A New Low Cost Automatic Strawberry Picking Machine based on Cross-Monopoly Walking Mechanism with Adjustable Dimension Capability

Xuewei Shi

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ABSTRACT

Agriculture is the foundation of a country's national economy, and improving agricultural technology and equipment is the inevitable requirement of a country's agricultural modernization. With the development of population aging and the decrease of a large number of agricultural labor force in the process of urbanization, the agricultural production cost is constantly increasing, and the agricultural automatic picking device can play an important role in reducing manual labor intensity and production costs, improving production efficiency and product quality, and ensuring the timely harvesting of fruits and vegetables. In many countries, strawberry picking is manual, not only with low efficiency, but also requires fruit farmers to bend over or squat to pick. Therefore, automated picking institutions are needed to reduce labor intensity and reduce production costs. Therefore, the strawberry picking mechanization, automation, in order to reduce labor costs, improve work efficiency, effectively reduce the labor burden of fruit farmers, is conducive to further expand the scale of strawberry production.

This paper is committed to develop a low cost new automatic strawberry picking device. In order to reduce the labor intensity of picking workers, improve the integrity of strawberry fruit and picking efficiency, a solar-assisted artificial strawberry picking device is designed with low cost, low energy consumption and portable convenience. The device is very light, and the pickers can easily make the device run and pick strawberries, which greatly reduces the labor intensity.

Keyword : Automatic picking, Picker claw, Positioning system, Solar energy

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Chapter 1

Introduction

1.1 Research Background

Agriculture is the foundation of a country's national economy, and improving agricultural technology and equipment is an inevitable requirement for the modernization of a country's agriculture. With the continuous improvement of science and technology at home and abroad, the automation technology of agricultural equipment has been greatly improved compared with the previous ones. In some specific agricultural fields, the automated mechanical devices have been able to replace the manual personnel to carry out a series of complex actions such as pesticide spraying, crop picking and sorting operations of crops. At the same time crop picking research is an important part of agricultural automation research, many large-scale crops such as corn, rice, wheat has been automated or semi-automated picking, but for the requirements of fine operation of the greenhouse fruit and vegetable picking, such as peppers, cucumbers, tomatoes, etc., the automated picking program is mostly in the experimental research stage, has not yet achieved large-scale application. With the gradual expansion of fruit and vegetable cultivation scale, the increasing cost of labor, and the increasing trend of aging phenomenon in rural areas, a large number of young people of working age, all of these have created certain obstacles to the development of modernization of agriculture and rural areas, the use of picking robots to replace manual picking of fruits and vegetables has become an inevitable trend[1].

At present, many countries have successively carried out the research work in the field of fruit and vegetable harvesting robots. The main research subjects involved include orange, apple, citrus, tomato, cherry tomato, asparagus, cucumber, melon, grape, cabbage, chrysanthemum, strawberry, mushroom, sweet pepper and other.

China's strawberry cultivation area and output rank first in the world. According to the data of "2016-2021 China's Strawberry Planting and Deep Processing Industry Market Outlook and Investment Planning and Analysis Report" reported by foresight Industry Research Institute, the output value of China's strawberries has exceeded 30 billion yuan, with the annual production area of nearly 2 million mu, and the annual output of about 2 million tons of [2]. In recent years, due to the improvement of the prevention and treatment of strawberry diseases and insect pests, and the progress of cultivation and cultivation techniques, strawberry planting has been greatly promoted in China. In recent years, the strawberry planting area in China has increased very rapidly, with several places with a planting area of more than 1,000 mu. China has become the largest country in the strawberry industry and market, ranking first in both consumption and production. In this paper, automatic strawberry picking was selected as the research object.

At the same time, there are also some problems during the strawberry picking period, strawberries on the market time early, strawberry picking labor intensity, and the picking cost is high, and now the cost of picking machines is high.That is the reason why the strawberry hand picking is still the most common method in China.

Figure 1 Traditional strawberry hand picking [2]

According to the agricultural and rural network, the input cost of one mu of greenhouse strawberry, strawberry is the main part of the input is greenhouse, using different raw materials, the cost of construction is not the same. Here the ordinary steel pipe greenhouse as an example, can be used for 5 to 7 years, the construction cost of 6000 yuan, with 6 years of depreciation calculation, the average annual needs about 1000 yuan. Other costs are as follows: strawberry seedlings, RMB 3000 per mu, RMB 500 for fertilizer, RMB 500 for pesticide, RMB 600 for rent, RMB 800 per year; labor costs, mainly the highest labor cost for strawberry picking, totaling RMB 2100. Finally, one mu of greenhouse strawberries need to invest about 8,400 yuan. According to the data, the cost of artificial picking accounts for about a quarter of the cost of strawberry planting, which shows that the cost of strawberry picking is too high[3].

Figure 2 Indoor greenhouse strawberry hand-picking [2]

Strawberry picking by hand is not only inefficient, but also requires farmers to bend down or squat to pick the problem, so there is a need for automated picking mechanism to reduce labor intensity and production costs. Mechanization and automation of strawberry picking to reduce labor costs, improve work efficiency, effectively reduce the labor burden of farmers, and help further expand the scale of strawberry production. The increasing shortage of agricultural labor and aging problems have put forward new requirements for the mechanization of fruit picking. With the development of aging population and the reduction of a large amount of agricultural labor in the urbanization process, which leads to the increasing cost of agricultural production, the shed picking robot can play a role in reducing labor intensity and production costs, improving production efficiency and product quality, and ensuring timely harvesting of fruits and vegetables The robot can play an important role in reducing manual labor and production costs, improving production efficiency and product quality, and ensuring timely harvesting of fruits and vegetables.

1.1.1 Mechanical shaking type and pneumatic shaking type pickers

Picking robot is a class of automated mechanical harvesting equipment with a sensing system for fruit or vegetable harvesting operations. Schertz and Brown, two American scholars, first proposed the concept of using machines to pick fruit, which is considered by the academia as the beginning of the research of agricultural picking robots.

The main research direction in the initial stage is mechanical shake type and pneumatic shake type, such a level of automation is not high, strictly speaking, it is semi-automation equipment.

1.1.2 Artificial strawberry picker

In order to reduce the frequency of bending and reduce labor intensity, the researchers designed an artificial assisted picking device as shown in the figure below.

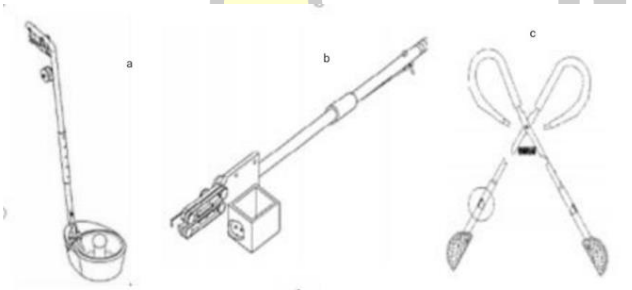


Figure 3 Artificial strawberry picking equipment [3]

Du Peisong et al. To design a standing picking collection integrated strawberry harvest device (figure a), use according to their height to adjust the length, naked eye identify mature strawberry, positioning the opening of the scissors at strawberry fruit stalk, press the activity handle, activity handle connection drive wire rope shear mechanism to complete the stem separation, the fruit under the inertial force, while the wire rope also drive the ratchet over a certain Angle, to prevent the fruit stacked in one direction.

Fan Hui et al. design a handheld strawberry picking device (figure b), also can realize the integration of harvesting, the device using DC motor drive belt, drive and another flat belt direct contact, by adjusting the belt tension of belt friction drive flat belt synchronous operation, picking rod front hook, trigger hook will pull fruit and stem back, fruit stem into between two belt and backward movement, conveyor belt center with blade cut fruit stem, two belt clamp part of the fruit stem and fruit transport into the collection device.

Hefei an agricultural science and technology company to design a can change the length of the strawberry picker, can be adjusted according to the working condition of the strawberry picker arm length, cut spoon inside are equipped with blade, working manually make two arms close to cut spoon envelope live strawberries, fruit stem is two cut spoon inside the blade cut, located above the collection device under the spring force of two shear spoon open, fruit fell into the harvesting device, complete picking.[5]

1.1.3 Strawberry picking robot for greenhouse ridge cultivation

Greenhouse ridge for strawberry picking machine, the type of machine is suitable for planting in greenhouses of strawberries, and to design a system alone, using binocular visual image processing technology, after recognition and positioning processing, manipulator execution seize stalk action, manipulator front blade complete cut off stalk action, so as to complete the picking. The strawberry-picking robot is far less efficient than farmers, and it takes about 10 seconds to pick and pick a strawberry on average, compared with just two or three seconds to be manual. Unable to make breakthrough improvements in flexibility, the shift has worked hard with standardized picking. For example, when a robot picks strawberries, its algorithm design requires it to remove strawberry pedicabs much as possible, which is hard and easy to stab other fruit. In order to attract customers, the robot can rely on machine vision to distinguish red fruit from green leaves and reveal as much red as possible. At the same time, the premise of the introduction of this robot is to have a supporting greenhouse structure, although the action is relatively slow, but full of confidence in it, I believe that the cost will be reduced in the future.

1.1.4 3D stereo camera system picking robot

It is well known that Shibuya Seiki has developed a 3 D stereo camera system strawberry picking robot, which requires a 3 D stereo camera system to capture the color of strawberries to determine the maturity of the fruit. It only takes 8 seconds to cut a strawberry. The robot can workday and night, replacing two-thirds of manual operations[1], but is expensive and widespread.

1.1.5 Walking arm-type strawberry picker

Walking arm-style strawberry picker. The main movement mechanism is the mechanical arm, which can achieve 6 degrees of freedom and 360 degrees of rotation. The picking mechanism does not aim to capture the fruit, but rather to cut the stalk of the strawberry. Mainly consists of walking, control, picking three parts, performing the picking is the mechanical arm. The grip control requirement of the terminal actuator is very high, and the grip system should have a certain flexibility, to compensate for the error caused by the control, to avoid the grip force is too small and grasp instability, resulting in strawberry falling[6]. The end actuator first rotates and adjusts the appropriate Angle, and then then grasps the handle. At the same time, there will be a nickel-chromium electrothermal wire cutting handle. The walking mechanism adopts the wheel structure and the moving mechanism of the silk rod slide platform, which can achieve more smooth walking in the relatively uneven ridge and ditch.

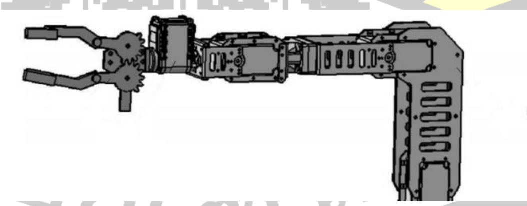


Figure 4 China Picking Machines[6]

At the same time, we can see that there are still some defects in the strawberry pickers developed in recent years. Some problems common in picking robots mainly exist in the following points:

1. The machine cost is too high. Compared with ordinary automation equipment, strawberry picking robot is more complex in the organization, especially in the control system. Due to the seasonal low efficiency of use, it requires high costs in manufacturing, use, maintenance, and other aspects. So it is particularly important to study a cheap and convenient maintenance picking robot.

2. Poor versatility, the picking type on the market robot is often only for a specific object, not universal, make all kinds of picking robot versatility is poor, with the rapid development of modern agriculture, put forward higher requirements for agricultural robot, to meet the many varieties of picking, need a strong environmental applicability.

3. Poor identification function, which is a common problem, when the machine is running, the environment is very complex, the fruit is generally surrounded by leaves and other shielding, need to be distinguished when picking, or can be effectively screened after picking.

