasp an efficiency of more than 90%. Compared with the expensive fruit and vegetable sorting machines on the market, this machine is inexpensive, easy to operate, and suitable for small and medium-sized enterprises. In order to further improve the accuracy of sorting and grading, CAI et al. [12] used a hybrid Gaussian background model and affine transformation model to obtain a reliable and accurate algorithm for extracting foreground targets, which enhanced the ability of the fruit and vegetable sorting machine to quickly and efficiently identify the images of fruits and vegetables and reached a new high level in terms of accuracy, which further enhanced the operational efficiency of the cold chain logistics of fruits and vegetables. ZHANG et al. [13] developed a remotely controllable intelligent sorting technology for fruits and vegetables that integrates a variety of modern intelligent technologies, such as remote control of the Internet of Things, PLC automatic control, computer data processing, and so on and realizes high-speed remote on-line intelligent sorting of fruits and vegetables. The system′s sorting accuracy reaches more than 93%. This system has greater advantages than traditional manual sorting and traditional local modeling methods in terms of cost, response speed, sorting accuracy, and management efficiency. WANG[14] proposed an efficient and fully automated method for removing bad fruits suitable for globular fruits and vegetables by integrating and synergistically applying computers, programmable logic controller (PLC) and mechanical mechanisms, and proposed a method for identifying bad fruits by using the hue-saturation-value (HSV) luminance contouring characteristics of the method to identify fruit stems and defects, breaking through the technical difficulties of partitioning the two, to achieve the purpose of removing bad fruits, reversing

the previous situation that bad fruits can only be removed manually with low efficiency and high error rate, and promoting the innovative development of intelligent grading and sorting of fruits and vegetables. BAI et al. [15] based on embedded machine vision, the comprehensive use of the STM32 microcontroller, the OpenMV machine vision module, and so on to design an intelligent sorting fruit robot (Figure 4) that can accurately determine the ripeness of the fruit and size of the fruit. The success rate of the robot in identifying the target fruit ripeness reaches 100%, and the sorting success rate is 87.5%, which has good reliability and practicality in replacing manual work to complete high-intensity, high-cost sorting work.

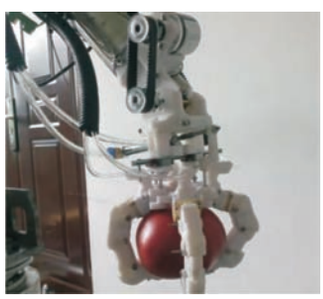


Figure 3 A picking and sorting robot for spherical fruits and vegetables

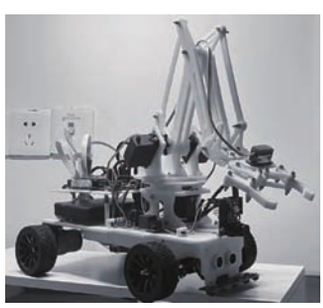


Figure 4 Intelligent sorting robot

The application of intelligent sorting technology in fruit and vegetable cold chain logistics not only reflects the innovative ability of modern technology but also demonstrates the logistics industry's far-reaching insight into future development, which has brought revolutionary changes to the whole industry. With the progress of technology, the cold chain logistics of fruits and vegetables will certainly develop in the direction of being more intelligent and efficient.

1.3 Intelligent Detection

Intelligent detection technology has gradually penetrated into all aspects of fruit and vegetable cold chain logistics, scholars at home and abroad explore the use of fruits and vegetables of their own mechanical, optical, acoustic, electrical and other physical properties, through the combination of advanced computer vision technology, near-infrared spectroscopy, acoustic characteristics of the application of technology, the electronic nose (tongue) technology, electrical and magnetic characteristics of the application of technology, X-ray and laser application of technology, etc. [16-17] and artificial intelligence algorithms to achieve accurate detection and monitoring of fruits and vegetables. These technologies have not only improved the efficiency of cold chain logistics and reduced human errors and labor costs, but have also significantly improved the quality and safety of fruits and vegetables. The Massachusetts Institute of Technology (MIT) in the United States set up a computer vision course in the 1970s and began a series of research projects. By the 1990s, computer vision technology had been widely used in industrial production[18]. It mainly focuses on four aspects, namely, positioning and navigation, detection, measurement, and recognition, and is more widely used in agricultural production processes. Developed countries such as the United States, Japan, Germany, and other countries almost all apply machine vision technology in all aspects of agricultural production[19].

