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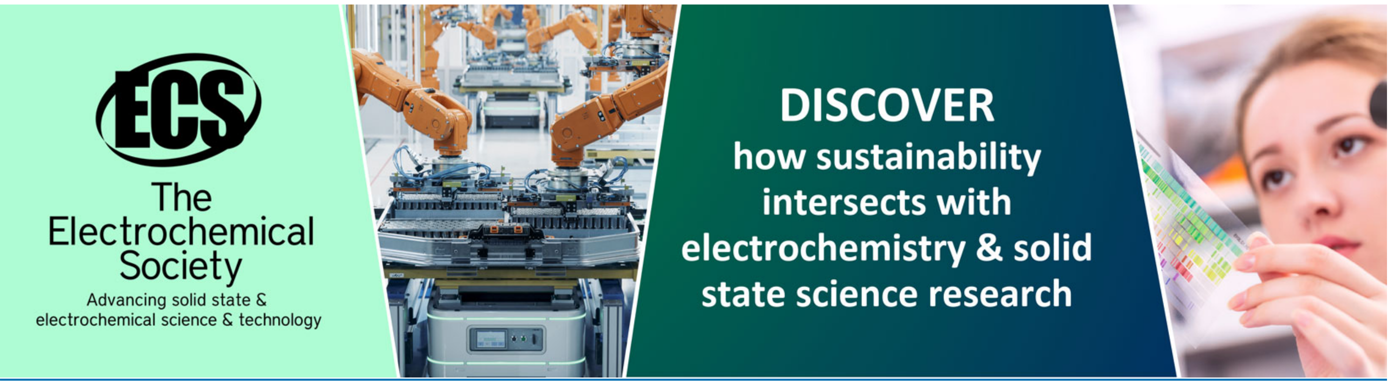

Design and Implementation of Intelligent Agricultural Picking Mobile Robot Based on Color Sensor

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Abstract. With the rapid development of artificial intelligence and the Internet of Things technologies, the degree of agricultural Informatization and intelligence has been further improved. Governments of every country attach great importance to agricultural modernization and intelligence. Based on this purpose, this project completely independently designed an intelligent mobile picking robot for application in agriculture. The picking mobile robot is mainly based on the STM32 development board, which is loaded with the color sensor, infrared sensor, and ultrasonic sensors, which is instead of the CCD sensor to identify maturity, thereby reducing the difficulty of the algorithm and realizing fast picking tasks. In the harvest season, the robot will be mainly used for picking fruits, which can completely, replaces farmers' operations, liberating labor, and breaking the constraints of time and space.

Keywords: Intelligent Agriculture, Maturity Recognition Module, Intelligent Pricking Robot.

1. Introduction

Fruit picking robot is the most time-consuming and laborious part of agricultural production. It is labor-intensive work, and it is urgent to realize automatic fruit picking to improve labor efficiency. With the increasingly mature electronic technology, artificial intelligence technology, and image processing technology, Japan and Western European developed countries have carried out a large number of researches on picking machines and equipment since the mid-1980s. A tomato picking robot was successfully developed in 1984, represented by Japan. The robot has 5 degrees of freedom and the manipulator is a joint type. In the early 1990s, Japan developed a tomato picking robot with seven degrees of freedom. These two robots mainly rely on a vision system to complete maturity recognition. The United Kingdom developed a mushroom picking robot in 1977. The robot can measure the position and shape of mushrooms through vision sensors to guide the end effector to selectively harvest mushrooms.

China began to study agricultural robots in the mid-1990s, and mainly carried out the research and development of mushroom, strawberry, cucumber, and tomato picking robots. Although with the joint efforts of domestic universities and scientific research institutions, major breakthroughs have been made in the key technology of picking robots, there is still a certain gap compared with western developed countries.

After reading domestic and foreign references, the fruit and vegetable picking mobile robot system have been compared and summarized and found that most of them rely on CCD graphic image sensors to recognize the ripeness of fruits and vegetables. The system cost is relatively high, and the intelligence of the entire system is low.

According to relevant data, British farmers have to pay the picker between 1 and 2 pounds for picking a kilogram of fruit. For intelligent picking mobile Robots, it can work for 24 hours, breaking the time and space limit. Since the picking robots will not feel tired, they can work 20 hours a day, and each robot will be able to pick more than 25000 fruits per day, far higher than the speed of 15000 fruits picked by human workers in eight hours a day.