4. Long time, due to the use of image and other processing systems, the efficiency of picking is generally relatively low and the control system is affected by it, and it takes a long time.

1.2 The Importance of the research project

With the development of science and technology, land-use agriculture will gradually form a new modern industry based on crop cultivation technology, with biotechnology as the guide, integrating mechanized operation, automatic cultivation facilities and artificial controllable environment. And the fruit and vegetable picking robot is the main operation task is to achieve the fruit and vegetable picking agricultural robot[7].

Now strawberry artificial picking is currently the most important form of strawberry picking, fruit farmers with both hands or scissors to take off the fruit from the vine and gently put into the side of the collection basket, need to repeatedly bend over to work. However, the strawberry picking cycle is short, and the mature strawberry picking is not done in time will greatly reduce the fruit quality, and have a direct impact on the later transportation, processing and sales. However, the high labor intensity, low picking efficiency and high labor cost greatly hinder the large-scale development of strawberry industry and dampen the production enthusiasm of fruit farmers, so we need to introduce mechanized harvesting to complete the heavy picking task.

Therefore, we need to develop a low cost, convenient maintenance, universal a strawberry picking machine.

1.3 Study significance

Developed strawberry picking machine is in order to better serve the modern agriculture, need to constantly improve the above problems in the research, so as to achieve the real service and society demand, in order to better achieve this goal, to develop a low-cost picker, and can adjust size according to different environment, to adapt to more environment, so that the machine meet strawberry picking.

This paper is committed to reducing the labor intensity of the pickers, improving the strawberry fruit integrity and picking efficiency, and designing a low cost, small energy consumption, portable based on solar energy and artificial strawberry picking device. This device is very light, picking workers can easily pick up strawberry picking, greatly reduce the labor intensity, the device depends on internal conveyor belt will pick strawberries to the device behind the net belt, precise control conveyor belt and pick cutting part of the transmission ratio, ensure that each strawberry has an independent conveyor belt grid, so as to improve the integrity of strawberry fruit.

There should be the following aspects, modular design, according to the required design of different functions to complete the desired effect, and strive to complete the required tasks with a few modules, and strive for high accuracy, stable performance, simple structure, low cost, the connection between modules as simple as possible;

open structure and control system. Open structure has a good versatility, can be adjusted at any time, has a very good environmental adaptability, it is suitable for the complex environment of strawberry picking. Meanwhile, the open control system can improve the utilization of equipment and promote the extensive utilization of agricultural machinery. When studying the picking robot, we should pay attention to the combination of agricultural machinery and agronomy, reduce the complexity of picking by changing the fruit and vegetable cultivation mode, and make the picking robot more efficient in visual positioning and recognition processing; accurately identify and locate the target fruits. Based on the dynamic visual recognition and positioning method, the multi-manipulator coordinated operation and multi-manipulator task allocation is proposed. In order to further improve the success rate of fruit picking, researchers need to conduct further research on image acquisition and processing.

The most important point is that it is economically cheap and easy to maintain. From the current research situation, most of them are still in the stage of research and improvement, and the practical wide application still needs a long way to go, we need to improve the efficiency of picking, reduce manufacturing and use costs, enhance the versatility and other aspects to do more in-depth research.

Chapter 2

Literature Review

2.1 Strawberry growth characteristics and planting methods

Strawberries, native to South America, are widely cultivated in all China and Europe. Strawberry has high nutritional value, contains a variety of nutrients, and has the health care effect, at the same time with its unique taste and bright appearance, lovely and unique appearance, sweet and sour delicious taste and nutrition is rich in value, widely loved by consumers[4].

Strawberry is a perennial herb with short plants, 10-30 cm high and not more than 30 cm. Strawberry is mostly asexual reproduction, its root is the stem source root, mainly composed of adventitious roots, belong to the beard root. The root system distribution is relatively shallow, 70% of the roots are distributed in the 30 cm soil layer, due to the shallow root system distribution, drought, high temperature, poor cold tolerance. Leaf morphology, leaves evergreen, for three compound leaves. Most varieties of strawberry belong to both sex flowers, flower flowers, strong flowers. The same inflorescence flowering has successively, early flowers early fruit, the fruit is also large, later the fruit gradually becomes smaller, the fruit generally grows in clusters on the flower stem. Its growth habits lead to a short maturity period, in winter, the cultivation in the heat preservation environment, also only need about 60 days to mature, the other seasons of 20-30 days can mature. In addition, the irregular ripening of strawberry fruit also directly leads to its long picking duration, especially in the greenhouse planted strawberry picking period of up to 5-6 months [4].

Figure 5 The cultivation and growth of strawberries [4]

Strawberry has a variety of different planting patterns, plastic greenhouses and greenhouse planting, currently in the greenhouse planting widely used in enterprise cooperatives, ordinary farmers generally with plastic greenhouses, plastic greenhouses according to the direction, can be divided into east-west and north-south direction, including east-west generally in the north wall, the cost is relatively low, but the light utilization is relatively low. National plastic greenhouses are even cheaper to grow. The general investment ability of domestic farmers is relatively low, generally using the former type of greenhouses for strawberry planting.

The open ground cultivation mode is more suitable for large operation machinery, but the environment is not structured enough, so it is difficult to realize the robot operation; the continuous greenhouse cultivation mode is more structured, which is smaller than the open ground greenhouse cultivation mode, which is difficult between the open ground cultivation and continuous greenhouse cultivation.

2.2 Strawberry picking problem

Strawberry skin has no protective layer, which is prone to damage, and has strict storage conditions. In order to ensure the commercial beauty and edible safety of strawberries, ripe fruits need to be picked every morning and evening during the harvest period. If the best picking period is missed, it is easy to lead to excessive maturity and even decay of strawberries, which will affect the income of farmers in the season. The unique growth mode of strawberry determines that the picking operation plays an important role in its planting and production process. Artificial picking of strawberries can ensure the integrity of the fruit to the greatest extent. For the traditional ridge cultivation mode, the pickers need to keep their heads low, bent over, cut off the fruit stalks with their nails, and then put them in the frame. Manpower picking requires people to bend over for constantly moving picking, and long hours of load labor will cause permanent damage to the lumbar spine.

Strawberries are very easy to deteriorate fresh fruit, fruit ripe after the time limit is very strong, must be picked as soon as possible. Picking takes up about a quarter of the time. Every year in the strawberry harvest season, picking becomes extremely heavy and hard work. With the gradual transfer of the rural young and middle-aged labor force to the secondary and tertiary industries and the continuous aging of the left-behind population, the annual strawberry picking labor force is extremely tight, and the labor cost is also increasing by year by year[8]. Strawberry planting industry urgently needs to realize the mechanization and automation of picking operations, so as to gradually reduce the dependence of artificial picking and reduce the cost of picking.

2.3 Research on the identification system of new strawberry automatic picking

The growth presentation of strawberry is irregular. The complexity of its growth environment and the environment of the planting area jointly determine the complexity and high difficulty of developing the strawberry picking device. Because there are many strawberry leaves around it, it brings many difficulties to the current image processing technology. With the rapid development of science and technology today, There have been a lot of technicians in the machine vision recognition and other aspects of the research, For example, the mechanical arm of picking path optimization, picking binocular positioning system research, While fewer people actually develop applications, There are also computer computer OpenCV, Mainly using the computer vision library for image processing operations, The strawberries were then further picked through the mechanical arm, The biggest problem with this picking is that the entire system is expensive to manufacture, And it is large in size, Especially in the strawberry picking work place is particularly tedious, This goes against the convenience and efficiency proposed by our automated control system, It also brings great challenges to the popularization and application of automation technology.

In the face of these problems, according to the early understanding of strawberry growth habits and the required picking situation, and the current existing technology to understand the identification technology of automatic strawberry-picking.

2.3.1 DSP identification control system

Some domestic scholars proposed to design a set of DSP low energy consumption, low cost, small size of the strawberry identification picking system, practice proved that the development of such a system can effectively improve the efficiency of labor production, reduce labor costs, reduce the intensity of human labor, for improving the implementation of modernization of agricultural production at home and abroad, accelerate the rate of intelligent popularization, accelerate the scientific progress of agriculture has important significance and operability.

Digital Signal Processing (DSP), mainly using DSP technology, consists of two modules, the upper module consists of TMS320DM642 image processing module, image acquisition module, video decoding module, power supply module, video encoding module, display module and serial communication module. The lower module consists of mainly STM32F103 main control module, power supply module, serial communication module, 3D slides, picking mechanism, sensor module, slide driver, servo driver and light compensation module. [9]

The two modules mainly transmit data through the RS232 serial communication module. After the image acquisition module in the upper module acquires the image of the area to be picked, the analog signal of the video is converted into a digital signal through the video decoding module and sent to the TMS320DM642 image processing module. The TMS320DM642 image processing module processes and analyzes the digital signal to extract the outline of the strawberry fruit, determine the position of the shape center, determine the three-dimensional matching and calculate the three-dimensional spatial coordinates of the strawberry fruit. The video encoding module converts the processed strawberry fruit image to analog signal again and sends it to the display for debugging. On the other hand, the TMS320DM642 image processing module sends the calculated data of the spatial 3D coordinates of the strawberry fruit to the STM32F103 main control module via serial communication. In this process, the power supply module provides electrical power to the upper computer sub-module[9].

The STM32F103 master control module in the lower module receives the data of the three-dimensional spatial coordinates of the strawberry fruit sent from the TMS320DM642 through the serial communication port and then extracts the valid values of the coordinates; then the three-dimensional slide is driven by the slide driver to the position directly in front of the strawberry fruit with picking; after that, the STM32F103 master control module controls the servo driver to drive the picking manipulator to After that, the STM32F103 main control module controls the servo driver to drive the picking robot to pick the strawberry fruit accurately; finally, the strawberry fruit is sent to the fruit collection box. During the work of the lower computer, the power supply module provides electrical power to the lower computer system, while the collision sensor and the touch sensor detect whether the 3D sliding table reaches the end point in real time, and the touch sensor detects whether the two palms of the picking robot have touched the strawberry fruit when the picking robot is grasping the strawberry fruit in real time. The light compensation module enables to make the TMS320DM642 image processing module to better process the external image and reduce the interference of external light source to the system[9].

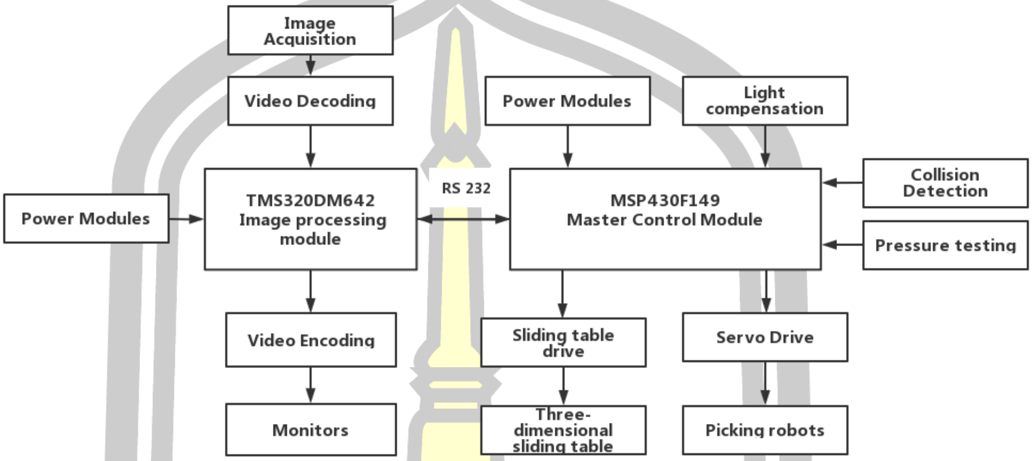


Figure 6 Block diagram of the system control structure of the strawberry picking robot[9]

The following functions are mainly realized by DSP technology: (1) the selection and design of the overall hardware scheme of the system, mainly the design of the control recognition system; (2) the acquisition and correction of the internal parameters of the binocular camera through VC; (3) the use of DSP to control the binocular camera for two-way video acquisition and the acquisition of the image of the threshold segmentation, Sobel edge processing, median filtering (3) the DSP controls the binocular camera for dual video acquisition and performs threshold segmentation, Sobel edge processing, median filtering and other operations on the acquired images, and finds the shape center through the processed images; (4) the simple matching and 3D reconstruction processing of feature points using the DSP is realized, and the calculation of 3D coordinates can be simply performed and the calculation results are delivered to the controller; (5) the communication between the DSP and the controller is realized, and the lower unit can realize the control of the 3D slide and manipulator according to the communication data; (6) the DSP and The controller can work in coordination to finish picking strawberries in a certain area.

