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Development of Structure and Control System of Self-Propelled Small Green Vegetables Combine Harvester

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ABSTRACT

In order to improve the intelligent mechanized harvesting ability of small green vegetables, a self-propelled small green vegetables intelligent combine harvester was designed according to its planting mode and agronomic requirements. It can simultaneously meet the requirements of mechanized harvesting operations for cutting, clamping and conveying, and collecting of small green vegetables. Additionally, this model adopts the electric drive chassis of the pure electric drive intelligent battery management system based on BMS technology, which realizes the intelligent balance matching of power. The harvester adopts the intelligent control system controlled by PLC to automatically detect the walking speed of the machine, the height of the cutter and the transmission speed, etc., so as to realize the rapid matching of each working part. It was found that the proportion of electricity consumption of the harvester in two hours was 23%, with an average harvesting efficiency of 0.16 hm²/h. Besides, the average loss rate was 4.22% during the normal operation of the harvester. This study provides a reference basis for the intelligent mechanized harvesting of small green vegetables.

Keywords: Electric walking chassis, Human-machine interface, Intelligent control system, Vegetable harvesting, Self-propelled harvester.

INTRODUCTION

Small green vegetables are the vegetable with the most abundant minerals and vitamins, which is native to China and widely cultivated. In recent years, with the rapid development of China's vegetable industry (Liu *et al*., 2021; Shen *et al*., 2022), the contradiction between the growing demand for vegetable products and the shortage of employees, and the high intensity of manual labor has become increasingly prominent (Qiao *et al*., 2017; Zhou *et al*., 2020; Zhang *et al*., 2022). In vegetable production, the mechanization degree of harvesting link is far lower than that of cultivating the land, sowing, transplanting and field management (Sandhu *et al*., 2021), and efficient mechanized harvesting of stem and leaf vegetables is a relatively complex process. At present, harvesting of leafy vegetables in China is mainly done manually. The existing combine harvester of small green vegetables cannot complete the cutting, orderly conveying, sorting, and collection operations at one time efficiently and intelligently, which restricts the further development of the small green vegetables industry (Li *et al*., 2019; Koo *et al*., 2021). Therefore, it is of great significance to design self-propelled small green vegetables combine harvester with good reliability and high versatility (Liu *et al*., 2022). Besides, it is also the direction of intelligent and mechanized harvesting of

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crops in the future (Du *et al*., 2019; Li *et al*., 2016; Fu *et al*., 2018).

Developed countries have relatively mature technologies for intelligent vegetable harvesting machinery (Kultongkham *et al*., 2021; Na *et al*., 2020; Wang *et al*., 2022). Many advanced control technologies, such as autonomous navigation systems, robot harvesting technology, and 3D sensor technology (Liu *et al*., 2018; Gonzalez-de-Santos *et al*., 2020), have been integrated into the vegetable harvester, which makes the mechanical harvesting develop in the direction of intelligence (Zhang *et al*., 2020). Leu *et al.* (2017) developed an intelligent asparagus harvester. The visual perception module based on 3D point cloud processing to detect the asparagus straw in the harvest period was used, which could harvest asparagus quickly and stably and adapt to a variety of operating environments. García-Manso *et al.* (2021) proposed a vision system method based on deep learning technology, which can locate and classify broccoli heads based on its state of maturity. However, the cost of machines and tools in developed countries is high and it is also difficult to adapt to the growth and harvest mode of leaf vegetables in China. Besides, it has strict agronomic requirements. Therefore, the machines and tools in developed countries are not suitable for large-scale promotion in China.

In order to reduce the intensity of manual labor and realize orderly mechanized harvest, a self-propelled intelligent combine harvester for small green vegetables was designed according to the planting mode and agronomic requirements of small green vegetables in this study. The machine can match the working speed of each component automatically through the intelligent control system controlled by PLC. Besides, it also can detect the walking speed, cutter height, cutting speed, and conveyor belt speed in real time, and adjust the distance between cutter and ridge surface adaptively to complete harvest intelligently and orderly.

MATERIALS AND METHODS

Structure and Technical Parameters of the Machine

Planting Mode and Agronomic Requirements of Small Green Vegetables

There are various varieties of small green vegetables in China, among which "Chinese little greens" is the most common variety. This paper focuses on the harvest of "Chinese little greens ". At present, small green vegetables are mostly planted in the greenhouse by ridge cultivation, and their growth is shown in Figures 1 and 2.