2. Main Modules and Design

This design is an intelligent picking robot with the STM32 series development board as the main controller. The robot uses STM32f103zet6 as MCU. It has 512KB flash, 64KB SRAM, four general timers, two basic timers, two advanced timers, and 112 I/O ports. The internal processor of the chip is a 32-bit high-performance ARM Cortex-M3 with a clock up to 72M.

The intelligent mobile picking robot worked in the agriculture field, mainly includes the following functional modules, such as motor drive module, intelligent tracking module, intelligent obstacle avoidance module, maturity recognition module, and intelligent picking module. The functions of the main module are as follows:

Motor drive module is mainly used in two parts in this system. First, it is the car body driving behavior for the intelligent mobile picking robot. Secondly, it is mainly used for the intelligent control of the mechanical arm of the intelligent mobile picking robot.

Intelligent tracking module is recognized by the infrared sensor so that the robot can complete the correct and stable tracking task. Farmers can regularly plant fruit trees or vegetable plants on both sides of the road, then making the picking robots to complete the work of identifying and picking while tracking.

Intelligent obstacle avoidance module can sense the surrounding environment, and real-time and plan a collision-free path, to control their speed and direction of the road, the ultimate safe destination to complete the navigation, and the corresponding task [2].

Intelligent maturity recognition module mainly relies on the color sensors to complete the maturity recognition task. The picking robot will analyze and process the data which is collected by the color sensors. The collected data by the color sensors are mainly composed of RGB values, which represent the red, green, and blue values of the three primary colors. That will be used to set the maturity value of fruits and vegetables [3].

Intelligent picking module can perform picking tasks flexibly. Among them, the robotic arms and claws are all independently designed. The robotic arm of the picking robot is driven by the motor to expand to the corresponding height and angle, and then the fruit is grasped by the mechanical claw precisely [4].

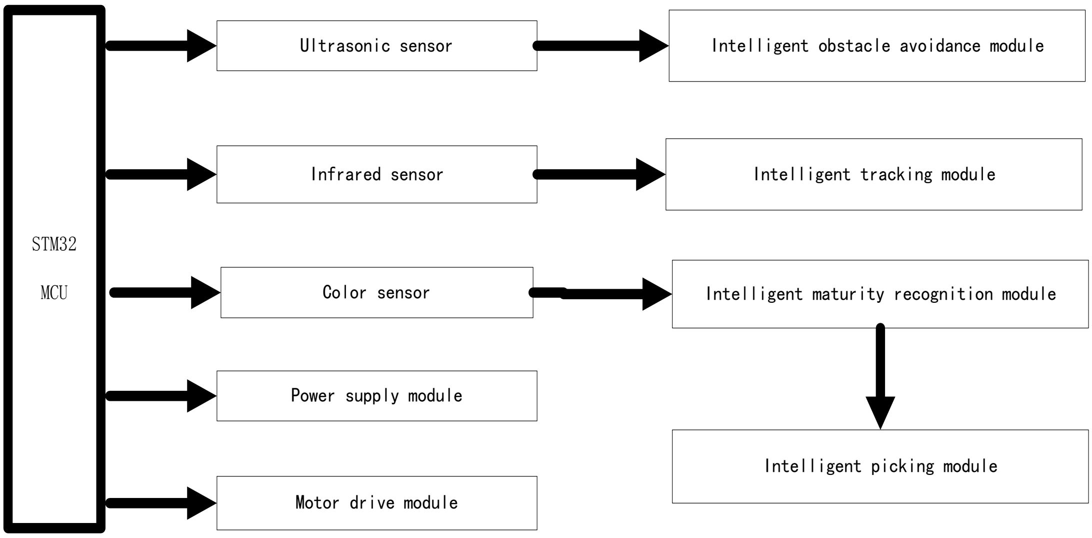

Fig.1 System function module

The mature recognition module is mainly completed by color sensors. Color sensor TCS230 is a programmable color light to frequency converter introduced by TAOS Company. There are red, blue, and green filters on the chip. It integrates the current frequency converter into a single CMOS circuit, which is packaged in a chip. There are about 64 photodiodes in the chip, which are divided into four parts: red, green, blue, and colorless filters. There are four LED lights, which can be turned on or off through the I/O port. Its function is to detect non-luminous objects that are to strengthen the reflection of object color through illumination. There are eight I/O ports: OUT, OE, S0, S1, S2, S3, VCC, GND. The power supply voltage of the system needs 3-5 voltage. The chip is selected by OE. The original state is a high impedance state, which can be used for multi-unit sharing of micro-controller through input line.S0 and S1 are pin values, which can be used to control the output scale factor, such as 100%, 20%, or 2%.