2.3.2 UWB strawberry identification system

This is a positioning scheme based on Ultra Wide Band (UWB)[10] technology to realize the relative positioning of the picking device and the collecting device, so as to complete the collecting system of following the picked strawberries by the collecting device.

The overall structure is mainly composed of a main controller (STM32F103ZET6), sound alarm, LED alarm, optical encoder, OLED display, DC gear motor driver, DC gear motor, 12V lithium battery, buck module, UWB base station, UWB tag, independent 5V power supply and ultrasonic sensor, a total of 13 module circuits, and its overall structure is shown below shown below[10].

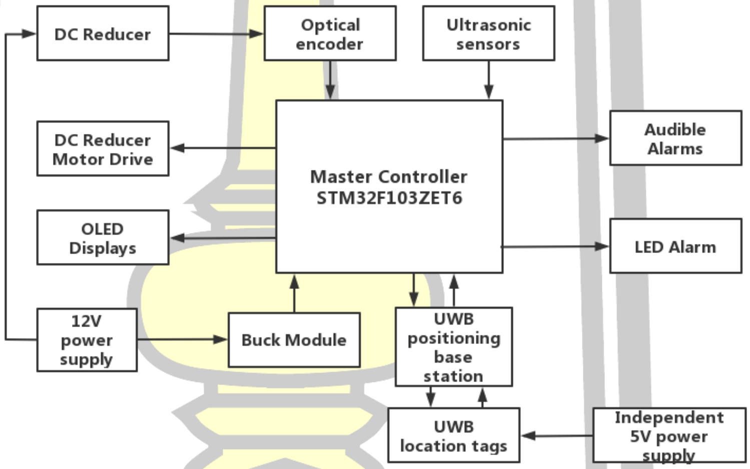


Figure 7 Overall structure of fruit picking following collection system[10]

When the UWB positioning tag on the picking device moves with the picking head, the collection device on the ground can follow the picking head in real time according to its position change to ensure that the picking device is always directly below the picking head, so that the picked fruits can fall into the collection device along the collection pipe.

The STM32F103ZET6 chip is used as the minimum system for the main controller, which is mainly used to collect sensor signals and control the movement of the collection device. 12 V power supply is used as the power supply system to follow the collection device, which provides the power source of the system. Since the required power supply voltage for the main controller is 5V, a step-down module also needs to be connected between the main power supply and the main controller. oLED display module is used to display information such as battery voltage level and system operation status to provide relevant interactive information to the user. The audible alarm and LED alarm are made by buzzer and colorful LED lights respectively, which emit buzzer sound and flashing light prompt when the system is malfunctioning to warn the user of the system problem. The DC gear motor driver, DC gear motor and photoelectric encoder form a closed-loop circuit to control the motor speed by incremental PID algorithm. Ultrasonic sensors are used to collect environmental information around the following collection device, enabling the device to detect a variety of obstacles, including fruit tree trunks. The UWB positioning base station in the system consists of three mutually independent UWB positioning modules, which are powered by the main controller. The overall flow of the designed fruit picking following collection system is shown in the following figure[10].

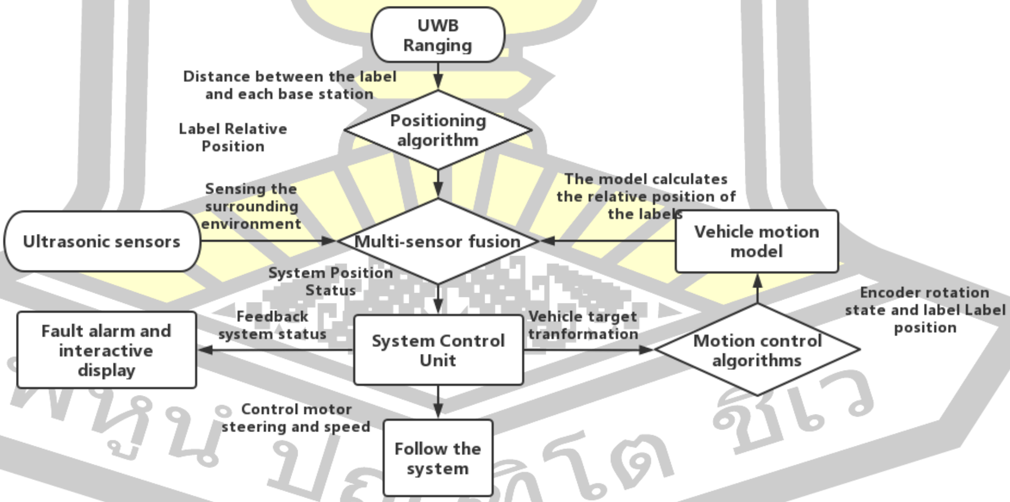


Figure 8 Overall flow chart of fruit picking following collection system[10]

How is the strawberry picking following system implemented? It uses the principle of UWB ranging, which is a carrier-free communication technology that does not require the use of carriers found in traditional communication schemes. The data is transmitted by sending very narrow pulses in nanoseconds, and the shaped pulses can be sent directly to the antenna end for transmission. It has a large signal bandwidth, high received multipath resolution, good fading resistance, and high ranging accuracy. It uses Decawave's DW1000 wireless transceiver chip as the signal transmitting and recovering integrated module, as shown in the figure below. The module has a built-in STM32 microprocessor and integrates all the devices needed in RF radio design such as DW1000 chip, antenna, power management and clock circuit. The control center can set UWB parameters, control signal transmission and reception, and measure the distance between the base station and the tag based on the time of arrival (TOF) of the signal via serial commands.

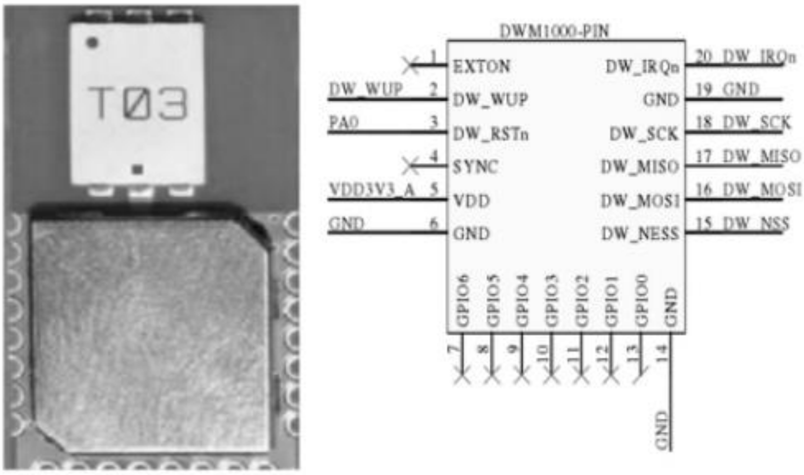


Figure 9 DW1000 module and its circuit diagram[10]

The TOF ranging method is implemented as Double-Sided Two-Way Ranging (DS-TWR), i.e., multiple polling and response communications are required between the positioning base station and the tag, and the implementation process is shown in the following figure. [10]

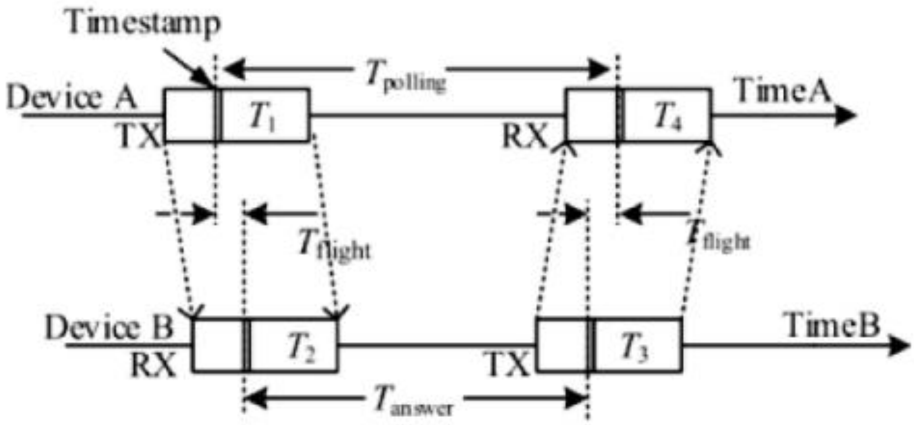


Figure 10 TOF distance measurement method implementation process[10]

$T_{polling}$ shown in the figure is the time interval from the time device A sends a polling signal to device B until it receives a response signal from device B. T_{answer} is the time interval from the time device B receives a polling signal from device A until it sends a response signal to device A [10].

Then the transmission time T_{flight} of the signal is:

$$T_{flight}=1/2\,(T_{polling}-T_{answer}) \quad (1)$$

UWB signals are electromagnetic waves, and there is a linear relationship between their propagation distance and time [6], i.e., the distance r between device A and device B is:

$$r=T_{flight}t\times c=1/2\,(T_{polling}-T_{answer}\times c \quad (2)$$

where c denotes the speed of signal propagation in the air

UWB positioning principle and algorithm. Most of the widely used UWB positioning schemes are based on the base station and the tag being on the same level or with a small difference in vertical distance, and then using relevant algorithms to achieve accurate positioning based on the distance between the tag and multiple base stations. However, the problem studied in this paper is very different. As shown in the model diagram in Figure 5a, when the system works, because the positioning base stations are arranged around the body, the distance between the base stations should be increased as much as possible to ensure the positioning accuracy, while the limitation of the relationship between the body and the environment requires that the distance between the base stations should not be too large, so each base station should be arranged in a range between 1m and 2m. The distance between base stations should be less than the height between the tag and the ground of at most 3m, so the height of the tag in the vertical direction cannot be ignored, and the projection of the tag in the plane of the base station must be solved in order to further use the positioning algorithm to solve the position of the tag relative to the plane of the base station. To simplify the calculation process, the complex positioning model of the system is simplified as in Figure 5b, where P0, P1 and P2 denote the locations of base station 0, base station 1 and base station 2 on the mobile device, respectively, and T0 is the location of the tag, point O is the center of the mobile device, T1 is the positive projection of the tag T0 on the plane formed by the three base stations, and the location of T1 is the relative position of the tag T0 and the mobile device. T1 position will be able to obtain the position relationship between the tag and the base station, which is the real-time position relationship between the picking device and the collecting device. [10]

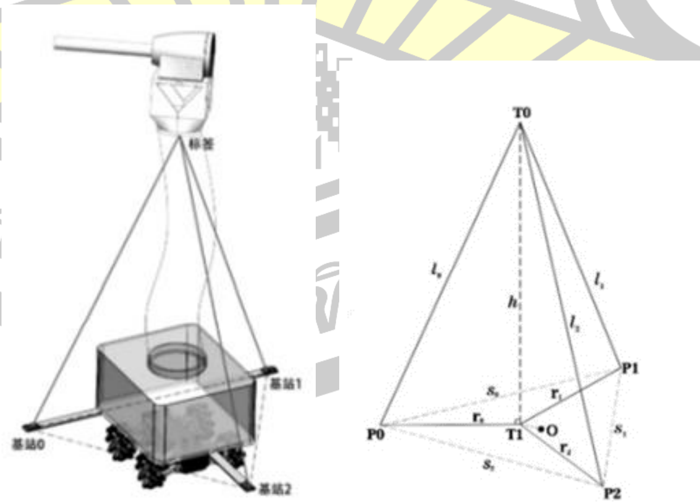


Figure 11 Positioning principle model diagram[10]

2.3.3 ROS system platform design

ROS is an acronym for Robot Operating System, a highly flexible software architecture for writing software programs for robots and is based on prototypes from the Stanford Artificial Intelligence Robot (STAIR) and Personal Robotics (PR) projects at Stanford University. Personal Robotics (PR) projects[11].

