Study on the control system of Agaricus bisporus picking robot

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Abstract. At present, the Agaricus bisporus industrialized cultivation has formed in the world, and fertilization, feeding, humidity control has been automated. However, no automation has been achieved in the human-like picking process. Therefore, an A. bisporus picking robot is designed and the control system is put forward. The control system of A. bisporus picking robot takes the motion control card as the core and Windows10 as the operating system. The upper computer receives a row of A. bisporus photographs taken by the camera and obtains A. bisporus coordinate points through image processing, and the stepper motor and DC motor are driven by the terminal board of the motion control card to pick the A. bisporus. Moreover, the parallel control system is designed to implement image processing and A. bisporus picking in order to improve the efficiency of A. bisporus picking robot. In addition, semi-closed loop system of stepping motor is adopted to compensate for the error caused by multi-step walking, and the control method of two-step walking of A. bisporus picking robot is proposed to solve some A. bisporus that can not be picked up. The experiment results show that the control system of A. bisporus picking robot runs smoothly and efficiently, and it has very strong application value.

1. Introduction

In recent years, with the rapid development of automation industry, people get rid of the tedious and arduous work, and robots instead of people complete the complex tasks. However, hand picking of A. bisporus is still a main way in the A. bisporus industrialized cultivation process. A. bisporus picking robots can improve work efficiency and reduce labour costs for enterprises, which makes it become a research hotspot.

However, A. bisporus grows overlapping and interconnected, and is easy to be damaged [1]. At present, Research groups in Australia and the United Kingdom have designed the robots to pick A. bisporus, but these robots are still in the development stage.

By our A. bisporus picking tests, picking process is determined and the A. bisporus picking robot is designed. The control system is implemented according to A. bisporus picking process.

2. Work principle

Figure 1 shows platform architecture diagram of the A. bisporus picking robot. It has three areas: (1) vision area is primarily a mobile camera that takes a region of A. bisporus and is driven by a stepper motor with an encoder; (2) picking area is mainly a collecting device that can move the X (long) and
Y (wide) axes, and is also driven by a stepping motor with an encoder. The Z-axis drop is driven by a stepper motor. And through the vacuum pump and the DC motor, the suction cup picks up the A. bisporus by suction and rotation; (3) auxiliary area is used to place various hardware devices, such as electrical cabinet, industrial control computer, vacuum pump and other components.

![Figure 1. platform architecture diagram of the A. bisporus picking robot](image)

2.1 Robot control process

The control process of A. bisporus picking robot is as follows:

1. The initialization of parameters is to eliminate the alarm information of emergency stop, clear the variable parameter, and all stepper motors returns to their coordinate origin through the travel switch. After initialization, image processing and A. bisporus picking control process enter their threads [2].

2. In the thread of image processing, the camera performs shooting and image processing after reaching the specified position. The centre coordinates of the mushroom point are obtained.

3. A. bisporus picking control process thread gets the array of centre coordinate points of the last shot of the A. bisporus, and the picking mechanism is moved to the corresponding position by extracting a single A. bisporus coordinate point, and it is picked up by rotation and suction. If it is picked up, A. bisporus is moved to the storage location, and then picking mechanism moves to the next point. If the A. bisporus are all picked, the picking mechanism returns to the reference point.

4. When both threads have finished running, the robot moves forward 140mm until it has reached the end. The A. bisporus coordinates obtained from the last image processing are passed to the picking mechanism.

2.2 Control method of two-step walking

The camera's field of vision is about 240*180mm. The average diameter of the A. bisporus that can be picked is about 40mm. Because the camera edge is distorted greatly and the edge of A. bisporus is usually incomplete, the centre coordinates of these A. bisporus obtained by image processing are inaccurate. According to the distortion experimental data and diameter of the A. bisporus that can be picked, the effective visual area is 200mm * 140mm. So to ensure that all the A. bisporus are captured by the camera, the picking robot can only move forward 140mm each time. And the width of the picking area(140mm) must be the same as the width of the visual effective area, so that the A. bisporus coordinate points in the two areas can correspond to each other.

One-stage walking scheme is to move the robot forward for 140mm after the camera has photographed the A. bisporus, and then the picking mechanism in the picking area will pick the A. bisporus. But this scheme would result in some A. bisporus being unable to be picked. As shown in Fig. 2, the picking area after the move can not coincide with the effective area before the move.
In order to solve this problem, we adopt a two-stage walking scheme. For this reason, it is necessary to add a blank area between the effective visual area and the picking area, as shown in Figure 3. The effective visual area before the movement can completely coincide with the picking area of the second movement, which ensures that all the A. bisporus are picked up.

The advantage of the two-stage walking scheme is that not only will A. bisporus not be missed, but the blank area can give more mechanical space to install some mechanisms and components.

3. Control system circuit design

3.1 Integrated system and circuit design
The system is mainly composed of upper computer (PC), camera, motion control card, touch screen, motor system and so on. The whole system is controlled by the C++ language of the VS platform of the upper computer. The platform is equipped with QT software for man-machine interaction and MySQL software to store data from mushroom coordinates [3]. The triggering mode of industrial camera is software triggering, which is connected with the upper computer through Gigabit Network wire, thus ensuring the stability and rapidity of image transmission. Motion control cards are connected by PCI slots to the upper computer, and data transmission and feedback through port line and terminal plate. By calling the function library instructions provided by the manufacturer, they can control various components and receive the feedback I/O signals (encoder pulse number, stroke
switch and photoelectric switching signal). The touch screen is connected with the upper computer through HDMI, which plays the role of human-machine interaction.

