

A Review of Orchard Robot Research

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Abstract: In modern agricultural production, orchards, as one of the important agricultural fields, are facing difficulties such as labor shortage, low production efficiency, and rising costs. To cope with these difficulties, orchard robots were introduced as an emerging technology. With the rapid development of robotics, artificial intelligence and machine learning, the application of intelligent robots in the agricultural field is becoming more and more mature. Advances in sensing technology, navigation technology, image recognition and other technologies have provided technical support for the research and application of orchard robots. Through the precise operation of orchard robots, precise management of orchard crops can be realized, including precise fertilization, pest and disease monitoring, directional irrigation, etc., so as to improve the yield and quality of orchards. This increases production efficiency, reduces costs, increases yields, and drives agriculture towards sustainable development. This paper combs the research status of picking robots by combining literature collation and market research, shows the scientific research results of various types of orchard picking robots at home and abroad, makes an in-depth analysis of the existing problems, and discusses the basic system composition of orchard picking robots Existing problems, and propose solutions to the problems found. Orchard picking robot has a huge application space in China, but due to the difficulty of research and development, there are still few economical and practical orchard picking robot products at home and abroad. It is necessary to increase the research and development of intelligent picking robots, integrate multidisciplinary high and new technologies, vigorously carry out innovative research on intelligent picking technology and equipment, improve the precision, portability, and low cost of robots, and promote the early application of orchard picking robots in China.

Keywords: Orchard Robot; Deep Learning; Algorithm; New Qualitative Productivity.

1. Introduction

During the two sessions, the deputies and CPPCC members will discuss and adopt a series of policies and regulations on science and technology and agricultural modernization. These policies and regulations encourage and guide the development of the agricultural sector, including agricultural mechanization and automation. As an important part of agricultural automation, orchard robots can alleviate the challenges faced by orchards, such as labor shortages, low production efficiency, and rising costs. Advances in sensing technology, navigation technology, image recognition and other technologies have provided technical support for the research and application of orchard robots. Through the precise operation of orchard robots, precise management of orchard crops can be realized, including precise fertilization, pest and disease monitoring, directional irrigation, etc., so as to improve orchard yield and quality [1]. This increases production efficiency, reduces costs, increases yields, and drives agriculture towards sustainable development. In 2023, in Aksu City, Xinjiang, the apple planting area will reach 139,500 mu, and the total fruit output is expected to be 572,200 tons, of which the total output of apples is expected to be 269,000 tons .

This level of production reflects the prosperity of apple cultivation and efficient agricultural management in the region. Through automated operations, the production efficiency of the orchard can be greatly improved and labor costs can be reduced. And reduce the use of pesticides, reduce environmental pollution, and improve the green safety level of fruits. Looking at the world, fruit production in the United States has a distinct seasonality, with different regions and different fruit harvest seasons. This leads to seasonal fluctuations in labor costs, and orchard robots can further

liberate productivity, replace manual picking, and reduce costs.

2. Research Status at Home and Abroad

Japan's Naoshi Kondo and others have developed and manufactured a robotic tomato picking robot with seven degrees of freedom. In the picking environment, the robot identifies and locates the ripe fruit through a binocular vision system, and after the picking robot separates the fruit from the fruit stalk through the wrist joint, the fruit is picked by inhalation with a soft padded end effector. However, when the picking robot is located in an environment with dense foliage, it cannot avoid obstacles to complete the picking operation, which affects the success rate of picking [2].

Lu Huaimin of Beijing Forestry University has developed a forest cone-picking robot, which is mainly composed of a 5-degree-of-freedom manipulator, a walking mechanism, a hydraulic drive system and a single-chip microcomputer control system. The efficiency of this robot is 500kg/day, which is 30-50 times that of manual labor. Moreover, the damage to the mother tree during harvesting is small, and the net harvesting rate is higher [3].

Zhou Yunshan and others from Jilin University of Technology studied mushroom picking robots. The system is mainly composed of mushroom conveyor belt, camera, picking manipulator, two-degree-of-freedom pneumatic servo mechanism, manipulator grasping control system and computer. The computer vision system provides the mushroom picking machine with the size and area information required for classification, and guides the robot to accurately reach the center of the mushroom to be picked, preventing the failure of grasping or damaging the mushroom

due to inaccuracy [4].

