



## XVII<sup>th</sup> World Congress of the International Commission of Agricultural and Biosystems Engineering (CIGR)

Hosted by the Canadian Society for Bioengineering (CSBE/SCGAB)  
Québec City, Canada June 13-17, 2010



### DESIGN AND APPLICATION STUDY OF TRANSPLANTING & HARVESTING ROBOT IN PLANT FACTORY

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#### CSBE101682 – Presented at Section III - Equipment Engineering for Plants

**ABSTRACT** Researched and developed a plant factory associated with transplanting & harvesting robot, this device mainly consists of static track, moving track movement device, moving track, mobile trolley device, pneumatic lifting device, pneumatic gripper device, pneumatic protected device and so on, with the application of the transplanting & harvesting robots, there's no need to leave the aisle for the workers between the seedbed, so that it can increase the effectively usage area of the greenhouse, and improve the space utilization.

**Keywords:** Plant factory, transplant, harvest, automatic control, robot

**INTRODUCTION** Plant factory is a high technology industry, which are concentrated reflection of modern biological technology, modern plant technology, computer information technology, machinery and automation technology. The plant factory has been the focus of recent research, because it is little affected by the natural conditions, strong planning on crop production, fast growth rate, short growth period, high automation, no pollution and so on[1].

In the traditional agriculture's production mood, transplant and harvest are always adopted manually operation, but this way is not merely with great labour intensity, low production efficiency, and also it will damage the production frequently because the inadvertently of the operator, which effect the improving of the commodity rate[2]. Whit the development of the auto transplanting & harvesting robot, which can reduce labor intensity, increase production rate, and also there's no need to leave the aisle for the workers between the seedbed, so that it can increase the greenhouse's effectively usage area, and improve the space utilization[3].

#### TRANSPLANTING ROBOT'S STRUCTURE DESIGN

Transplanting & harvesting robot be placed in the greenhouse is used for flowers planting or vegetable seedlings management which are grown in the plug. And it is mainly consisted of static track, moving track movement device, moving track, mobile trolley device, pneumatic lifting device, pneumatic gripper device, pneumatic protected device, moving track movement detection device, mobile trolley detection device and so on.

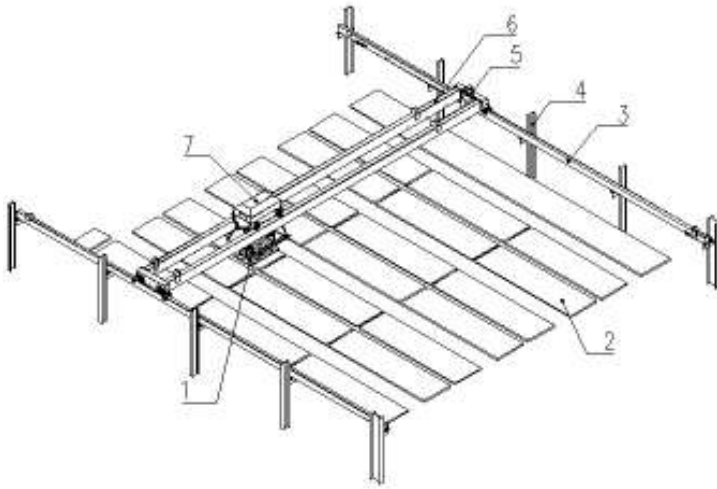


Fig.1 Transplant & harvesting robot's top view

1. Plug 2.seedbed 3. Static track 4.greenhouse doorpost 5.moving track movement device  
6.moving track 7.mobile trolley device

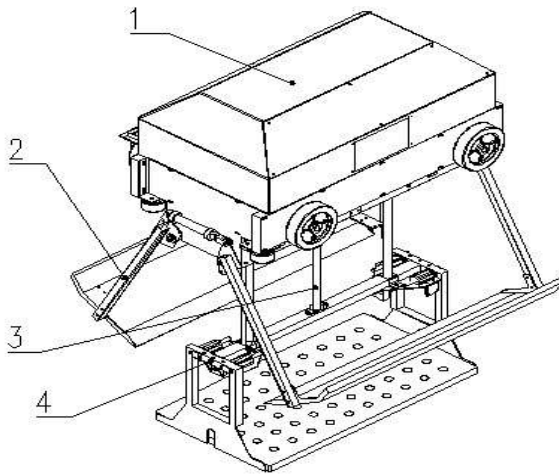


Fig.2 Transplant & harvesting robot's main body

1. Mobile trolley device 2.pneumatic protected device 3.pneumatic lifting device  
4.pneumatic gripper device

Mobile trolley device

Mobile trolley device is the main part of the transplanting & harvesting robot, which have some important components like variable decelerating motor, air combined elements, the damper of mobile detection device and so on. The mobile trolley device is mainly applied to examine the position of the plug, receive the instruction from the control system, and to transplant or harvest according to the instruction.