When computer vision technology was first applied to the field of fruit and vegetable sorting and inspection, it mainly relied on simple image processing algorithms for basic color, shape, and size detection. These early systems had limited detection accuracy and could only meet basic needs. With the development of machine learning and image processing technology, computer vision systems began to integrate more advanced algorithms, such as feature extraction and pattern recognition, which improved detection accuracy and speed and were able to identify more complex surface defects and qualities of fruits and vegetables. In recent years, the application of artificial intelligence technology has given computer vision systems the ability to learn and optimize themselves. Through the training of a large amount of data, these systems can identify the quality problems of fruits and vegetables more accurately and promote the development of intelligent detection technology with high precision and efficiency.

Using computer vision technology, XU[20] proposed a method for detecting and separating melon tips based on corner point detection and applied support vector machines as a classification method to identify melon defects with a recognition rate of 96%. WU[21] obtained three parameters of blood orange, namely size, girth, and ripeness, through computer vision non-destructive testing technology, introduced the concept of fuzzy clustering, and established the affiliation function for blood orange grading through the empirical method. However, in maturity analysis, this method is difficult to effectively analyze the damaged parts and color-making parts of blood oranges, and further improvement of the method is needed. Light is one of the essential factors in the visual formation process. Spectral imaging technology has become a hot spot in the application of fruit and vegetable quality inspection[22]. GUO et al. [23] concluded that near-infrared spectroscopic detection technology has the advantages of non-destructive, fast, and green, which makes it suitable for building an intelligent detection system for fruits and vegetables, However, to increase the accuracy of the detection results, the near-infrared spectroscopy acquisition procedure must be standardized. The United States and Japan launched a variety of portable analyzers based on near-infrared detection technology in fruit and vegetable quality testing, which has good performance and has become a mainstream product in the market[24]. Acoustic technology is also widely used in fruit and vegetable detection. The use of an automated tapping device to create an acoustic model for melon ripeness detection utilizing auditory peaks was successfully investigated by ZHANG et al. [25], and the experimental results showed a substantial linear connection. However, using only one method of tapping will unavoidably harm the melon and compromise its integrity. As a result, researchers have tried to combine several methods to achieve non-destructive detection. GAO et al. [26] proposed a new non-destructive detection algorithm based on band magnitude vector (BMV) audio features and highly correlated with ripeness, and the algorithm achieved 86.96% accuracy for the classification of round melon species and 91.67% accuracy for the classification of ellipsoidal melon species, with better detection and classification results. ZHANG et al. [27] similarly proposed that the BMV feature is the feature with the highest correlation with watermelon ripeness. YANG et al. [28] creatively proposed the combination of spectral and acoustic technologies to achieve fast and non-destructive detection of fruit ripeness at anytime and anywhere through App+5G artificial intelligence technology. FENG[29] used chemometrics to construct a fruit and vegetable freshness and related quality detection model based on electronic nose and low-field nuclear magnetic resonance (NMR) and concluded that the electronic nose analysis combined with the partial least squares model can effectively predict the freshness and related quality of cherry tomatoes; the use of low-field NMR analysis combined with the support vector machine model can effectively predict the freshness and related quality of cucumbers; and at the same time, a 'Fruit and vegetable freshness and related quality detection model' was developed. At the same time, we have developed a 'Fruit and Vegetable Freshness Intelligent Detection System', which realizes the intelligent detection of fruit and vegetable freshness and related qualities, which is of great significance in promoting the development of intelligent detection technology. Laser technology has been widely used in industry, medicine, and other fields. In recent years, laser technology has tried to apply it to the quality inspection of fruits and vegetables. It can not only carry out the internal quality inspection of fruits and vegetables to determine the maturity of fruits and vegetables, sugar and acidity, pH, etc., but it can also be applied to fruits and vegetables pesticide residues on the detection of fruits and vegetables to protect the quality and safety of fruits and vegetables. It is a new technology that is developing and has great potential[30-31].