Zhang Tiezhong of China Agricultural University designed three kinds of picking robots for strawberries cultivated in common greenhouses in China. The manipulators in the form of bridge type, 4 degrees of freedom gross door type and 3 degrees of freedom Cartesian coordinates were used for cross-row harvesting, and the color images were obtained through the color CCD sensing system, and the target strawberries were identified and positioned through image processing, and then the end effector was controlled for harvesting. At the same time, practical problems such as the biological characteristics, ripeness, and multiple strawberry shading of strawberries were studied, which provided a design basis and theoretical basis for strawberry picking [5].

Zhang Ruihe, Ji Changying and others from Nanjing Agricultural University used binocular stereo vision technology to locate the red tomato in tomato picking, transformed the image into grayscale, and then corroded and expanded the two-dimensional histogram of the image to remove small clumps, extracted the edge of the background area, and then used the fitting curve to realize the segmentation of the color image and separate the tomato from the background. After the target is calibrated, the area matching is used to realize the registration of the target in the conjugate image. Using the principle of stereo imaging, the three-dimensional coordinates of the target are recovered from two two-dimensional images. Through the analysis of experimental data, it is concluded that when the distance between the target and the camera is 300mm-400mm, the depth error can be controlled to about 3%-4% [6].

3. Problems Encountered by Orchard Robots and Countermeasures

3.1. General Problems Faced by the Development of Orchard Robots:

(1) Robots need to be highly flexible, adaptable, and precise to adapt to the growth of different fruit trees.

(2) The environmental friendliness of the robot

In order to deal with the above problems, we need to start from the aspects of robot design optimization, intelligent control system, and sensor technology improvement. At the same time, combined with artificial intelligence, machine learning and other technologies, the intelligent level of orchard robots is improved, so that they can better adapt to the orchard environment and improve operation efficiency. At the same time, it is necessary to develop collision detection and obstacle avoidance technology, emergency stop function, remote monitoring and control, and comply with relevant standards and regulations. In addition, energy efficiency can be improved, chemical use can be reduced, regular maintenance and cleaning. Orchard robots can be charged using solar panels, which is very effective, especially in the sunny Xinjiang region. It can also be integrated with existing clean energy systems, such as solar power systems for household or agricultural use.

The research and application of orchard robots can not only promote the transformation and upgrading of agricultural production methods, improve the production efficiency and quality of orchards, but also provide new technical support for the development of agricultural modernization. By continuously improving and optimizing orchard robot technology, the intelligent, efficient and sustainable development of agricultural production can be realized, and

new impetus can be injected into the future development of the agricultural industry. As an important part of the new quality productivity, orchard robots have great development potential and broad application prospects, which will bring revolutionary changes to orchard production and help the sustainable development of the agricultural industry [1,7].

3.2. Energy Consumption Problems Encountered by Orchard Robots

The energy consumption of an orchard robot often depends on its design and the tasks it needs to perform. For example, a robot used to pick fruit may require fine motor control, which may consume more energy. In contrast, normal robots, such as industrial robots, may be more efficient when performing repetitive tasks [8]. However, as technology has evolved, so has the energy efficiency of orchard robots. The size of orchard robots is usually designed based on the needs of their work in the orchard. They need to be small enough to move from tree to tree, but they need to have enough space for robotic arms and other equipment that pick or process fruit. With the development of new energy technologies, some orchard robots may also use solar energy or other renewable energy sources to reduce their impact on the environment. Orchard robots will be more inclined to use new energy technologies because they need to work long hours in an outdoor environment and may be far away from traditional power sources. The use of solar energy or other renewable energy sources can help the robot continue to work without the need for frequent recharging or battery replacement.

3.3. Safety Problems Encountered by Orchard Robots

Orchard robots are often designed to be all-in-one in order to operate independently in an outdoor environment. They require compact designs and integrated systems to adapt to complex orchard environments. Connectivity is needed to transmit data, receive updates, and conduct remote monitoring, and the ability to connect is critical to precision agriculture and smart management [1]. Orchard robots collect data about soil, climate, and crop growth, but this data is often non-privacy-related and focuses more on crop management and efficiency. When it comes to safety, orchards need to ensure that they operate safely in an outdoor environment without causing harm to workers or crops. At the same time, they are equipped with a variety of sensors to avoid obstacles.