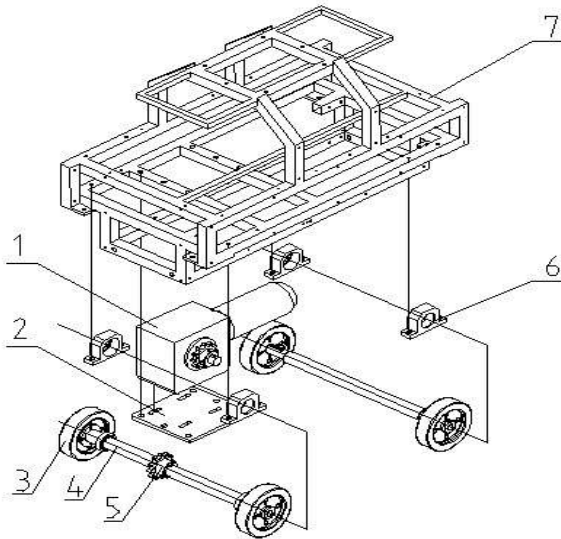


Fig.3 mobile trolley device

1. The turbine & worm variable decelerating motor
- 2.trolley motor base
- 3.φ200 wheel
- 4.trolley driving shaft
5. Sprocket of the trolley's bearing
- 6.trolley bearing supports
- 7.trolley frame

#### Moving track movement device

The transplanting & harvesting robot has realized the auto transportation vertically by the moving track movement device. And the device mainly consists of the vehicle frame of the moving track, driving shaft and driven shaft of the moving track, the turbine & worm variable decelerating motor, NSK bearing, φ200 wheel, the front retaining plate of the moving track, moving track shell, moving track encoder device, assistant wheels of the moving track and so on. Moving track movement device let the motor to make reciprocating movement along the seedbed which is controlled by the frequency converter.

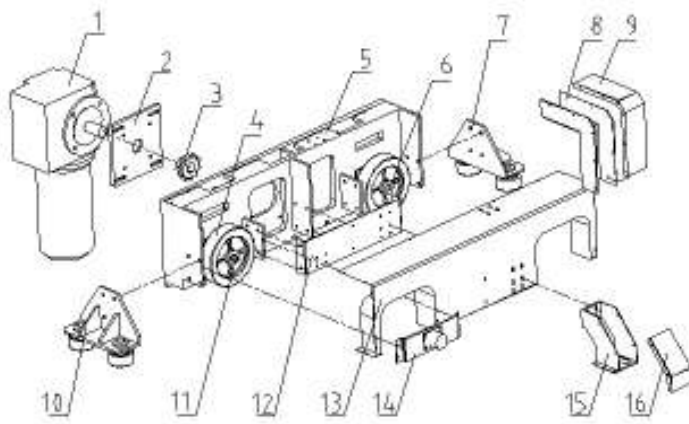


Fig.4 moving track movement device

1.The turbine & worm variable decelerating motor 2.moving track motor base 3.moving track sprocket 4.φ200 wheel 5. The vehicle frame of the moving track 6.driven shaft of the moving track 7.assistant wheels of the moving track 8.moving track trunking 9.cover plate of the moving track trunking 10.assistant wheels of the moving track 11. Driving shaft of the moving track 12.the front retaining plate of the moving track 13.moving track shell 14.moving track encoder device 15.articulated chain stents of the moving track 16.cover plate of the moving track’s articulated chain stents.

### Pneumatic lifting device

The pneumatic lifting device mainly consists of cylinder top retaining plate, lifting cylinder, lifter guide rod, trolley bottom plate, flange linear bearing, lower part of faxed facilities of the lifting cylinder, cylinder rod fixed flange, electromagnetic valve and so on. It is controlled by the electromagnetic valve, let the gripper device achieve vertical movement. When the cylinder drops, the pneumatic gripper open and grasp the plug, then shrink the gripper and rise the cylinder.

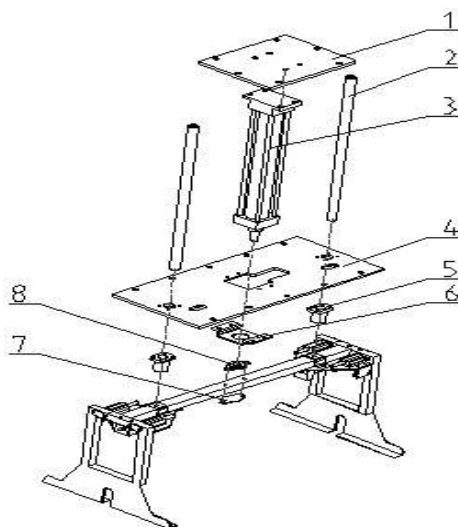


Fig.5 pneumatic lifting device

1.cylinder top retaining plate 2.lifter guide rod 3.Lifting cylinder 4.trolley bottom plate  
5.flange linear bearing 6.lower part of faxed facilities of the lifting cylinder 7.cylinder rod  
fixed flange 8.cylinder rod fixed flange