The planting dimensions of small green vegetables are as follows: The plant spacing of small green vegetables is 100~150 mm, width of the normal vegetable ridge is 850~900 mm, and the ridge height is 80~120 mm. The upper and lower parts of the ridge and ditch width are 120~150 mm and 250~300 mm, respectively. The center distance of the ridge and ditch is about 1200 mm. The flatness in the width direction of the ridge surface is less than or equal to 15 mm. The parallelism between the ridge

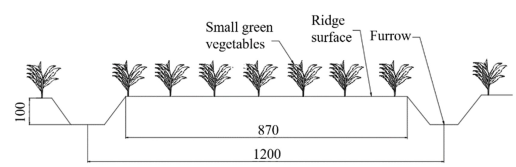

Figure 1. Schematic diagram of planting mode of small green vegetables.

Figure 2. Small green vegetables planted in the field during harvest.

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surface and the bottom surface of the furrow is less than or equal to 12 mm. By the harvest time, the total length of small green vegetable plants is about 150~200 mm.

Structure and Working Principle of the Whole Machine

A self-propelled electric intelligent small green vegetables harvester was designed according to the planting mode and agronomic requirements of "Chinese little greens". It mainly includes header adaptive adjustment device, hydraulic lifting device, self-propelled chassis, intelligent control system, lithium battery power supply system, orderly harvesting header combination, and so on. The self-propelled electric intelligent small green vegetables harvester can complete quickly and efficiently the operations of cutting, clamping, conveying, sorting, and collecting of small green vegetables. Its basic structure is shown in Figure 3.

During harvesting, the electric harvester cuts off the stalks by the reciprocating cutter device, and the cut vegetables are lifted to the collection box by clamping and conveying to complete the fast and intelligent combined harvesting. Additionally, the intelligent control system can intelligently adjust the height of the cutter and complete the automatic matching of the rotational speed of key working parts. The technical parameters of small green vegetables combine harvester are shown in Table 1.

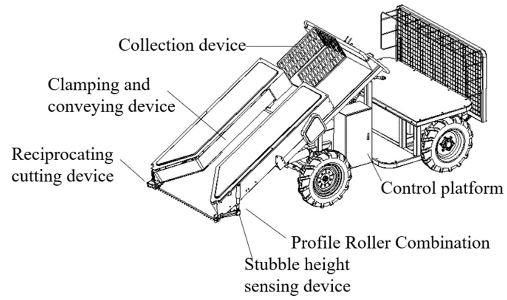

Figure 3. Structure diagram of self-propelled small green vegetables harvester.

Table 1. Technical parameters of small green vegetables combine harvester.

Serial number	Parameter	Numerical value
1	Machine dimensions size (Length×Width×Height)	3100×1350×1400 mm
2	Forward speed	0~2 m s^{-1}
3	Total weight	≤600 kg
4	Operation walking speed	0.2~0.6 m s^{-1}
5	Actual stroke of oil cylinder	≥ 217 mm
6	Maximum lifting height of the header	≥ 500 mm
7	Electric push rod stroke	100 mm
8	Maximum steering angle	40°
9	Minimum turning radius	≤ 3500 mm
10	Road braking distance	1500 mm
11	Cutting width	900 mm
12	Cutter driving motor speed	1500 rpm
13	Reciprocating cutting frequency	30~50 Hz
14	Reciprocating cutting motor speed	3000 rpm
15	Header side longitudinal conveying speed	0.1~0.6 rpm
16	Side longitudinal conveying motor speed	3000 rpm

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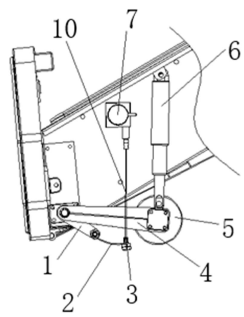
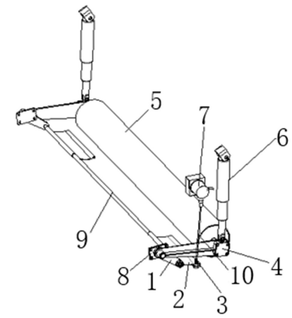


(a) Structure diagram of stubble height sensing device



(b) Profile structure diagram of ridge surface

Figure 4. The structure of header self-adaptive adjustment device. **Note:** 1. The support arm of sensing plate; 2. Stubble sensing plate; 3. Rope buckle; 4. The support arm of profiling roll; 5. Profiling roll; 6. Electric push rod; 7. Pull rope displacement sensor; 8. The fixed support of sensing plate; 9. The connecting rod of sensing plate; 10. Pull rope.