The system can be gated the filter mode by setting the high and low-level values of S2 and S3. When the value of S2 and S3 is settled as"0", the red filter will be selected. When the value of S2 is designed as "0" and the value of S3 was designed as "1", the blue filter is selected; When the value of S2 is designed as "1" and the value of S3 was designed as "0", the colorless filter is selected; When the value of S2 is designed as "1" and the value of S3 was designed as "1", the green filter is selected; The color of the fruit could be identified by the value of the three colors.

The main component of the intelligent picking module is a steering gear, which is a position servo drive device. The key points and difficulties of this system are mainly used to adjust the degree and freedom for the mechanical arm joints, so as to rotate to the best corresponding angle for picking. The steering gear used in this system is mainly composed of a plastic shell, small circuit board, motor, and gear [6]. There are three wires outside the steering gear [10], the red wire is the power control wire, the brown wire is the ground wire, and the orange wire is the signal wire. When STM32's main control board produced a PWM pulse, which is the input data for the signal wire. The PWM with different occupied times could control the steering wheel to rotate at different angles. When the high level of the input was 2.5% of a cycle, the rotation angle of the sub chief was 0 degree; When the high level of the input was 5% of a cycle, the rotation angle of the sub chief was 45 degree; When the high level of the input was 7.5% of a cycle, the rotation angle of the sub chief was 90 degree; When the high level of the input was 10% of a cycle, the rotation angle of the sub chief was 135 degree; When the high level of the input was 12.5% of a cycle, the rotation angle of the sub chief was 180 degree.

3. Software Design

After the intelligent picking robot is initialized and started, including delay function initialization, timer initialization, external interrupt initialization, TCS230 color sensors initialization, white balance setting, serial port initialization, and TCRT500 infrared tracking sensor module initialization.

After various initializations are completed, the TCRT500 infrared sensor will start to identify the laid black tracking line, which is installed in front of the intelligent picking robot. When the black line is detected, the LED light on the sensor will go out, and the corresponding number “0” will return to the main controller, when the black line is not detected, it will return “1” to the main controller. According to the return value of the infrared sensor, the main controller STM32 controls the L298N motor, which can drive the DC motor in the corresponding direction, so that the robot can walk along the black line, moving forward, moving back, turning right, or turning left. When the two infrared tracking sensors detect the horizontal black line, the main controller STM32 controls the robot to stop and then drives the color sensors TCS230 to detect the color of the fruit. The color sensors are used to identify the RGB color value of the fruit, dealing and analyzing data, deciding whether or not to pick it. During the whole journey of the intelligent picking mobile robot. The intelligent obstacle avoidance module has been working, detecting whether there are static or dynamic obstacles during the process of robot walking. If there are obstacles, the obstacle avoidance algorithm is called and the path optimization is performed. The specific work-flow of the picking robot is as follows:

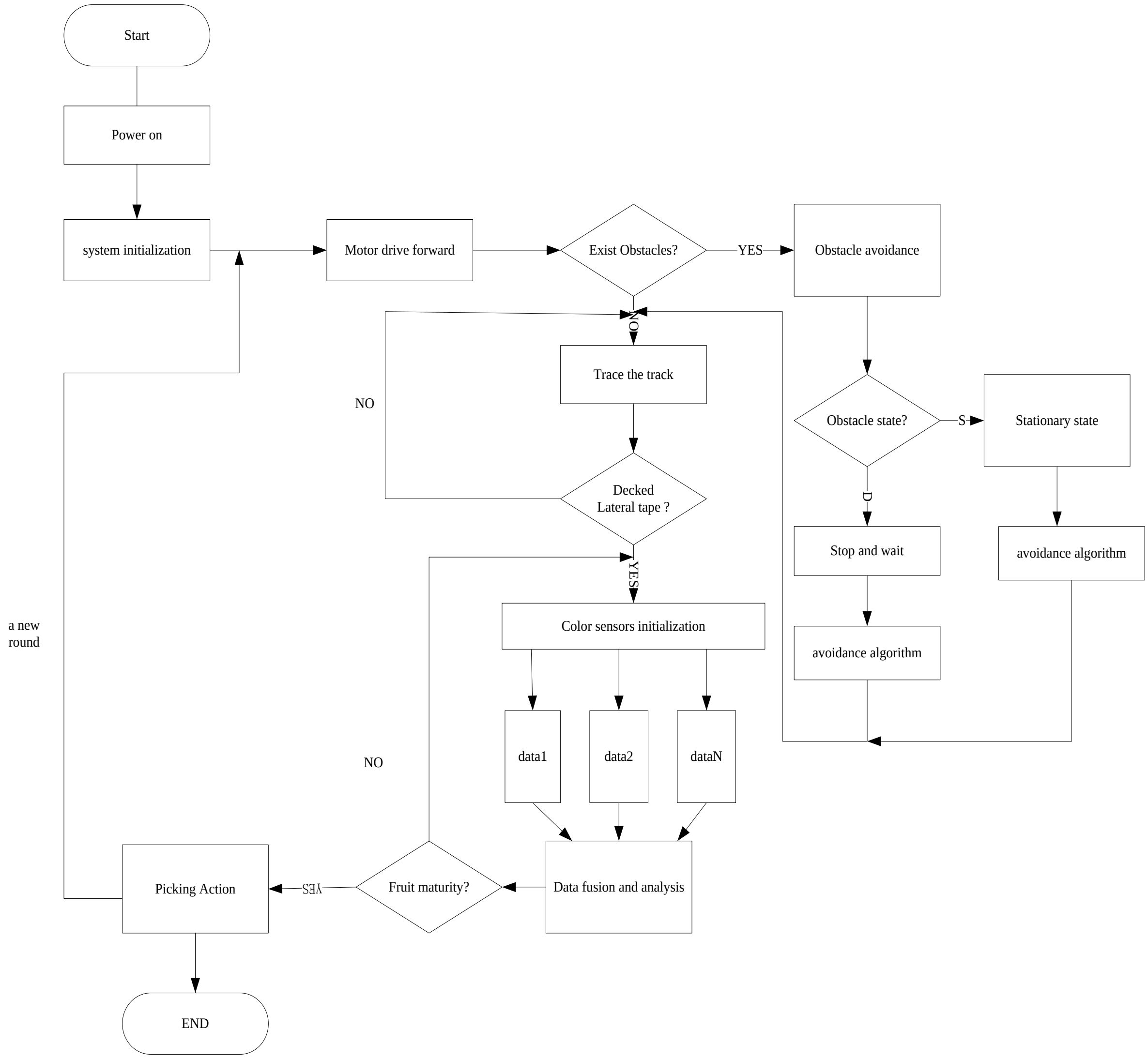

Fig.2 Program system work-flow

4. System Experiment

Before doing the system experiment, here is an effective description of the working environment of the agricultural intelligent mobile picking robot. That is shown in the model diagram below. The experimental model has a rectangular area, which is a regular rectangle surrounded by black tape. The four black sides of the rectangle are the track of the intelligent agricultural picking mobile robot. At the same time, during the picking mobile robot walking along with the rectangular, where there are fruit trees or plants, a horizontal black tape will be added to realize the basic positioning of the fruit. When an intelligent agricultural mobile picking robot encounters horizontal black tape, It can automatically call the intelligent fruit maturity recognition program, and collect the color values of different parts of the fruit in real-time for many times, carrying out an effective data fusion and processing date to generate the decision data, which can decide whether or not to call the intelligent picking module. So the intelligent picking module can control the mechanical arm to reach the appropriate height and angle, opening the mechanical claw, the claw grasps the fruit and picks by regular rotation from left to right.

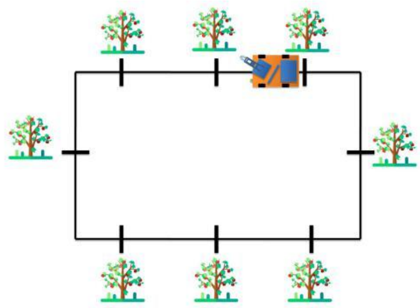

Fig.3 Experimental scene model

4.1. Intelligent Tracking Module Experiment

The intelligent tracking module mainly relies on an infrared sensor, and its model is TRCT5000. The main function of the module is to continuously judge the position of the black line and adjust the direction of the intelligent mobile picking robot through the perception of the black line on the road so that the robot can move or stop on the specified route[7].