It contains a large amount of tool software, library code, and convention protocols designed to simplify the difficulty and complexity of the process of creating complex, robust robot behaviors across robotic platforms.

The ROS designers expressed"ROS=Plumbing+Tools+Capabilities+Ecosystem", i.e., ROS is a collection of communication mechanisms, tool packages, high-level robot skills, and robot ecosystems[11].

The main features of the ROS system platform are the distributed architecture that allows multiple processes to run simultaneously, support for multiple programming languages such as Python, C++, Lisp, Octave, etc., and the ability to develop free source.

2.4 System research of new strawberry automatic picking and picking mechanism

The main way of fruit picking has two types: the first type is the grasping and cutting way, that is, after the end-effector grasps the fruit, the use of cutters such as scissors, blades, saws and so on to cut the fruit stalk, the way of generality is stronger, especially for the fruit and the fruit stalk combination force is larger, such as cucumber, but it is not easy to determine the cutting position of the fruit stalk, and to prevent injury to the crop branches and vines during the cutting process, the end-effector The accuracy requirement is higher. The second type is the bionic picking method, that is, after using the end-effector to grasp the fruit, according to the characteristics of the fruit and stalk connection, the separation of the fruit and stalk is realized by twisting, folding, tugging and other actions. This method is mainly applicable to the picking where the fruit and stalk connection is more fragile, but this method requires the end-effector to carry out multi-degree of freedom movement, which has higher control requirements for the end-effector and requires larger torque.

2.4.1 DOBOT picking robot arm

Yuejiang Technology DOBOT Robot Magician second generation multi-joint type (RRR) robotic arm, which is a 4-degree of freedom robotic arm, three rotational degrees of freedom (one degree of freedom each for base, big arm and small arm) are realized by high precision stepper motor and reducer, one degree of freedom servo for wrist, and pneumatic hand claw for hand. It is a high precision and high stability consumer-grade desktop intelligent robotic arm, which can achieve 0.2mm repeatable positioning accuracy. The robotic arm can achieve a variety of functions such as sucking, clamping, laser engraving, writing and drawing, 3D printing, etc. Its user interface is friendly and the control software can be used on a variety of terminals. With expanded interface and integrated graphical programming development, it is easy to be able to secondary development[1].

Figure 12 DOBOT robot arm physical picture[1]

Mechanical arm is mainly two ways to move, one is the coordinate system control, a single circumference control mode. Coordinate system control mode, that is, the origin of the coordinate system in the large arm, small arm and the base of the three motors three axis intersection position, four axes (XYZ in line with the right-hand rule) is defined as follows: X axis perpendicular to the fixed base forward, Y axis perpendicular to the fixed base to the left, Z axis vertical up, R axis for the end of the servo center, 16 counterclockwise direction is positive. During the movement, R-axis and Y-axis will move together. In the coordinate system mode, for example, the end sucks a square, and the R-axis servo will adjust the direction in real time when moving Y-axis to ensure that the attitude of the end of the square relative to the coordinate origin will not change. Single-axis control mode, that is, the target object of robotic arm operation is each independent axis, and each axis takes counterclockwise direction as the positive direction[1].

DOBOT robotic arm uses ArduinoMega2560 development board to control three stepper motor drivers, two servos, vacuum pump and solenoid valve drivers. DOBOT robotic arm provides SDK (software development kit) for secondary development, including DOBOT communication protocol and DOBOT function library.

Some robotic arms in the study have excessive power consumption, slow movement speed, low flexibility, and small height and extension depth. Although such designs can meet the requirements of picking experiments, it is difficult to meet the demands of actual picking scenarios in terms of picking efficiency. The control response speed and the picking range of the robot arm affect the picking efficiency to a certain extent, and many picking robots have the problem of low picking efficiency, which will seriously affect the application of picking robots.

Domestic researchers have also proposed a multi-terminal picking robot program, each picking end of the assignment of a certain operating area, while starting picking work, which is also an effective solution to improve efficiency. The optimal picking mechanical structure needs to be selected for the design of the picking robot arm.

2.4.2 Shear picking mechanism

A domestic design of a shear type strawberry picking mechanism, it can quickly cut the strawberry stems, so as to achieve rapid picking of strawberries, the principle of the shear device is similar to the principle of scissors, the head has two sharp blades, one blade is fixed on the body of the device, not movable; the other blade can be turned around the established axis of a certain angle remote between the two blades there is a spring device, can make the two blades shear together after the automatic opening and closing movement. After the blades are sheared together, the shearing device can be automatically popped open under the pull of the traction gate wire, and the regular opening and closing movement can be done to complete the picking of strawberries[12].

The most important feature of this picking mechanism is the lower cost, easier manufacturing and assembly.

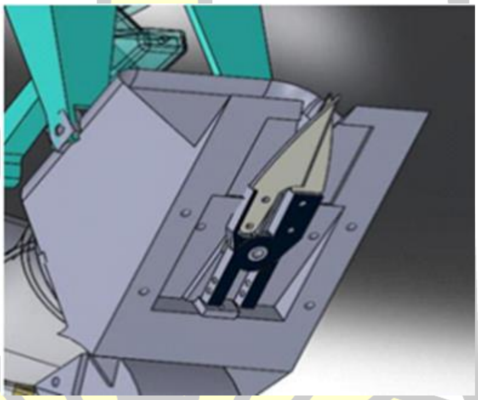


Figure 13 Shear picking mechanism[12]

2.5 Research on the walking mechanism of the new automatic strawberry picking

The mobile platform provides the support platform for the picking robot arm and other systems that can move. The platform makes the robot arm partition to pick fruits by moving during the operation, and the stability of the mobile platform is also necessary for the robot arm to operate accurately. In some studies, a small mobile platform is used to carry a long robot arm, which causes the center of gravity of the entire robot to change during the movement of the robot, eventually causing the robot to wobble and causing problems such as inaccurate positioning. There are also some studies in which the robot chassis is too low, making the robot arm picking height limited. For the case of shaking mobile platform, the size and quality of the mobile platform can be upgraded to ensure the stability of the picking robot operation process; for the difficult problem of low mobile platform, an autonomous lifting type platform can be added, or a lifting type Z-axis design can be added to the robot arm, and the robot arm can be mounted on the lifting type platform or Z-axis to enhance the whole robot operation range.

2.5.1 Crawler walking mechanism

Crawler walking mechanism is the supporting parts of the machine, which is used to support the machine, bear the force generated by the mechanism in the process of operation, and complete the needle machine marching, backward, transfer and operation movement.

Crawler travel mechanism is mainly composed of guide wheel, tensioning device, crawler frame, supporting wheel, drive device, carrier wheel and crawler plate. The whole machine is connected to the track frame by articulation or rigid way, and the track frame transfers the gravity of the whole machine to the supporting wheels and then to the track plate. The driving force generated by the driving wheel forces the track plate to have a backward force relative to the ground, and the ground has a forward friction force on the track plate, which is the traction force and drives the machine forward.

Drive device, there are usually hydraulic motor drive and motor drive two ways. Although the motor drive method has good reliability and easy maintenance, it can only provide one kind of running speed, which cannot be adjusted, and the high speed of the motor needs to be reduced to the low speed of the driving wheel, which inevitably requires a large reduction ratio, resulting in a large size of the gearbox, and the space is restricted. In addition, the running space of the bracket truck is very large, which increases the difficulty of cable management and is not suitable for the use of a wide range of moving inverted surface. The hydraulic motor drive method can realize infinitely adjustable speed and overload protection, and the hydraulic motor and reducer are highly integrated and compact, which is more suitable for heavy-duty operation in limited space underground.

Tracks are considered to be mobile roads carried by the tracked vehicle itself, which are continuously laid in front of the vehicle and automatically retracted when the vehicle passes by. The tracks carry the weight of the vehicle and transfer it to the ground, and the vehicle is often driven in mud, sand, rocks and other harsh conditions, requiring sufficient strength and rigidity. The tracks must be made light enough to reduce the dynamic load during operation by minimizing the amount of metal. In order to ensure that the vehicle has sufficient traction, the tracks are required to have good adhesion performance. Crawler vehicles can be divided into integral and combined according to the structure form. Combined track structure has good sealing performance, and mud and sand are not easy to enter, but its structure is complex, with many parts and difficult to load and unload. Integral crawler structure is widely used because of its compact size, simple structure and easy disassembly and maintenance, which is suitable for harsh environment. The integral track type is shown in the figure below. [13]

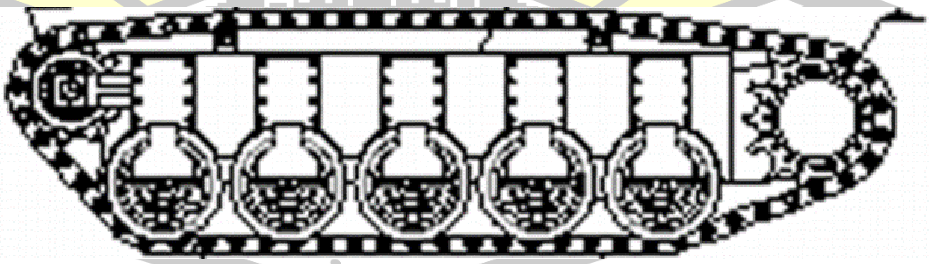


Figure 14 Crawler travel mechanism[13]

The supporting wheels carry the weight of the truck and transfer it to the tracks. The supporting wheels roll on the tracks. The wheels are clamped to the tracks by the rim, which ensures that the wheels roll back and forth on the tracks and do not fall off the tracks. The number of pivot wheels increases with the weight of the machine, and the arrangement of the pivot wheels should take into account the cooperation between the pivot wheels, the guide wheels and the chain wheels to prevent mutual interference. In addition, we should also consider the problem of uniform distribution of the ground pressure of the whole machine and try to choose a larger supporting wheel to reduce the rolling resistance of the supporting wheel and improve the running efficiency of the whole vehicle. For low-speed crawler vehicles, we usually use smaller multiple supporting wheels to distribute them evenly and try to increase the grounding length of the crawler without affecting the use of the premise, to reduce the grounding ratio pressure[13].