#### Pneumatic gripper device

The pneumatic gripper device is used for grasping and placing the plug. And it is mainly consisted of the main girder of the pneumatic gripper, gripper, gripper cylinder, cylinder connecting plate, sensor detection device, faxed facilities of the lifting cord guide pillar, linear sliding unit, gripper guide rod, fixed charge method end plate of the guide rod and so on. pneumatic gripper device is controlled by the electromagnetic valve, cylinder control the gripper open and grasp the aperture disk, when the Sensor detection device detect the plug, cylinder control the gripper shrink.

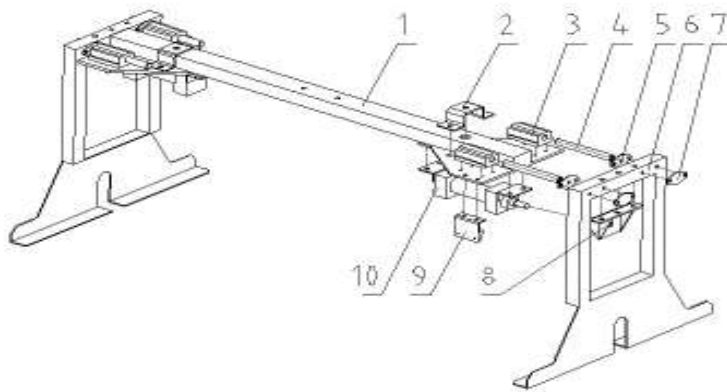


Fig.6 pneumatic gripper device

1.the main girder of the pneumatic gripper 2.faxed facilities of the lifting cord guide pillar  
3.linear sliding unit 4.gripper guide rod 5.guide rod fixed flange 6.gripper 7.guide rod  
fixed flange 8.cylinder connecting plate 9.sensor detection device 10.gripper cylinder

#### Pneumatic protected device

Gripper would be jitter or take place displacement because of the excessive movement, when the transplanting & harvesting robot is working. So we design the pneumatic protected device to avoid this phenomenon. It is mainly consisted of protection bearing, NSK bearing, bearing end plate, protection pole, cylinder, protection bottom plate, damper, damper guide rod, damper guide rod faxed facilities and so on. Pneumatic protected device is to protect the plug to prevent falling when the gripper is moving, after the gripper device grasping the plug and lifting.

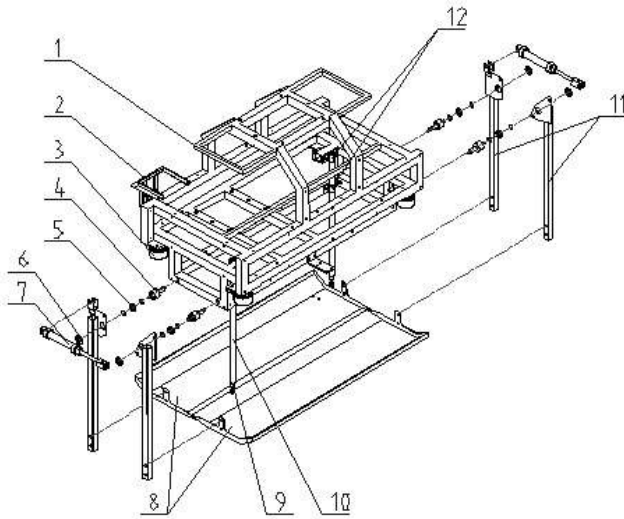


Fig.7 pneumatic protected device

1.trolley frame 2.mobile trolley detection device 3.assistant wheels of the trolley 4.Protection bearing 5.NSK bearing 6.bearing end plate 7.Protection cylinder 8.Protection bottom plate 9.damper 10.Damper guide rod 11.protection pole 12.damper guide rod faxed facilities

#### Transplanting & harvesting robot's operating mechanism

When the staff place the plug on the zero coordinate position of system default and press the start button, the plug transplanting conveying device will move if the detection device detects the plug at the zero position, or suggests no plug. With an example of a signal: Transplanting & harvesting robot drive the sprocket through the turbine & worm variable decelerating motor, then the sprocket drive the  $\Phi 200$  wheels moving to the zero position, the cylinder in the Pneumatic protected device (protective device) shrink, and the pole drive the protection device opening the bottom plate, then the gripper cylinder drive the gripper opening in the pneumatic gripper device, the lifting cylinder drive the pneumatic gripper device falling, and then shrink the gripper after falling in the certain lever. The lifting cylinder would drive the pneumatic gripper device rising if detect the plug, when rising in a certain lever, the protection cylinder open and the pole drive the bottom plate shrinking, then according to the procedure move the trolley to the destination. The moving track movement device's moving is driven by the turbine & worm variable decelerating motor which drive the sprocket, then the sprocket drive the  $\Phi 200$  wheels moving to the vertical coordinate position; and the mobile trolley device's moving is driven by the turbine & worm variable decelerating motor too, which drive the sprocket, then the sprocket drive the trolley's driving shaft let the  $\Phi 200$  wheels move to the lateral coordinate position. The mode which place the plug the same as that grasp the plug, then realize the automatic transmission by repeat the transmission.