During the experiment, the system first calls the initialization function of the infrared sensor infrared-init ( ), its function is to connect the power supply and sets the output mode push-pull. At the same time, the following four functions are needed to complete the path planning of the picking robot, such as Turn-left( ), Turn-Right( ), Go( ), and Stop( ), which mainly can control the picking robot to turn left, turn right, go forward or stop. For example, when the infrared sensor on the left side does not receive the reflected infrared signal, but the right side receives the reflected infrared signal, the mobile robot will shift to the left, and the system needs to control the mobile robot to turn to the right, and return to the normal state[8].

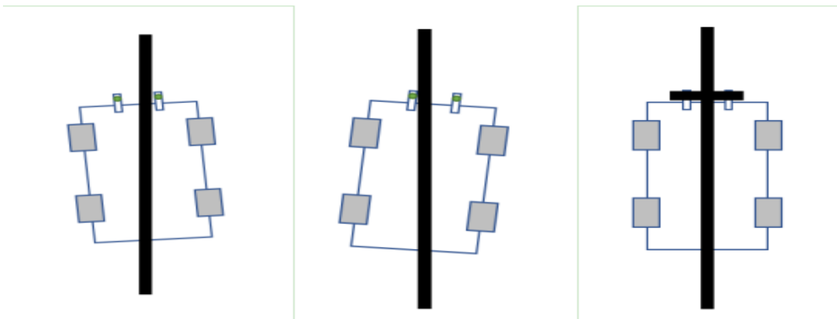

Fig.4 Adjust robot position.

4.2. Maturity Recognition Module Experiment

Two pairs of color sensors are installed on the robotic arm of this intelligent mobile picking robot to operate on the color sensor, then designing S2 and S3 as “1”, the red filter will be selected[9]. The first system performs the white balance initialization and set the amount to zero. System transfer 10s to delay function and then save the count value amount to the corresponding color variable. Last set amount value to zero again. Continue to follow the previous method to select the blue and green filters, and save the corresponding color variables. Take reading the red value as an example, set S2 and S3 to zero, strobe the red filter, set the count value to zero, delay 10ms through the delay function. Take reading the red value as an example, setting S2 and S3 as zero, selecting the red filter, set the count value to zero, delay 10ms through the delay function, and then set S2 to 1, S3 to 0, no filtering Using the formula R= (amount)*255/ (red color variable value saved during white balance), convert the number of square waves into R-value. In one clock cycle, the robotic arm rotates and locates at different parts of the fruit, collects different RGB colors, and uses a data fusion algorithm to generate the final RGB control decision value. The specific output factors are shown in Tab.1:

S0	S1	output factors
H(1)	H(1)	100%
H(1)	L(0)	20%
L(0)	H(1)	2%
L(0)	L(0)	0

Tab.1 Specific output factors

The specific selection mode of the filter is as shown in Table 2:

S2	S3	selected mode
H(1)	H(1)	green
L(0)	H(1)	blue
H(1)	L(0)	Colorless
L(0)	L(0)	red

Tab.2 Color filter selected mode

When the initial program of the design was initiated, both S0 and S1 were set to high levels, and the scale of the output was 100%. Then the white balance was initially activated. Call the delay function and pass the parameter t=10s, and then the system selects the red filter, blue filter, and green filter separately. Reading the data output by the out port. Finally, calculate the RGB values corresponding to different colors by using calculation formulas. Therefore, the intelligent mobile picking robot can decide whether to pick fruits and vegetables according to this value[8].

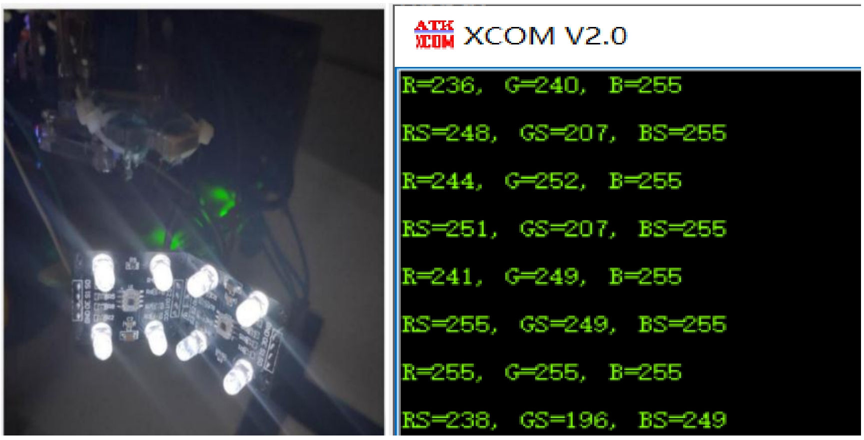

Fig.5 RGB collection value

On this basis, there will be a rule when identifying the color of the fruit, that is, the R value of the mature fruit (red color) will be greater than the G value, and the R value of the immature fruit (green) will be less than or equal to the G value. When judging ripe fruit, the value of R and G is used to judge whether the fruit is ripe. (The value of R is from the first color sensor, the value of RS is from the second sensor[9].