The supporting wheels are fixed to the track frame and are in contact with the upper tracks to support them. The role of the carrier wheel is to hold the track, reduce the amount of track sag, and prevent the track from vibrating too much and slipping sideways. The installation height of the carrier wheel should be similar to the normal running height of the track. To prevent vibration jump, the installation height of the carrier wheel can be increased, but it will increase the friction with the track and affect the driving efficiency. The installation quantity of the carrier wheel is related to the size of the axis distance between the driving wheel and the guiding wheel, and when it is larger than 2m, 2 groups of carrier wheels are generally installed, and when it is smaller than 2m, 1 group of carrier wheels is installed[14].

In general, the position of the guide wheel is designed in the front, and the drive wheel is arranged in the back, and the guide wheel is designed to reduce the center of gravity of the vehicle. In the design process, the position of the guide wheel is usually designed to be adjustable, the front and rear adjustable range is more than one-half of the track pitch, when the track wears out in the process of the vehicle pitch becomes longer, take the next section of the track plate, still can maintain the tension of the track.

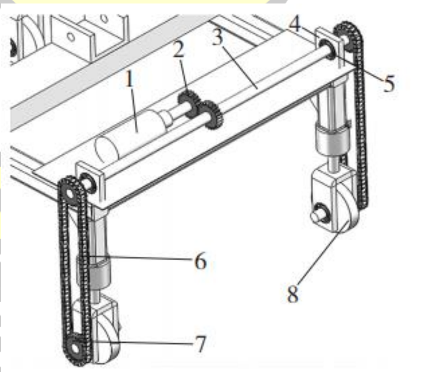
Crawler travel mechanism has been widely used in the machinery industry, and the factors affecting its travel are not only related to the structure and parameters of the machinery, but also have a close relationship with the nature of the ground soil. The design should be comprehensive analysis and research, carefully analyze the technical parameters, in order to ensure that the crawler walking mechanism in good condition, fully meet the requirements of use.

2.5.2 Wheeled walking mechanism

Strawberry picking robot can largely save labor, reduce costs and improve economic efficiency. A reasonable walking mechanism is very important for efficient and smooth walking of strawberry picking robot and effective crossing of obstacles.

Domestic analysis and research is mainly conducted for most of the ground monopoly type strawberry planting patterns in China, so as to analyze and design the wheeled walking mechanism, which can be assembled above the walking mechanism to walk between the monopolies and facilitate image recognition of the robot.

This cross-monopoly walking mechanism was designed mainly based on the specific monopoly type of strawberry cultivation. The width of the pathway (i.e., the transverse distance between the monopoly and the monopoly) is about 300 mm, and the height of the monopoly is about 260 mm. size. According to the working environment and functional requirements, there should be a mounting tab and a mounting base for the picking robot on top of the walking mechanism. After the robot picks the strawberries, the strawberries should be placed in the box containing the strawberries, so the walking mechanism should be designed with a strawberry tray for storing the strawberries, and the tray should not be too thick to prevent crushing the strawberries below due to too thick. Since the mechanism is cross-monopoly walking, the driving motor of the walking mechanism should be placed on the top of the mechanism, so the walking mechanism is provided with a loading table above for mounting the motor. The transmission process involves a drive shaft, so a support with mounting bearings should be provided so that the power can be continuously transmitted smoothly and efficiently. Since the power transmission of the walking mechanism is carried out by two drive shafts with a large center distance, the walking speed of the walking mechanism, the quality of the walking mechanism and the stability and efficiency of the walking, and the power transmission in the vertical direction, the belt drive or chain drive can be used. Walking mechanism in the strawberry planting field walking, because the soil is relatively soft, need to provide a larger transmission power, belt drive overload will overload slippage, and can not effectively ensure the transmission ratio; and chain drive can transmit a larger power, no slippage phenomenon can also ensure accurate transmission ratio, very suitable for the design requirements of the walking mechanism, so the walking mechanism of the vertical direction of the transmission can choose to transmit a larger force Chain drive. The DC power supply converts electrical energy into mechanical energy of the motor, and transmits the power to the wheel axle through the gear drive, drive shaft and chain drive, which in turn causes the wheel to rotate and the mechanism to travel. [15]



Note:

1. Motor	5. Bearing
2. Gear	6. Drive chain
3. Drive shaft	7. Chain gear
4. Fixed support	8. Wheel

Figure 15 Schematic diagram of the driving system of the travel mechanism[15]

Replacing tires by a tracked travel mechanism is considered one of the effective means of mitigating soil compaction by agricultural vehicles. Compared with tires, tracks have a larger grounding area and can effectively reduce the average pressure of the vehicle on the soil. However, the stress distribution between the track and soil contact surfaces is extremely uneven, with stresses concentrated mainly under each load-bearing wheel, and the ability of tracks to mitigate soil compaction is an issue that is currently under investigation. In this study, the maximum vertical and horizontal stresses in soil at 0.15 and 0.35 m depths were tested and compared between tires and tracked vehicles of similar loading masses, and the effect of vehicle speed on the magnitude of vertical and horizontal stresses in soil was investigated. Based on the soil compaction analysis model, the maximum vertical and horizontal stress distributions in the soil at 0.1 to 0.7m depths compacted by tires and tracks were calculated. The effects of tire and tracked vehicle compaction on the magnitude of soil permeability, prior consolidation pressure and dry capacity were compared by indoor tests on soil samples at 0.15 and 0.35m depths. The results show that the crawler can reduce the vertical and horizontal stresses in the soil compared with the tire, but the reduction of vertical stress is greater than that of horizontal stress; the average maximum vertical stresses acting on the soil at 0.15 and 0.35m depths are about 2.2 and 2.0 times that of the crawler, respectively, while the average maximum horizontal stresses are only about 1.2 and 1.1 times that of the crawler, respectively. The maximum vertical and horizontal stresses under the action of tires were significantly greater in the surface soil than in the tracks, but the difference between the two stresses decreased gradually with the increase of soil depth, with no significant difference at 0.7 and 0.4 m depth, respectively. The vertical and horizontal stresses in the soil at 0.15 and 0.35m depths under tire and track compaction both decreased with the increase of vehicle driving speed, and the stress reduction rate under the track action was greater than that of the tire. The permeability of the soil at 0.15 and 0.35m depths under track action was significantly less than that of tires.[14]

2.6 Research on the energy mechanism of new automatic strawberry picking

Nowadays, the world is facing the problems of energy shortage and environmental pollution. As society has been advocating environmental protection and energy saving, those polluting resources such as coal, oil and natural gas are gradually replaced by new energy sources, and every country is trying its best to study new clean energy sources, and the extent and value of the research has become a symbol of national development, so it is urgent to study new green energy sources. Among them, solar energy has the advantages of inexhaustible, non-polluting, clean, etc., so it has received the attention of researchers. 136 countries around the world are currently involved in the popularization of the application of solar cells, of which 95 countries are carrying out large-scale research and development of solar cells, and actively producing a variety of new energy-saving products[16].

High efficiency solar cells are widely used due to their low cost, ideal forbidden band width, high light absorption, high photoelectric conversion rate, stable cell performance and simple cell structure. With the research and development of solar cells, solar cells have been widely used in industry, agriculture, military and daily life, especially they are used in remote areas, mountains, deserts, islands and rural areas, which can save the cost of expensive transmission lines. Research on efficient solar cells has also become an effective way to change the global energy shortage.

Solar cells are devices that convert light energy directly into electricity through the photoelectric or photochemical effect. As soon as it is illuminated by light, it can output voltage and current instantaneously. In physics it is called solar photovoltaic (Photovoltaic, photo light, voltaics electricity, abbreviated as PV), or PV for short. Thin-film solar cells working with the photovoltaic effect are the mainstream, while wet solar cells working with the photochemical effect are still in their infancy. Solar cells according to the different materials used, solar cells can also be divided into:

crystalline silicon solar cells, multi compound thin film solar cells, polymer multilayer modified electrode type solar cells[17].

2.6.1 Thin Film Solar Cells

Thin film solar cells are a new type of photovoltaic device to alleviate the energy crisis. Thin film solar cells can be manufactured using inexpensive ceramic, graphite, metal sheets and other different materials as substrates, forming a thin film that can generate voltage with a thickness of only a few μm, and the current conversion efficiency can reach up to 13%. In addition to the flat surface, thin-film solar cells can also be made into non-flat structures because of their flexibility and have a wide range of applications, and can be combined with buildings or become part of the building body, which is very widely used.

Silicon material is the dominant material in solar cells today, and silicon material accounts for nearly 40% of the cost share of finished solar cells, while the thickness of amorphous silicon solar cells is less than 1 μm, less than 1/100 of the thickness of crystalline silicon solar cells, which greatly reduces the manufacturing cost, and due to the advantages of amorphous silicon solar cells such as very low manufacturing temperature (-200℃) and easy to realize large area, it makes it in the thin film In terms of manufacturing methods, there are electron cyclotron resonance method, photochemical vapor deposition method, direct current glow discharge method, radio frequency glow discharge method, sputtering method and hot wire method. In particular, the RF glow discharge method has become an internationally recognized mature technology due to its low-temperature process (-200℃), which is easy to achieve large area and high-volume continuous production. In terms of material research, a-SiC window layer, gradient interface layer, μC-SiCp layer, etc. have been studied, which have significantly improved the short-wave spectral response of the cell. This is due to the fact that the photogenerated carriers of a-Si solar cells are mainly generated in the i-layer, and the incident light is partially absorbed by the player before reaching the i-layer, which is ineffective for power generation. In contrast, a-SiC and μC-SiC materials have a wider optical bandgap than p-type a-Si, thus reducing the absorption of light and increasing the light reaching the i-layer; together with the adoption of gradient interface layers, the transport characteristics of photoelectrons at the a-SiC/a-Si heterojunction interface are improved. In terms of increasing the long-wave response, the glass/TCO/p1i1n1/p2i2n2/p3i3n3/ZnO/Ag/Al structure is adopted with a suede TCO film, a suede multilayer back-reflective electrode (ZnO/Ag/Al) and a multi-bandgap stacked structure. The glassy TCO film and multilayer back-reflective electrode reduce the reflection and transmission loss of light and increase the light propagation distance in the i-layer, thus increasing the light absorption in the i-layer. In the multi-bandgap structure, the bandgap width of i-layer decreases from the direction of light incidence in order to absorb sunlight in segments, which broadens the spectral response and improves the conversion efficiency. Gradient bandgap design and microcrystalline doping layers in tunnel junctions are also used to improve carrier collection in order to improve the efficiency of stacked cells[18].

Thin film solar modules are composed of glass substrate, metal layer, transparent conductive layer, electrical function box, adhesive material, and semiconductor layer. Nowadays, the industry has sufficient technical certainty to replace silicon crystals with thin film in the manufacture of solar cells. Japan's Industrial Technology Research Institute in February has developed the world's highest solar energy conversion rate of organic thin-film solar cells, the conversion rate has reached four times the existing organic thin-film solar cells. The previous organic thin-film solar cells are two layers of organic semiconductor film together, from solar energy to electricity conversion rate of about 1%. The new organic thin-film solar cell adds a hybrid film in the middle of the original two-layer structure, turning it into a three-layer structure, which increases the contact area between the molecules that generate electricity, thus greatly increasing the solar energy conversion rate[19].

Chapter 3

Methodology

3.1 Overall structure design of the new strawberry automatic picking system

3.1.1 Overall design of the walking mechanism

This design is mainly for most of our country's ground monopoly strawberry planting mode to analyze and research, so as to analyze and design the walking mechanism, which can picking device above the walking mechanism to walk between the monopoly, the image recognition of the picking device. The working schematic sketch is shown.