#### Transplanting & harvesting robot's automatic detection and control system

The transplanting & harvesting robot's control belongs to the area of intelligent control technology. The software and hardware of the control system have an important influence on the quality and efficiency of the robot's picking. The transplanting & harvesting robot

adopt the PLC control system, through the hardware interface to receive the information from sensor, and then give the directions enable the acting device (stepper motor □ pneumatic device □ gripper) to work after the logic operation, output the corresponding movements on lifting or translational [4].

The hardware components of the system

The hardware of the control system is mainly consisted of PLC controller, encoder, converter, motor, cylinder, electromagnetic valve, photoelectric switch and so on. The whole control system has two control modes, automatic transplant control and automatic harvest control. The control system can control seven rows of the seedbeds from A to G, also can control two or three among them, as shown in Figure 8[5].

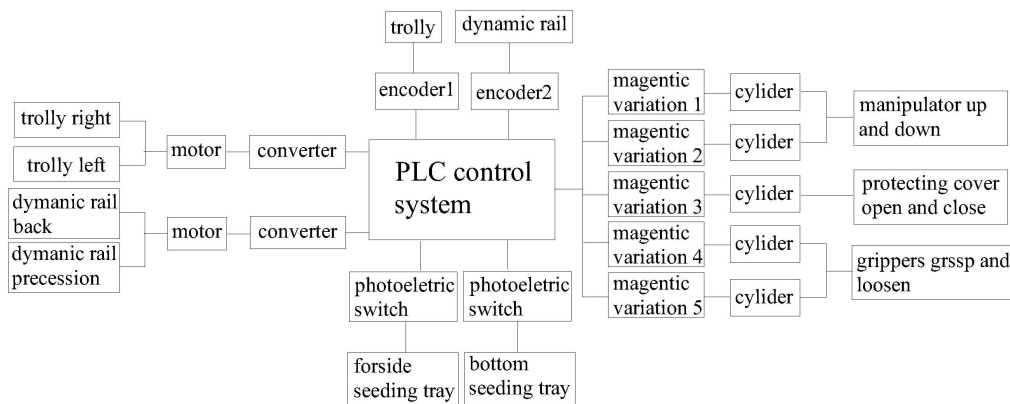


Fig.8 PLC control system

### Automation control process

As shown in Figure 8, DC power supplies the system the main power, which is installed in the control cabinet. The Configuration of the computer is CPU Intel Celeron III/866. PLC controller connected to the computer by the RS-232 serial communication. Electromagnetic valve control the cylinder and silk pole's movement in the X/Y/Z three directions, to realize the manipulator's lifting, gripper's grasping, protecting cover's opening and closing, the position sensor that on the three coordinate axis output the digital signals into the PLC by the digital input terminal[6]. Photoelectric switch control the position of the inferior plug and front end plug. Encoder control the trolley and moving track's movement. Driving stepper motor control the moving track's left-right shifts and trolley's forward and back by the frequency converter.

In addition, this robot has a vision sensor system as safety control system. When the robot is running meet the frontage obstacle, it will transfer the information to the computer by the vision sensor and judged by computer. The robot will follow the instruction to slow down until to stop. Transplanting & harvesting robot can be sure the job position and the speed by the computer system, not only have these advantages like safety, rapid and so on, but also improve the utilization of greenhouse space and work efficiency[7][8].

## CONCLUSION

After the transplanting & harvesting robot application, there's no need to leave the aisle for workers between the seedbeds, and then increase the greenhouse's effectively usage area, improve the space utilization. In addition, transplanting & harvesting robot's operation need 1-2 workers at most, only need to place the plug at the end of the fixed position, then it can be achieved automatically display, and can be sure to place orderly and beautifully. By reducing the number of labor, it will increase the investment costs temporary, but for the long run, it will reduce the cost of labor and employment.

In the agriculture planting system, transplanting and harvesting are the labor-intensive operations which reckoned time-consuming, intensive and high requirement. So, the research of automatic transplanting & harvesting robot in plant factory will enhance the automatic level of protected agriculture in our nation. With the popularity and promotion of protected agriculture high-tech, the plant factory automatic transplanting & harvesting robot's development will toward the directions of automation, intelligent, multifunctional.

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