4.3. Intelligent Picking Module Experiment

This system uses two servos to control the robotic arm. The right servo is used to stretch the length of the robotic arm, another robotic arm is used to control the closing of the paws[10].The specific picking process of the system is as follows:

First, the robot is already powered on and initialized; the intelligent mobile picking robot traces the black tape. At the same time, the system activates the intelligent obstacle avoidance module and relies on the ultrasonic sensor to detect whether there are obstacles during the tracing[11].

When the robot detects a static or dynamic obstacle ahead, the system will execute a barrier algorithm and path planning to achieve safe and stable obstacle avoidance.When the robot is in progress and encounters the horizontal black tape mark, when the robot is running and encounters the horizontal black tape mark, it means that there are just plants at this position [12]. The intelligent mobile picking robot stops moving, the system drive motor controls the two mechanical arms to automatically extend and retract, and the height adjustment matches the fruit position. The mobile picking robot will call the maturity recognition module function to identify and judge the fruit that fruit is ripe or not. Then the experiment will be started. If this fruit is ripe, as the color sensor receives the RGB value, which R value is more than the G value is also more than 233. Making sure that the chaw holding on to the fruit as below fig 7(2) and rotating the fruit, putting the fruit in the basket. If this fruit is not ripe, then making the mobile picking robot go to look forward to the next fruit. Through many experiments and tests, the whole system has achieved a more ideal effect.

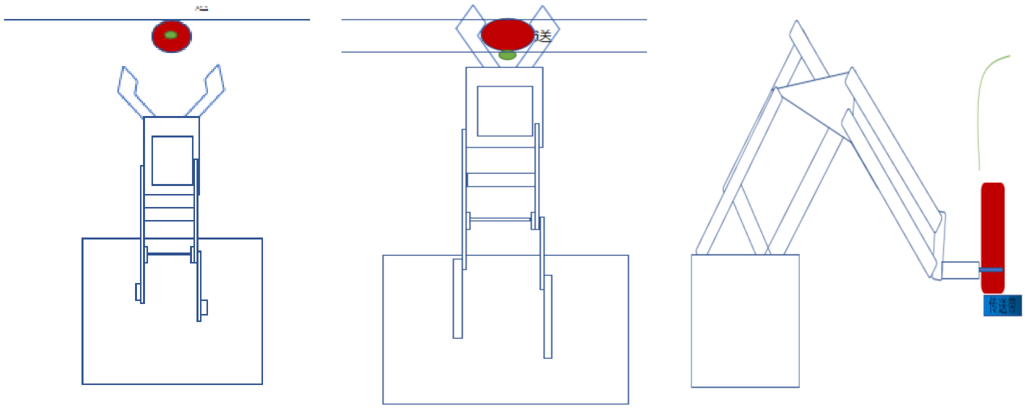

Fig.6 The robot's mechanical arm

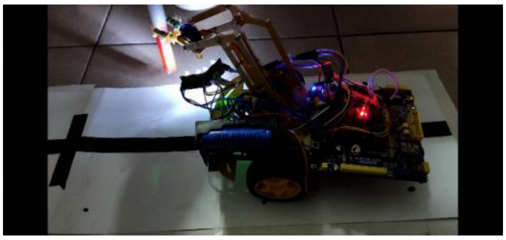

Fig.7 The system physical picture

5. Conclusion

The agricultural picking robot has been designed independently. After a series of unit tests and functional integration tests, the infrared sensors, ultrasonic sensors, and color sensors of the system can work normally, the base data can be collected in real-time. Through analysis of data, the system can use a multi-sensors data fusion algorithm to generate intelligent decision data for the control of the picking robotic arm, which can pick the fruits instead of farmers. The experiment is relatively successful and achieved the expected results. Compared with similar products at home and abroad, it can reduce power consumption and cost.

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