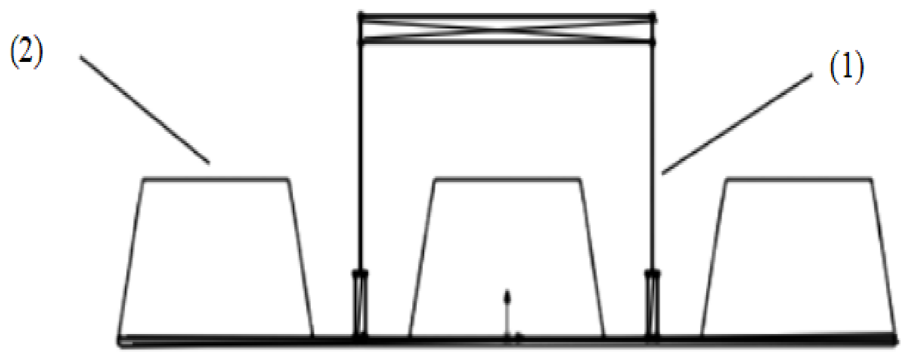


Figure 16 Strawberry and picking mechanism location relationship map[15]

Note:

(1) Strawberry field walking machine

(2) Ridge-type strawberry planting ground

This cross-monopoly walking mechanism was designed according to the specific monopoly type of strawberry cultivation. The width of the pathway (i.e., the transverse distance between the monopoly and the monopoly) is about 300 mm, and the height of the monopoly is about 260 mm. dimensions.

According to the field situation, the overall design of the strawberry picking vehicle is shown in Figure 17.

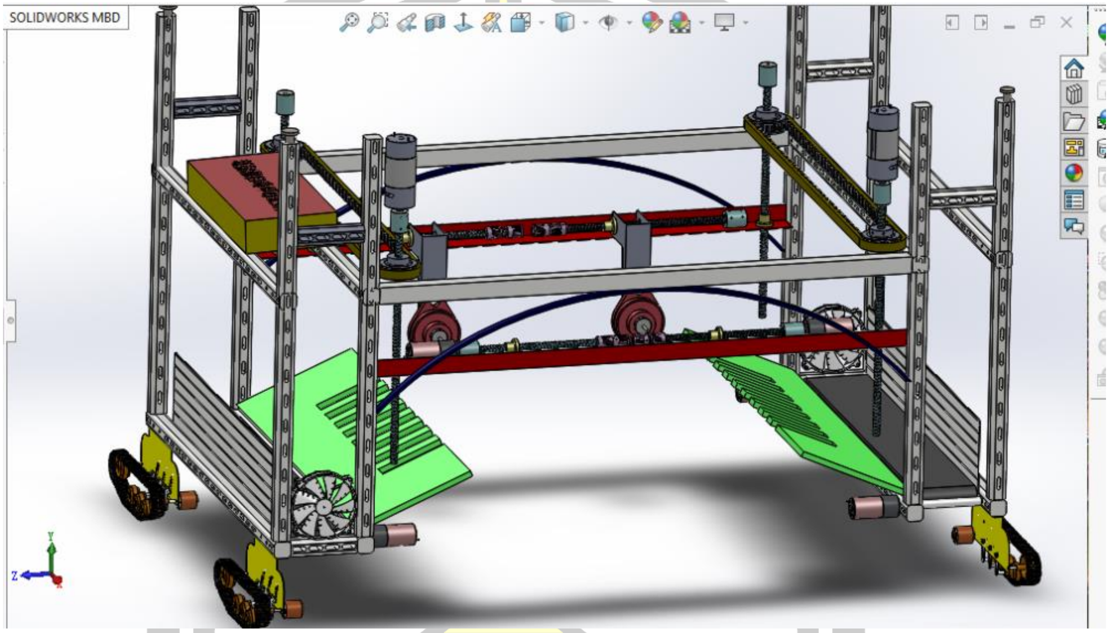


Figure 17 Overall design of walking mechanism of strawberry picker (SolidWorks modeling drawing)

Figure 18 Wheel-type and track-type modeling (SolidWorks modeling drawing)

According to the working environment and functional requirements, the whole strawberry picking cart uses electric motor to control the crawler walking mechanism to move forward, backward, left, right, left and right. Take forward and backward as an example, the direction of motion of the four track wheels are forward, at this time, the left and right forces of the four wheels cancel each other, while the up and down forces are in the same direction, and the cart moves forward. According to this analysis method, other forms of motion can be derived accordingly.

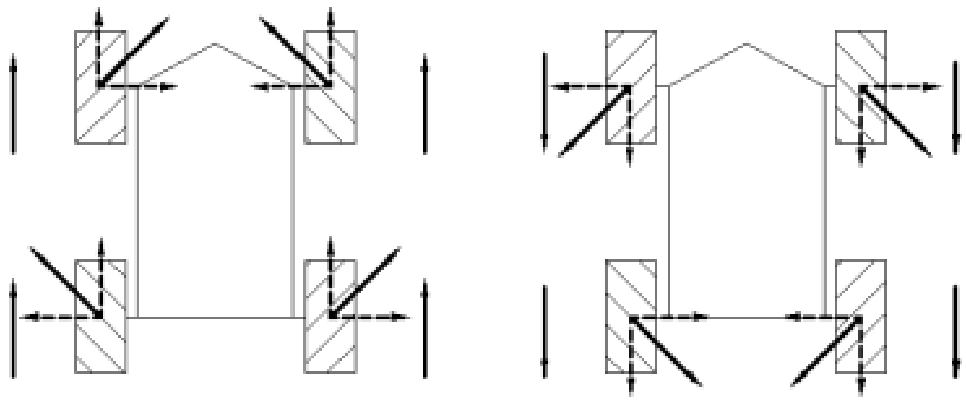


Figure 19 Forward and Backward

Replacing tires by a tracked travel mechanism is considered one of the effective means of mitigating soil compaction by large agricultural vehicles. Compared with tires, tracks have a larger grounding area and can effectively reduce the average pressure of the vehicle on the soil. However, the stress distribution between the track and soil contact surfaces is extremely uneven, with stresses concentrated mainly under each load-bearing wheel, and the tracks have the ability to mitigate soil compaction. The maximum vertical and horizontal stresses in the soil at 0.15 and 0.35m depths were tested and compared with those of a tire and a tracked vehicle of similar loading capacity by burying pressure sensors in the soil, and the effect of vehicle travel speed on the magnitude of vertical and horizontal stresses in the soil was also investigated. Based on the soil compaction analysis model, the maximum vertical and horizontal stress distributions in the soil at 0.1 to 0.7m depths compacted by tires and tracks were calculated. The effects of tire and tracked vehicle compaction on the magnitude of soil permeability, prior consolidation pressure and dry capacity were compared by indoor tests on soil samples at 0.15 and 0.35m depths. The results show that the crawler can reduce the vertical and horizontal stresses in the soil compared with the tire, but the reduction of vertical stress is greater than that of horizontal stress; the average maximum vertical stresses acting on the soil at 0.15 and 0.35m depths are about 2.2 and 2.0 times that of the crawler, respectively, while the average maximum horizontal stresses are only about 1.2 and 1.1 times that of the crawler, respectively. The maximum vertical and horizontal stresses under the action of tires were significantly greater in the surface soil than in the tracks, but the difference between the two stresses decreased gradually with the increase of soil depth, with no significant difference at 0.7 and 0.4 m depth, respectively. The vertical and horizontal stresses in the soil at 0.15 and 0.35m depths under tire and track compaction both decreased with the increase of vehicle driving speed, and the stress reduction rate under the track action was greater than that of the tire. The permeability of the soil within 0.15 and 0.35 m depth under track action is significantly less than that of tires [19], which is the reason for the selection of the tracked structure[20].

3.1.2 Overall design of picking and collecting mechanism

According to the working environment and functional requirements, a picking mechanism should be provided on top of the walking mechanism. A picking claw is designed, which mainly uses the combined motion of small motor-driven track wheel advance plus the rotation of the blade on the hand claw to cut off the strawberry stem, and adjusts the overall aluminum alloy frame and hand claw by using motor-controlled screw and gear belt to improve the practicality of the product, and saves smaller fruits by changing the distance of the hand claw. The material of the blade is tool-grade stainless steel Yuan can avoid the rusting of the blade due to water on the blade after picking, and also make the blade more heat and wear resistant.

After the strawberries are picked by the picking device, they need to be transported to the fruit storage device by the conveyor belt. The transmission mechanism of the conveyor belt is controlled by the electric motor, and the conveyor belt movement is controlled by a precise transmission ratio of 2:1 to ensure that the corresponding toothed belt reaches the designated position after each strawberry shearing, so that the strawberry fruit can be transferred. Therefore, the conveyor belt has many features such as compact structure, high efficiency and long life. Meanwhile, fans are added on both sides to clean some branches and leaves of picked strawberries by the wind of the fans; strawberries are transported to the collection box by the special toothed belt, and sieving plates are added on both sides of the collection box to be able to classify the size of strawberries and reduce the workload.