1.4 Intelligent transport

There are two ways that intelligence transport has expressed. Firstly, cold chain transport trucks are outfitted with sophisticated sensors and monitoring gear to monitor important transit-related variables like temperature and humidity. This remote monitoring is made possible by Internet of Things technology. The second is the use of sophisticated detection and information management systems in the highway's green

channel. To successfully increase management efficiency, intelligent information management systems combine 'Internet +' and 'big data', gather data in real-time, employ network transmission, etc., and create an intelligent information management model after conducting extensive usage, analysis, and statistical research[32]. A highway intelligent logistics green channel verification system was proposed by LI et al. [33]. It uses big data technology to accomplish active monitoring, dynamic supervision, and reasonable release in one of the contemporary new management tools, thereby increasing logistics efficiency and effectiveness. Currently, the highway on the Green Channel's fresh and live agricultural products vehicle inspection relies heavily on personal experience, specific gravity, sensory, and document checking methods; as a result, detection efficiency is low, results are subpar, and have more numerous issues. Specifically, intelligent detection methods are crucial. With the help of perspective imaging technology, fruits and vegetables can be quickly identified, as well as whether a passing vehicle is carrying non-agricultural products. It can be done without having to open the fruit and vegetable packaging, minimizing damage and waste, speeding up the customs clearance process, and increasing the effectiveness of the inspection of green vehicles, all of which contribute to improved logistics efficiency. However, the technology is still in its early stages of development, particularly when dealing with complex packaging and large quantities of goods. Cobalt-60, the ray source used in the online inspection, has a strong penetration rate, high clarity, and good imaging quality, making it suitable for use in the intelligent green pass link of fruits and vegetables[34]. Another quick and effective physical approach is the radar detection method. The technique relies on high-frequency electromagnetic waves to ascertain the medium's distribution pattern, and the dielectric constant's influence on the speed at which electromagnetic waves propagate is correlated with the medium's water content. Since fruits and vegetables are high in water content, it is possible to detect whether a vehicle contains any illegal commodities by using radar-detecting technology to measure the water content of the products within[35].

Intelligent transport makes real-time monitoring of refrigerated trucks, containers, and other transport vehicles possible. It also enhances safety during transportation and guarantees the quality of fruits and vegetables. However, long-distance transport necessitates additional testing of the equipment's stability and dependability. Combining a perspective imaging system with Internet of Things technology allows for real-time monitoring and data analysis of the entire cold chain logistics process for fruits and vegetables, leading to more efficient cargo inspection and classification. Additionally, the system records inspection data for each batch of fruits and vegetables, which serves as the foundation for quality control and problem-solving in the future. However, the operator must possess specific professional skills to interpret the perspective image, which is a higher requirement of the professional level of personnel.

2 Problems

Intelligent technology improves the efficiency and accuracy of fruit and vegetable cold chain logistics through various ways and links and is in the stage of rapid development. Automated and intelligent loading and unloading equipment, transport tools, and sorting systems have dramatically improved the overall efficiency of logistics operations. At the same time, intelligent temperature control systems ensure that fruits and vegetables are transported and stored under appropriate temperature and humidity conditions, thereby reducing fruit and vegetable waste and quality issues. Although intelligent technology has brought significant benefits, there are also some problems in its practical application.

1) The transformation, upgrading, and maintenance costs of intelligent technology are relatively high, including the costs of equipment purchase, installation, operation and maintenance, and energy consumption. This is a large economic burden for small and medium-sized enterprises, and some enterprises can hardly afford it and still use the traditional manpower-based approach, which limits the further promotion of intelligent technology, a phenomenon that is particularly obvious in small enterprises of fruit and vegetable origins.

2) The difficulty of technological integration. The application of intelligent technology needs to be effectively integrated with the existing cold chain logistics system, and there are often problems with the compatibility and coordination between different systems, which increases the complexity and difficulty of technology application. For example, the AGV system needs to be seamlessly integrated with other systems of cold chain logistics, such as warehouse management systems, sorting systems, etc. In a cold storage and humid environment, the operation stability of AGV equipment influences the continuity of other systems' operations, and the compatibility and coordination problems between the systems increase the difficulty of technology application. In addition, there are many varieties of fruits and vegetables, with large differences in shape, color, size, and other characteristics, and the intelligent sorting system needs to be combined with more advanced technologies, such as artificial intelligence, big data, the Internet of Things, etc., when dealing with diversified products. The fusion of multiple technologies further improves the complexity of the application of intelligent technology.