Design of Key Components and Parameters

Design of Header Self-Adaptive Adjustment Device

In order to realize the self-adaptive adjustment of the height of the header, a ridge surface profiling structure was adopted. During the cutting operation, the sensing plate collects the height of the stubble of the vegetables and feeds it back to the control box through the displacement sensor to control the up-and-down movement of the electric push rod. Therefore, the harvester can adjust the distance between the cutter and the ridge surface adaptively according to the corresponding stubble height. The structure of the header self-adaptive adjustment device is shown in Figure 4.

To enable the header to adapt to the normal ridge width of small green vegetables planted in the greenhouse and to increase the cutting width as much as possible to improve the harvesting

Table 2. Estimation of profiling roll diameter.

Serial number	Diameter of profiling roll (mm)	Subsidence depth (mm)	Grounding width of profiling roll (mm)	Grounding length of profiling roll (mm)	Grounding area of profiling roll (cm^2)	Soil pressure (kPa)
1	60	3	26.15	900	235.35	29.74
2		6	36.00		324.00	21.60
3		10	44.72		402.48	17.39
4		15	51.96		467.64	14.97
5	80	3	30.40	900	273.60	25.58
6		6	42.14		379.26	18.46
7		10	52.92		476.28	14.70
8		15	62.45		562.05	12.45
9	100	3	34.12	900	307.08	22.80
10		6	47.50		427.50	16.37
11		10	60.00		540.00	12.96
12		15	71.41		642.69	10.89

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efficiency, the length of the profiling roller selected in this design is 900 mm. At the same time, the diameter of the profiling roll in the ridge surface profiling structure is the key to the design. The total mass of the header is 106 kg, and the profiling roller is arranged in its center, accounting for about 65% of the total mass. In the case of normal soil moisture, the pressure bearing capacity of the ridge surface of soft vegetables is 0.25~0.75 kg cm^{-2}. Besides, the grounding width, grounding area and soil bearing pressure of the profiling roller under different diameters and different subsidence depths were calculated, respectively, and the specific results obtained are shown in Table 2.

After calculation, the final choice was made of the profiling roll with a diameter of 100 mm. The bearing pressure of the soil and the harm caused by the compaction of the soil during the harvesting process can be reduced by appropriately increasing the grounding width and area.

Design of Chassis Drive System

The electric drive chassis of the intelligent battery management system was adopted based on BMS (Battery Management System) technology. It can realize the intelligent balance and matching of harvester power. The chassis power system is mainly composed of a power supply system, electric drive system, and auxiliary system. At present, the driving arrangement of pure electric chassis mainly includes motor central drive and electric wheel drive, which can be divided into six types, as shown in Figure 5.

The central drive arrangement of the motor is shown in Figure 5. It can be divided into axis vertical type, axis parallel type, and coaxial type according to the position relationship between the power input and output of the motor. The vertical type with transmission and the vertical type without transmission are shown in Figures 5-b and -c, respectively. Since the motor and transmission shaft take up too much chassis space and the lithium battery cannot be arranged, these two arrangements were not adopted. The electric wheel drive with speed reducer and electric wheel drive without speed reducer are shown in Figures 5-e and -f, respectively. The traditional mechanical ordinary differential in these two types was canceled, and the differential adjustment when turning was completed by independently controlling the torque of the