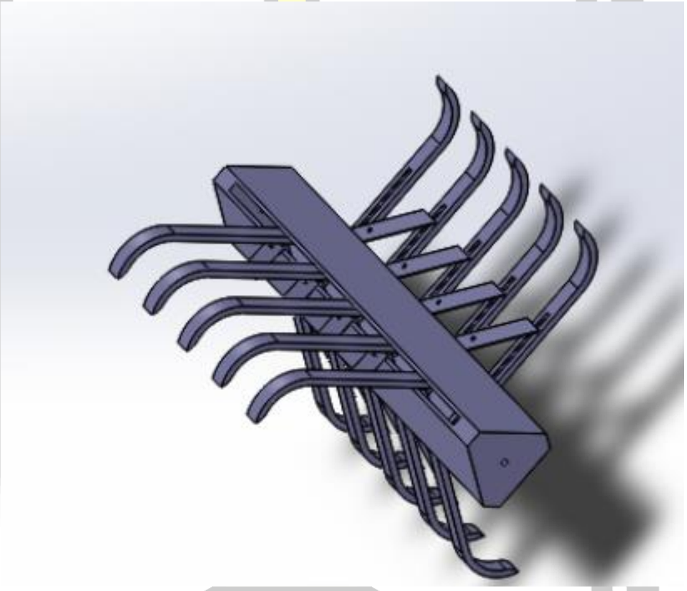


Figure 20 Picking mechanical claws

Figure 21 Silk bar adjustment device

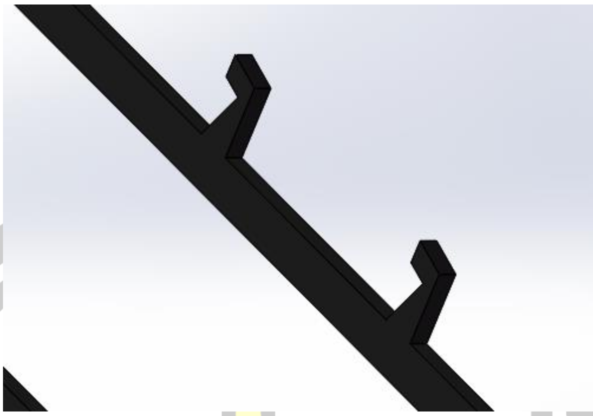


Figure 22 Ted belt transmission device

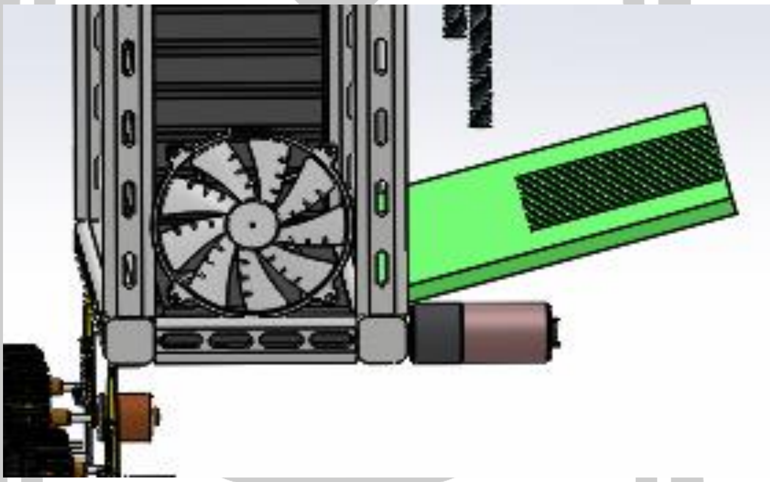


Figure 23 Small fan

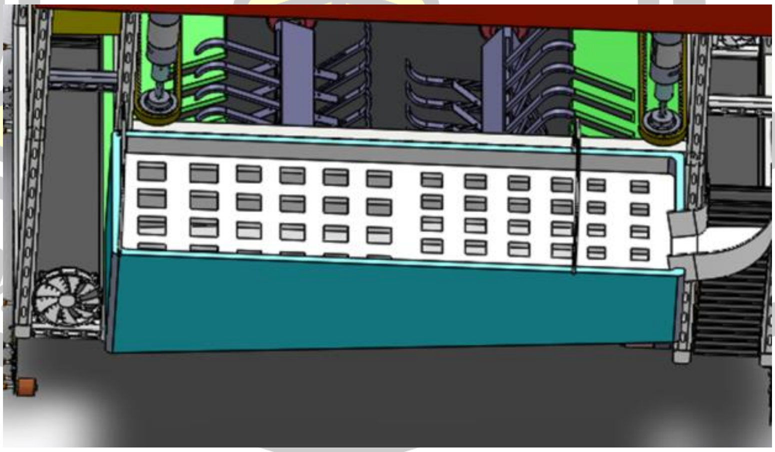


Figure 24 Picking collection and screening device

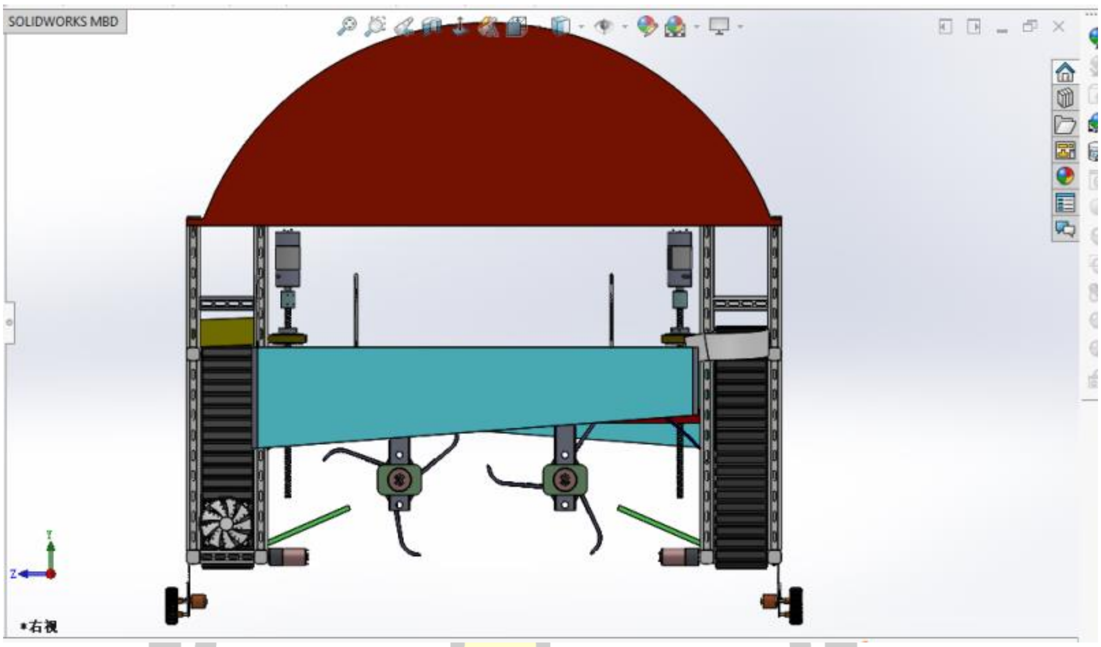


Figure 25 SolidWorks Modeling Drawing

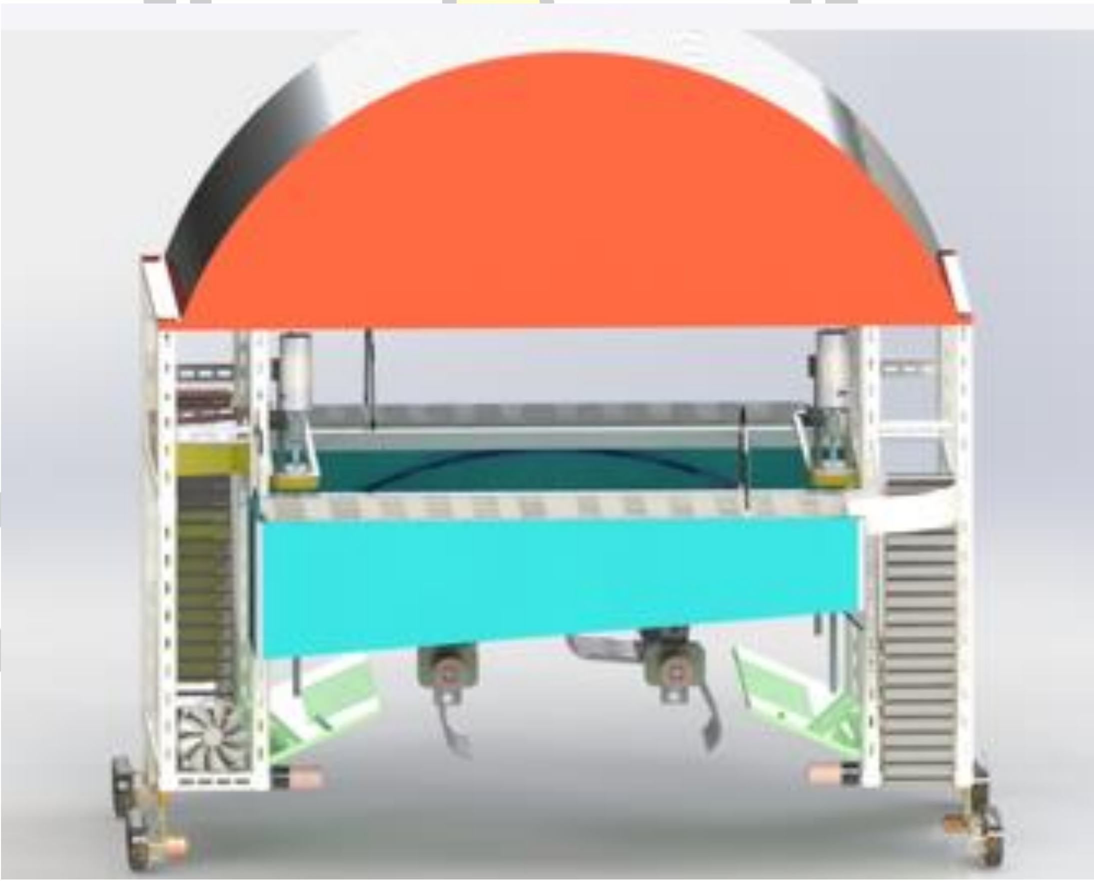


Figure 26 SolidWorks Rendering graphics

3.2 Machine design cost and generality analysis

The cost of manufacturing the machine is an important factor. Robot generally need to integrate the whole, walking, control, execution, and other institutions form a coordinated system[21], to complete more complex operations, although with the development of electronic technology, various components cost is much cheaper than the past, but because agriculture is the most basic industry, determines the agricultural production cost cannot be high, therefore, relative agricultural low cost requirements, relatively complex robot cost or easy to show high [22].

The picking mechanism designed in this article is modular design, the picking device is a combination of small motor to drive the crawler wheel forward plus the rotation of the blade on the claw to cut off the strawberry stem, picking grasp and belt wheel are easy to make, while easy to buy, and cheap.

In terms of size adjustment, when the motor is used to control the bumper and gear belt to adjust the overall aluminum alloy rack and claw, which can be adjusted according to the height of the strawberry plantation to improve the practicality of the product. The bumper and gear belt are common equipment in life, so the purchase cost is low.

The collection device uses two picking boxes with a sieve plate that vibrates so that strawberries of different sizes fall from different holes, making it cheap to make.

Energy supply device is a solar panel, according to the price of solar panel can know, home solar panel 150W, the price is 733 yuan. The general price is 5-10 yuan / W, and the price of solar panels is cheaper, in the long term, more environmentally friendly, in line with the current mainstream.

Chapter 4

Testing Results and Feasibility Analysis

4.1 Selection of actual parameters of strawberry picking

Twenty strawberries were randomly selected for size measurement, because strawberry planting has been normalized. In order to reduce relative errors, two directions were selected for actual measurement of strawberries, and the actual size parameters of strawberries were measured in Table 1. The diameter of strawberries was denoted by D, the height by H, and the mass by G. The strawberries studied in this paper are all row strawberries planted in greenhouses, and the strawberries selected are all strawberries planted in greenhouses.

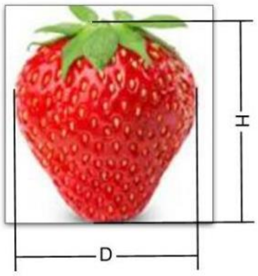


Figure 27 Schematic diagram of strawberry measurement parameters

Table 1 Actual measured parameters of the strawberry

Measurement parameter	**Diameter （D mm）**	**Height （H cm）**	**Quality （G g）**
Mean value Standard	2.51	3.71	12.3
deviation	0.218	0.231	0.411
Note: 20 strawberries were randomly selected, and the measured parameters were repeated.			

4.2 Feasibility analysis of design parameters

Picking mechanism can adapt to different ridge slope by changing the Angle of picking claw. When the movement of the claws is exactly tangent to the ridge surface, the working range of the claws is optimal. As shown in the picture below. The trajectory of the Java tip is irregularly circular, and the center of curvature of the trajectory is constantly changing. The center of curvature of the ideal working trajectory coincides with the center of rotation A. The smaller the frame rod Angle, the greater the curvature of the trajectory, and the easier the ridge surface interference. The curvature of the ideal working trajectory is greater than that of the actual working trajectory, and the ideal working trajectory is the critical state of interference. If the ideal working trajectory does not interfere with the ridge surface, the actual working will not interfere with the ridge surface. After the slope of the ridge is given, the minimum Angle of the frame rod under the ideal condition is found θ min.