3.4. The Selection of Orchard Robots at Home and Abroad

Domestically produced orchard robots can usually provide faster and more localized after-sales service, because the manufacturer or service center may be located in China, and the response time and repair cost may be lower. and are not affected by international sanctions, as they are produced and managed entirely domestically. At the same time, prices are usually more competitive, as they may enjoy the cost advantage of local production and have no import duties. With the advancement of domestic technology, the accuracy of orchard robots may be high, and may even be comparable to international brands in some aspects. Imported orchard robots rely on international service networks, which leads to longer response times and higher service costs. and may be affected by international political and economic relations, such as trade restrictions or embargoes, affecting the supply and repair services. Imported robots can be more expensive

because of the need to consider shipping costs, import taxes, and possible exchange rate fluctuations. However, it has a strong reputation for accuracy and reliability, especially in high-tech and precision engineering [9]. In terms of automation and integrated systems, it has advanced storage solutions. Therefore, domestic orchard robots still have a long way to go, and the development of orchard robots is imminent. The difference between domestic and imported orchard robots in terms of accuracy may gradually shrink with the development of technology. Domestic robots may have advantages in terms of cost and localized services, while imported robots may lead in terms of technological maturity and accuracy. The final choice should be based on the specific application needs, budget, and technical specifications.

3.5. The Learning Cost of Orchard Robots

In terms of the learning cost of the orchard robot, if it is equipped with an intuitive user interface and graphical operation, then the learning cost may be reduced. Complex command-line interfaces or systems that require expertise to operate can increase learning costs. In addition, manufacturers provide training courses to help users become familiar with the operation and maintenance of the robot, so the learning cost will be greatly reduced [10]. To reduce the cost of learning, manufacturers often design robots with user-friendliness in mind and provide adequate training and resources to help users master the necessary skills.

3.6. Algorithm Problems of Orchard Robots

In terms of algorithms, the following ways can be used for development and processing.

Video stream processing: Video stream processing algorithms are used to analyze real-time video data from cameras installed on robots. These algorithms can identify fruit trees, fruits, branches, and other obstacles and classify them. Video stream processing can also be used to monitor the health of crops, for example by analyzing the color and shape of leaves to detect diseases or nutrient deficiencies [11].

Frame pulling: Frame drawing is the process of extracting individual image frames from a continuous video stream. These individual frames can then be used for more detailed analysis, e.g. using image recognition technology to identify specific fruits or diseases. Frame extraction algorithms need to take into account frame rate and resolution to ensure that sufficient detail is captured without generating too much data, thus reducing processing requirements [12].

Machine learning and deep learning: Machine learning algorithms, especially deep learning models, such as convolutional neural networks (CNNs), are widely used to improve the accuracy of image recognition and classification. These algorithms can learn how to recognize different objects and environmental conditions by training large amounts of labeled data.

Real-time processing and decision-making: Orchard robots' algorithms need to be able to process video data in real-time and make quick decisions. This includes determining when to pick fruit, how to avoid obstacles, and adjusting its path of movement if necessary.

Integration and optimization: Algorithms need to be integrated with other robotic systems (e.g., robotic arms, navigation systems) for seamless operation. To improve efficiency and performance, algorithms are often optimized to reduce the need for computational resources while maintaining the required accuracy [1].

4. Conclusion

Orchard robots can improve agricultural production efficiency, reduce manpower requirements and improve operation speed and accuracy by automating tasks such as picking, pruning, and fertilization. The robot can work 24 hours a day, regardless of the season and weather, to ensure that crops are managed and harvested in a timely manner. It can be operated at low altitudes (close to the ground), which makes efficient use of the space in the orchard and reduces the dependence on large machinery. Robots can access narrow and hard-to-reach areas, improving crop management and harvest efficiency. Orchard robots are designed to use clean energy sources such as electricity or solar energy, reducing dependence on fossil fuels and lowering greenhouse gas emissions. Robots with clean energy can help enable sustainable agriculture and reduce environmental impact. At the same time, the orchard robot can monitor the growth status of crops in real time, adjust the production plan according to market demand, and achieve on-demand production. Robot-assisted precision agriculture can improve crop quality and meet consumer demand for high-quality agricultural products. Orchard robots can alleviate the problem of labor shortages in agriculture, especially in the context of an aging population and rising labor costs. In the long run, although the initial investment is high, robots can reduce operating costs and improve the economic efficiency of agriculture.

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