3.2 circuit design

3.2.1 Stepper motor circuit design

Compared with servo motors, stepper motors and its stepping driver are smaller in size than servo motors and its server driver at the same torque, enabling them to be mounted on mobile robot.

To ensure the positioning accuracy of stepping motor, PID algorithm is adopted. The computational amount of incremental PID control algorithm is much smaller than that of position control algorithm [4, 5]. Therefore, incremental PID algorithm and differential encoder are used in semi-closed loop control, and through the upper machine repair error. The expression of incremental PID is as follows:

\[ \Delta U_k = K_p(e_k - e_{k-1}) + K_I e_k + K_D (e_k - 2e_{k-1} + e_{k-2}) + U_o \]  

in the formula:  
- \( U_k \) is the computer output value at the kth sampling;  
- \( e_k \) is the input deviation value at the kth sampling;  
- \( e_{k-1} \) is the input deviation value at the kth sampling;  
- \( K_p \) is the proportionality coefficient;  
- \( K_I \) is the Integral coefficient;  
- \( K_D \) is the differential coefficient;  
- \( U_o \) is the original initial value when starting PID control.

Although the PID algorithm can correct the error of a section, the picking mechanism needs to walk several times in order to pick and store mushrooms, which makes the accumulated error may increase until the picking mechanism returns to the coordinate origin. A comparison system is designed for this, as shown in figure 4.

\[ E_p = P_p - A_p \]  
\[ E_s = E_p * P_m \]

By comparing the actual pulse \((A_p)\) with the planned pulse \((P_p)\), the pulse error \((E_p)\) is known. The path of each pulse \((P_m)\) multiplied by the pulse error can get the path error \((E_s)\). When the path error exceeds the error value, the upper computer sends out instructions to make the X axes and Y axes return to reference and then continue to pick, thus ensuring the picking accuracy.

![Figure 4. Feedback control model design](image)

3.2.2 DC motor circuit design

The DC motor is used to rotate the sucker so that the mushroom rhizome is disconnected from other rhizomes to increase the success rate of harvesting. Through the terminal board EXO port and two relays to achieve the positive and negative reversal of the DC motor, one end of the motor is connected to port 3 (positive) of No. 2 relay and port 6 (negative) of No. 3 relay, and the other end of DC motor is the same principle. When one of the EXO ports is turned on, the relay is turned on, the positive and negative stages are turned on, and the DC motor is turned on. The wiring mode is shown in Figure 5 of the DC motor positive and negative module.
3.2.3 Component circuit design

In addition to the Z axis, each stepper motor requires two limit switches to ensure that the work slipway driven by the motor does not hit the mechanism. Using photoelectric switch as the limit of work slipway, and the corresponding ports are Limit0 to Limit3. Due to the limited space, the Z axis motor only has a positive limit corresponding to the Limit4 port. The wiring is shown in Figure 5.

Each work slipway needs to return to the original point. Considering the efficiency and accuracy of returning to the origin point, first each work slipway returns to the origin at a faster speed of V1. Then when the slipway hits the speed-reducing switch, the slipway moves slowly at speed V2. Finally, when the slider hits the stroke switch, it moves backwards at V2 speed to the origin point. Therefore, each stepper motor needs a speed-reducing switch and stroke switch to enable the work slipway to return to the origin point accurately and quickly. The corresponding ports of the stroke switch are from HOME0 to HOME3, while the corresponding ports of the speed-reducing switch are from EXI1 to EXI4. The wiring is shown in Figure 5.

An emergency stop button is needed. To be safe, when the emergency stop button is pressed, the power supply is cut off not only by hardware, but also by software. The corresponding port is EXI5. The wiring is shown in Figure 5.

4. Experiments

After the experimental test at the mushroom base, the mushroom picking robot reached the expected requirements, as shown in Figure 6. The success rate of picking a single A. bisporus reached 88%, and the success of picking a group of A. bisporus that overlapped and staggered reached 71%.
The camera can photograph a region of A. bisporus continuously, and the picking mechanism can also pick a region of A. bisporus continuously. Multi-threading of C++11 further improves efficiency. The two-step walking mode makes the visual coordinate system and the picking coordinate system coincide completely, which ensures that all A. bisporus can be picked up.

The semi-closed loop design of the stepper motor based on PID algorithm ensures the positioning accuracy of the picking mechanism, so that it can pick A. bisporus quickly and accurately.

Based on the VS platform, QT is used as the interface, which makes it possible to interact with the mushroom picking robot and see the current axis and the machine running in real time. When the mushroom picking robot is not working properly, it can give an alarm in time, and the alarm can be removed artificially through the interface.

5. Conclusions

The control system is designed based on the self-developed A. bisporus picking robot. The parallel control system is designed to implement image processing and A. bisporus picking, which improves the efficiency of robots. The semi-closed loop system based on PID algorithm has effectively solved the phenomenon of step out and overshoot of stepping motor. Therefore, the A. bisporus picking robot based on this control system has high efficiency and smooth operation, which has great commercial value. Furthermore, the future A. bisporus picking robot can further improve the picking efficiency by adding more than one picking mechanism and reduce the volume of the robot when conditions permit.

References

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