3) There is a relative shortage of professional talents in the industry. Each link of intelligent cold chain logistics needs to be equipped with talents who master advanced technology and management skills to guarantee the stable and sustainable functioning of equipment and machines. In particular, perspective imaging technology involves high-precision image processing and data analysis, which is of high complexity and requires professional technicians to operate and maintain. Due to the lack of a corresponding professional technical force and a low level of information technology, some enterprises find it difficult to adapt to intelligent transformation, which affects the promotion and application of intelligent technology and then restricts the development of intelligent cold chain logistics.

4) Industry standards and norms are not yet perfect. Due to the lack of unified national standards and industry norms, different cold chain logistics enterprises may adopt different technologies and operation standards, resulting in uneven service quality and safety levels. This is mainly because intelligent technology involves several fields, such as computer science, data science, and electronic engineering. The crossover of these fields makes it more complicated to formulate unified standards and specifications, which usually requires a longer period and multi-party consultations, which results in the updating of standards not being able to adapt to the rapid development of the technology.

3 Development trends and prospects

In the future, with the continuous development of IoT, artificial intelligence, big data, and blockchain technology, intelligent technology will be more widely and deeply applied in fruit and vegetable cold chain logistics, and the intelligent development of cold chain logistics mainly focuses on several aspects, such as cost reduction, technological integration, talent cultivation, and the improvement of standards.

1) Actively apply the Internet of Things, big data, artificial intelligence, and other cutting-edge technologies to improve the perception, analysis, and decision-making abilities of intelligent equipment. Increase investment in intelligent equipment technology research and development and innovation, and improve equipment performance through independent research and development or cooperative development of new intelligent equipment. At the same time, focus on the application of new materials to reduce the manufacturing cost of equipment. Strive for relevant government subsidies and tax incentives to expand the application scale of intelligent equipment and reduce the unit cost so that small and medium-sized enterprises can also accept it, thus expanding the application scope of intelligent technology. When more cold chain logistics enterprises adopt intelligent equipment, a scale effect can be formed, gradually reducing the procurement and maintenance costs of the equipment.

2) Strengthen the integration of intelligent technology and cold chain logistics systems and use big data and cloud computing technology to build an intelligent cold chain logistics platform integrating information collection, processing, analysis, and application. Establish a unified data exchange standard, realize data sharing and exchange between different systems, ensure smooth and seamless information flow between various systems, and improve the synergy and

compatibility of the whole system.

3) Pay attention to the cultivation of intelligent technology talents from the viewpoint of universities; strengthen school-enterprise cooperation in addition to theoretical courses; carry out practical training, internship training, and other forms of teaching. Combined with the latest practical needs of the frontier, the leading enterprises in the industry cooperate to set up training courses to ensure that students fully master the required skills. On the part of enterprises, more encouragement should be given to employees to continuously learn and adapt to new technologies and tools and to improve their adaptability and learning ability, to enhance the technical level and management ability of the practitioners and to promote the wide application of intelligent technologies. The government should introduce relevant policies and provide the necessary financial support and policy inclination.

4) The government and relevant organizations should speed up the formulation and improvement of intelligent technology standards in the field of cold chain logistics to adapt to the rapid development of the technology. By formulating more perfect industry standards and norms, they can promote the application and popularization of intelligent technology in cold chain logistics, promote the healthy development of the cold chain logistics industry, and facilitate the standardization and efficiency of cold chain logistics.

To sum up, the cold chain logistics of fruit, vegetable, and agricultural products based on intelligent technology are in a stage of rapid development. Although it faces challenges such as high costs, technological integration, and talent shortages, the development prospects of cold chain logistics are broad through technological innovation, cost control, talent cultivation, and policy guidance. In the future, with the in-depth application of intelligent technology and the improvement of industry standards, cold chain logistics will be more efficient and safer, which will further promote the quality improvement and market competitiveness of fruit, vegetable, and agricultural products.

References

[1] Ministry of Transport of the People's Republic of China. Circular of the General Office of the Ministry of Transport on the Issuance of Technical Guidelines for Intelligent Refrigerated Container Terminal Equipment [EB/OL]. https://xxgk. mot. gov. cn/2020/jigou/syj/202209/t20220922_3684094. html, 2022－09－22.

[2] General Office of the State Council of the People's Republic of China. Circular of the General Office of the State Council on the Issuance of the '14th Five-Year Plan' for the Development of Modern Logistics [EB/OL]. https://www. gov. cn/zhengce/zhengceku/2022－12/15/content_5732092. htm, 2022－12－15.