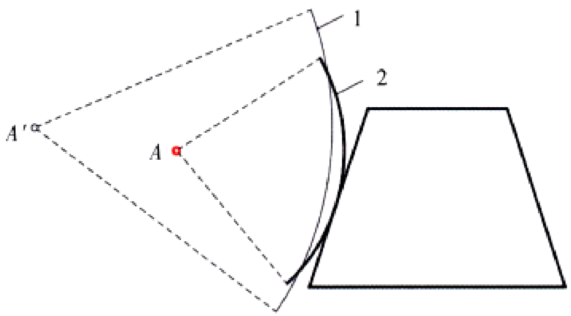


Figure 28 The movement path of the picking claw is tangent to the ridge surface Actual working track; Ideal working path; 2. *A*:a rotary center of picking mechanism; *A′* – a actual center of rotation

In view of the relationship between the Angle of picking claws and the slope of ridge, Figure 28 was simplified into geometric figures and the O-xy rectangular coordinate system was established, as shown in Figure 29

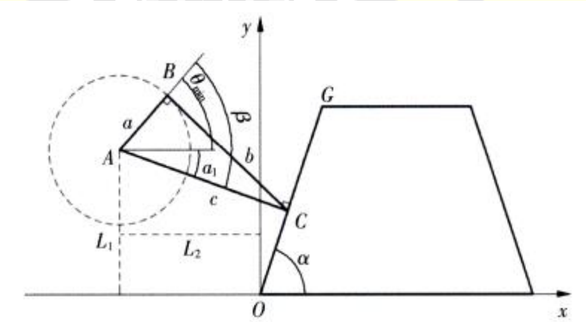


Figure 29 Simplified geometry of pickinga -- length of picking claw;
L1 -- vertical distance from the center of rotation to the ground; L2 -- Horizontal distance from center of rotation to ridge surface

According to the geometric figure analysis in Figure 14, it can be obtained:

$$\theta \min = \arcsin \frac{b}{c} + \alpha - \pi/2 \quad (4.1)$$

Among them:

$$c = \left[\left(\frac{L_1 \tan\alpha - L_2}{1 + \tan\alpha \bullet \tan\alpha} + L_2 \right)^2 + \left(\frac{L_1 \tan\alpha \bullet \tan\alpha - L_2 \tan\alpha}{1 + \tan\alpha \bullet \tan\alpha} L_1 \right)^2 \right]^{1/2} \quad (4.2)$$

$$b = \sqrt{c^2 - a^2} \quad (4.3)$$

The slope of ridge land is between 30° and 70°. According to the actual ridge conditions, the given parameters: L1=250 mm, L2=180 mm, and α=72.5 mm. According to the formula, the relationship between the Angle of picking claw and the slope of ridge can be obtained.

Table 2 Relationship diagram between picking claw angle and ridge slope

Machine Rod Angle θ/(°)	25	30	35	40	45	50
Slope α/(°)	40	45	50	55	60	65

4.3 Positioning and picking experiment tests

The rationale for picking is that, Machines run walking between elevated strawberry rows, In the process of moving, you encounter ripe strawberries and stop moving forward, Vision positioning camera works, Identify the presence of ripe strawberries, To obtain the spatial coordinates of the picking points, After the transformation of the coordinates, The system constantly adjusts the picking mechanism to reach near the picking point, The fine value of the coordinates obtained for the vision binocular visual positioning camera, The end-effector subsequently cuts and clamps the fruit under the control of the control system, After completing the harvest, the fruit is returned to the collection device, Wait for the vision binocular positioning camera to get the information about the next available strawberry picking point, Start the picking directly from the position of the fruit recovery device.

The experiment adopts the positioning accuracy test of the positioning system and obtains the average positioning error. The experiment included an elevated strawberry picking prototype system, a three-coordinate meter (precision 0.01mm). Binocular vision is the positioning of the center of gravity of strawberry fruit, and the close-up camera is the positioning of strawberry fruit handle.

experimental procedure:

1. Install the experimental instrument firmly and pinpoint the location of the picking equipment as the origin of the picking.

2. Move the picking mechanism to the running track and reset the equipment to prepare to start the equipment.

3. Vision binocular recognition acquisition images, to obtain the pixel coordinates of the strawberry center of gravity, binocular vision positioning.

4. The picking equipment reaches the binocular positioning position, the close-up camera collects the image, obtains the pixel coordinates of the strawberry handle picking point through Photoshop, and the close-up camera obtains the positioning coordinates (X, Y, Z).

5. Measure the actual coordinates (Xw, Yw, Zw) of the strawberry fruit handle picking point with the coordinate instrument, and record them.

6. 20 strawberries were selected for positioning and recorded the coordinates of 20 picking point coordinates actors and the measurement results of 20 far-near combination positioning system positioning test.

The shed is elevated to grow strawberries, and the distance of the adjacent strawberry frame is 800mm. The picking robot walks on the track between the cultivation frame. The main distribution space of strawberry fruit is within the 150mm and 100mm area. The test results data are documented in Table 3. According to the test, the average positioning error of the near and far view combined positioning system for the 20 picking points in the space is 4.81mm, and the maximum positioning error is 5.77mm.

Table 3 Positioning accuracy test

Number	Coordinate measuring (Xw, Yw, Zw)	test results (X, Y, Z)	coordinate error (ΔX, ΔY, ΔZ)	error
1	(244.42，71.87，562.43)	(249.31，76.89，560.47)	(4.89，5.02，-1.96)	7.277
2	(19.48，75.92，549.40)	(22.39，80.61，547.02)	(2.91，4.69，-2.38)	6.011
3	(82.13，78.45，550.62)	(85.54，74.47，553.26)	(3.41，-3.98，2.64)	5.868
4	(221.20，51.89，550.57)	(224.12，55.61，555.35)	(2.92，3.72，4.78)	6.724
5	(171.00，148.82，529.98)	(172.95，143.62，534.07)	(1.95，-5.2，4.09)	6.897
6	(319.38，71.65，551.98)	(322.54，69.62，547.38)	(3.16，-2.03，-4.6)	5.939
7	(35.43，80.59，540.61)	(39.82，84.27，536.54)	(4.39，3.68，-4.07)	7.027
8	(50.43，73.38，550.44)	(46.76，69.79，546.28)	(-3.67，-3.59，-4.16)	6.608
9	(324.41，48.36，553.14)	(327.97，52.74，555.29)	(3.56，4.38，2.15)	6.040
10	(115.67，69.48，558.21)	(119.09，73.22，561.46)	(3.42，3.74，3.25)	6.021
11	(339.32，19.58，556.54)	(334.07，16.94，553.82)	(-5.25，-2.64，-2.72)	6.475
12	(149.00，82.47，229.43)	(144.49，84.78，557.01)	(-4.51，2.31，-2.42)	5.615
13	(276.84，136.76，564.42)	(273.06，139.42，566.79)	(-3.79，2.00，2.37)	5.194
14	(5.12，43.39，548.87)	(1.64，46.25，552.7)	(-3.48，2.86，3.83)	5.913
15	(212.22，25.47，550.36)	(209.71，22.53，547.58)	(-2.51，-2.94，-2.78)	4.762
16	(253.90，74.76，571.67)	(156.73，70.6，575.66)	(2.83，-4.16，3.99)	6.421
17	(33.32，73.12，546.13)	(35.21，76.53，550.39)	(1.89，3.41，4.26)	5.775
18	(184.70，75.74，550.32)	(189.13，79.67，552.78)	(4.43，3.93，2.46)	6.413
19	(92.51，91.37，554.76)	(189.13，87.62，551.59)	(-2.91，-3.75，-3.17)	5.708
20	(138.90，70.47，546.54)	(143.39，66.73，549.75)	(4.49，-3.74，3.21)	6.667

Note that the unit of error in the table is mm

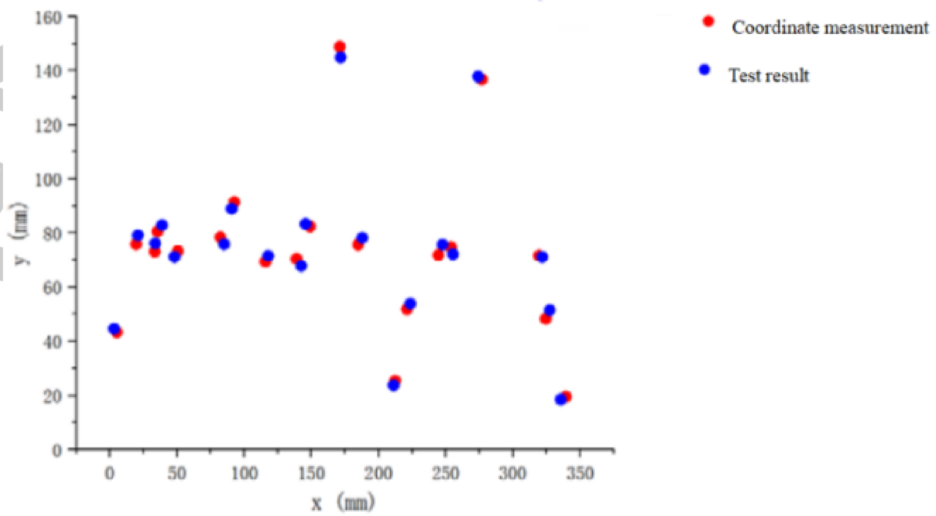


Figure 30 The positioning experiment results are displayed in X-Y plane

4.4 Picking experimental design and test

The claw picking design was optimized by direct cutting, as shown in Figure 39 below.

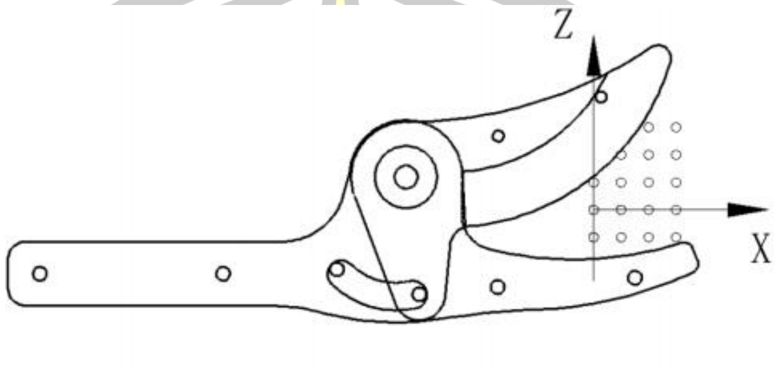


Figure 31 Picking claws

The coordinate system was established with the positioning center as the origin. In the area to be cut, 20 shear test points were arranged with a spacing of 6 mm. Each test site had two shear tests, and 40 shear tests were recorded.

Figure 32 Arrive at the picking point

Figure 33 Cut the operation

Through the experiment, 20 strawberries were picked by positioning, and the successful picking rate was 80%. Among them, the strawberries that were not picked successfully were not picked successfully for positioning reasons.

Chapter 5

Conclusions

5.1 Conclusions

Through the measurement and analysis of the physical parameters related to strawberry fruit and stalk, the fruit distribution distance is 25mm-65mm, the average fruit mass is 20.40g, the average diameter of the stalk is 2.16mm, the average shear force of single blade is 9.53N, and the average shear force of double blade is 5.20N. The size of the end actuator is 54mm, 54 mm, 190mm, and the mass of the prototype is about 2.50kg. The structure is simple. By theoretical verification, it proves that the end actuator can complete the cutting and collection of strawberry fruit. The berries were positioned by the strawberry visual system with an average localization error of 4.82mm and a maximum localization error of 5.77mm. In the positioning experiment, 20 samples were picked, and the successful picking rate was 80%.

5.2 Future work

In this study, the design was based on the existing objects, the actual production, and there were still many deficiencies in this study. The practicability of other elevated planting modes and other varieties was uncertain. In addition, for the failure of strawberry fruits with vines and special posture, further research is needed on the actual adaptability and versatility of the end actuator.

The system is studied based on the image coordinates of the picking point after image processing. However, the image processing and the extraction of the picking point have a serious impact on the accuracy of the positioning system, so the re-depth research of the positioning system needs to combine the image processing and other problems.

Further strengthen the connection with the strawberry picking prototype, design the elevated strawberry picking prototype under the planting environment of elevated strawberry, realize automatic picking, and further improve the picking efficiency on the basis of ensuring the accuracy and success rate of picking.

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