[3] State Council of the People's Republic of China. Circular of the State Council on the issuance of the '14th Five－Year Plan' for promoting modernisation of agriculture and rural areas [EB/OL]. https://www. gov. cn/gongbao/content/2022/content_5675948. htm, 2021－11－12.

[4] Central Committee of the Communist Party of China, State Council of the People's Republic of China. CPC Central Committee State Council on the complete and accurate comprehensive implementation of the new development concept to do a good job of carbon peak carbon neutral work [EB/OL]. https://www. gov. cn/zhengce/2021－10/24/content_5644613. htm, 2021－09－22.

[5] CPC Central Committee, State Council of the People's Republic of China. CPC Central Committee State Council Issues Outline of Strategic Planning for Expanding Domestic Demand (2022－2035) [EB/OL]. https://www. gov. cn/gongbao/content/2023/content_5736706. htm, 2022－12－14.

[6] China Federation of Logistics and Purchasing Cold Chain Logistics Professional Committee and other editors. China cold chain logistics development report (2023) [M]. Beijing: China Fortune Publishing House Ltd, 2023.

[7] XU Hangyu. Design and implementation of control system for warehouse handling robot [D]. Nanjing: Nanjing University of Science and Technology, 2017.

[8] WANG Zhendong, GUO Xiaojun, WANG Haifeng, et al. AGV positioning and magnetic navigation based on RFID [J]. Equipment Manufacturing Technology, 2021(7): 106－110.

[9] ZHENG Jinsong. Design and application of control system for warehouse logistics handling robot [J]. Packaging and Food Machinery, 2023, 41(3): 59－64.

[10] LI Dunmai. Research on AGV SLAM algorithm based on lidar and vision fusion and path planning [D]. Changchun: Jilin University, 2023.

[11] GAO Xudong, HAN Xichun, ZHANG Zhengsu, et al. Design of a fruit and vegetable sorting robot intelligent system [J]. Technology & Economy in Areas of Communications, 2016, 18(6): 61－64, 74.

[12] CAI Xinyao, HE Kaiji, ZHANG Chenyang, et al. Implementation of target extraction algorithm in fruit and vegetable intelligent sorting system [J]. Journal of Southwest Minzu University (Natural Science Edition), 2019, 45(2): 178－184.

[13] ZHANG Ying, CHENG Ruqi, CHEN Shaohui. Research on fruit and vegetable intelligent sorting technology of high speed remote control based on PLC [J]. Storage and Process, 2021, 21(12): 111－117.

[14] WANG Lei. Exploratory research on spherical agricultural product sorter based on machine vision [J]. Southern Agricultural Machinery, 2022, 53(10): 9－12, 23.

[15] BAI Zhenwei, YAN Fuwei, YUAN Peihai, et al. Design and experiment of fruit sorting robot based on embedded machine vision [J]. Journal of Intelligent Agricultural Mechanization, 2023, 4(3): 61－70.

[16] LAKSHMI S, PANDEY A K, RAVI N, et al. Non-destructive quality monitoring of fresh fruits and vegetables [J]. Defence Life Science Journal, 2017, 2: 103－110.

[17] SHEN Haijun. Research on intelligent detection of apple freshness based on low-field nuclear magnetic resonance technology [D]. Yangzhou: Yangzhou University, 2023.

[18] WANG Tiesheng. Development and application of computer vision technology [J]. Information System Engineering, 2022(4): 63－66.

[19] YANG Tao, LI Xiaoxiao. Research progress of machine vision technology in modern agricultural production [J]. Journal of Chinese Agricultural Mechanization, 2021, 42(3): 171－181.

[20] XU Yingying. Study on melon external quality inspection based on computer vision [D]. Lanzhou: Gansu Agricultural University, 2011.

[21] WU Guangxu. Research on non-destructive detection and grading technology of blood orange based on computer vision [D]. Chongqing: Southwest University, 2016.

[22] LÜ Jiayu, ZHU Danshi, FENG Xuqiao, et al. Intelligent sensing technology and its application in quality inspection of fresh fruits and vegetables [J]. Food and Fermentation Industry, 2014, 40(11): 215－221.

[23] GUO Zhiming, GUO Gang, WANG Mingming, et al. Progress in non-destructive testing of fruit and vegetable quality and safety by near-infrared spectroscopy [J]. Journal of Food Safety and Quality Inspection, 2019, 10(24): 8280－8288.

[24] LIU Yan, ZHOU Xinqi, YU Xiaofeng, et al. Research progress on the application of non-destructive testing technology in fruit and vegetable quality testing [J]. Journal of Zhejiang University (Agriculture and Life Science Edition), 2020, 46(1): 27－37.

[25] ZHANG Shuai, SHI Lei, ZHANG Benhua. Ripeness detection method of melon based on acoustic characteristics [J]. Journal of Agricultural Mechanization Research, 2011, 33(10): 126－129.

[26] GAO Guandong, TENG Guifa, XIAO Ke, et al. Non-destructive detection of watermelon ripeness based on BMV features [J]. Journal of Agricultural Engineering, 2010, 26(8): 326－330.

[27] ZHANG Yuxin, ZHAO Yang, TAO Jia. Research on non-destructive detection technology of watermelon ripeness based on audio characteristics [J]. Journal of Hebei Agricultural University, 2011, 34(2): 114－118.

[28] YANG Fan, LU Lixin. Design of non-destructive fruit ripening detection system based on spectral imaging and acoustic technology [J]. Journal of Lanzhou College of Arts and Sciences (Natural Science Edition), 2023, 37(1): 60－65.

[29] FENG Lei. Research on intelligent detection of cucumber and cherry tomato freshness based on electronic nose and low-field nuclear magnetic resonance [D]. Wuxi: Jiangnan University, 2019.

[30] CUI Di, ZHANG Wen, YING Yibin. Application of laser Doppler vibrometry in agricultural product quality detection [J]. Journal of Agricultural Machinery, 2013, 44(7): 160－164.

[31] YU Huafen, QIN Li. Research progress of laser technology in agricultural product quality inspection [J]. Agriculture and Technology, 2019, 39(21): 49－50.

[32] LIU Peng. Design and realization of highway green channel information management system [D]. Xi′an: Chang′an University, 2017.

[33] LI Jianli, YUAN Huabing, JIN Bo, et al. Research and application of green channel verification system for highway intelligent logistics [J]. China Logistics and Purchasing, 2022(13): 45－47.

[34] XUE Chunfeng. Research and application of intelligent detection system for highway green channel vehicles [C]// Highway Operation and Management Branch of China Highway Society. Proceedings of the 2011 Annual Meeting of Highway Operation and Management Branch of China Highway Society and the 18th National Seminar on Highway Operation and Management. Toll Management Branch of North China Expressway Company Limited, 2011: 5.

[35] NIU Jianqiang, MENG Hongfei, YANG Ruirui, et al. Research on rapid detection program for green channel vehicles [J]. China Traffic Information Technology, 2010(11): 116－117, 119.

基于智能化技术的果蔬农产品产地冷链物流发展现状与展望

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摘要：果蔬产地冷链是降低产品损耗、提高产品品质的首要环节，更是薄弱环节。随着大数据技术在冷链物流中的应用，智能化设备与技术已成为提高果蔬产地冷链物流效率、延长果蔬保鲜期、降低果蔬损耗的重要载体，在果蔬预冷、分拣包装、检测、仓储、运输等方面有着诸多优势。本文通过研究总结国内外近几年发展迅速、使用广泛的智能化技术，包括以电磁或光学技术为基础的AGV智能搬运，以传感器、电子光学等技术为基础的智能分拣，以计算机视觉技术为基础的智能检测，以透视成像技术为基础的智能运输等，分析研究各学者在果蔬冷链仓储、分拣、检测、运输等环节中智能化技术应用的创新研究及取得的成果，提高了果蔬冷链物流效率。然而，智能化技术在果蔬冷链物流中的应用也面临诸多问题。成本高、技术融合难度高和人才短缺等挑战，使得智能化技术在果蔬冷链领域的发展受到一定限制。为解决当前存在的问题，提出通过自主研发、技术创新等手段进行成本控制，降低小型企业进入门槛。加强智能化技术与冷链物流系统的集成，提高数据安全性和系统兼容性。同时，政府应出台相关政策，提供必要的资金支持和人才培养机制。加快制定和完善冷链物流领域的智能化技术标准。通过技术创新、成本控制、人才培养和政策引导，推动农业产业升级，为果蔬冷链物流提质增效提供思路。

关键词：果蔬；冷链物流；AGV智能搬运；计算机视觉；光谱检测