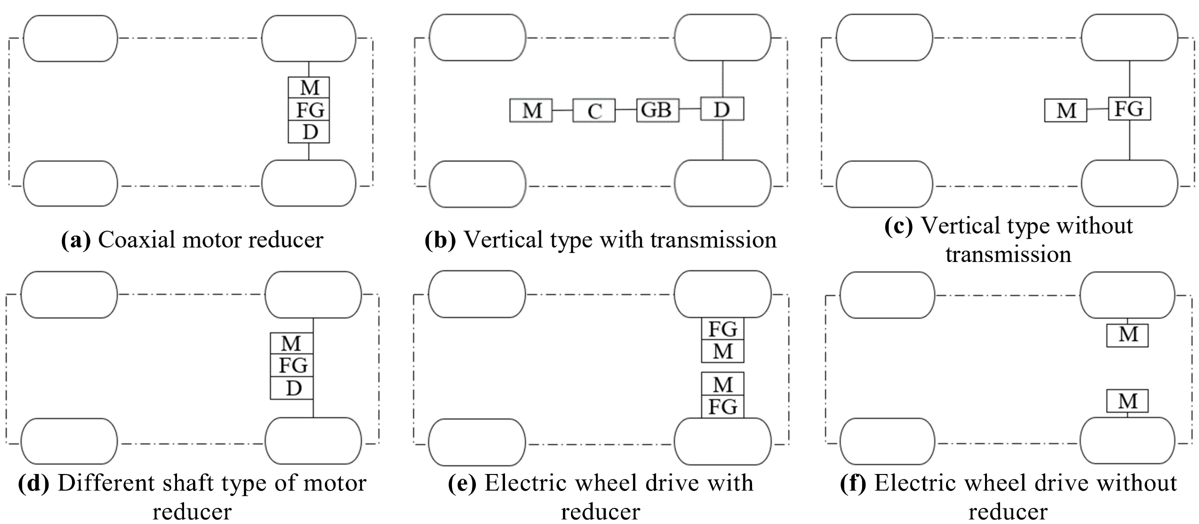

Figure 5. Driving structure of pure electric chassis. **Note:** C is the Clutch, M is the Motor, D is the Differential, GB is the transmission, and FG is the Fixed ratio reducer.

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two wheels. However, the key technical reliability of the relevant electronic control is not enough.

The driving structure design of the electric chassis is carried out by using the coaxial motor reducer in this study, which is shown in Figure 5 (a). The electric motor, fixed reduction ratio reducer, and differential are formed as a whole, which is coaxially arranged at the bottom of the harvester. Therefore, less space was taken up than other structures by using a coaxial motor reducer, and the quality of the whole machine was reduced effectively.

Additionally, the electric motor is the core power unit of the whole machine in the pure electric chassis structure. Therefore, the selection of an appropriate motor is helpful to improve the efficiency of power transmission and the power performance of the whole machine. This design selected a permanent magnet brushless motor with a rated voltage of 48V, a rated power of 2,000W and a rated speed of 3,000 rpm, which can meet the torque requirements of the electric chassis at low speeds and power requirements at high speeds. At the same time, the selected controller adopts high-power MOSFET high-frequency design, which can output a large starting current and provide a strict battery current limit. Therefore, it can provide good acceleration and climbing ability when working under the relatively small output current conditions.

According to the above analysis, the corresponding accessories were selected, and the size and shape were determined. The schematic diagram of the chassis structure of the whole machine is shown in Figure 6.

In this design, the lifting of the header is realized by two hydraulic cylinders, so that the header lifting mechanism can adjust the height of the header accurately and quickly. The technical parameters of the header lifting cylinder are shown in Table 3.

Intelligent Control System and Program Design

In order to improve the reliability and response speed of the control system, we reduced the signal processing time as much as possible, and realized the rapid matching of each working part. The intelligent control system of this design adopts PLC control, mainly including programmable controller, touch screen, ultrasonic sensor, photoelectric encoder, DC motor, and other components. The hardware structure of the system is shown in Figure 7.

The PLC adopted the XDC-24T-C programmable controller of Wuxi XinJe Electric Co., Ltd., with DC 24V working voltage and 24 IO interfaces, which has ultra-high processing speed and enhanced signal processing ability. It can connect up to 16 expansion modules, and it has an internal self-contained PID. Additionally, it

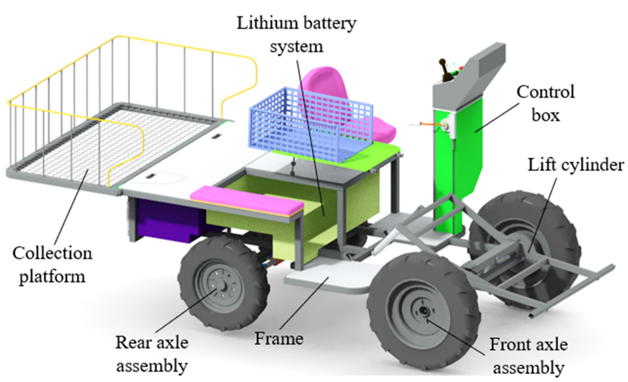

Figure 6. Schematic diagram of the walking chassis structure.

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Table 3. Technical parameters of header lifting cylinder.

Serial number	Project	Numerical value
1	Header lift cylinder	2
2	Minimum thrust of piston rod	578 kgf
3	Single cylinder piston rod thrust	350 kgf
4	Cylinder inner diameter	63 mm
5	Piston rod diameter	35 mm
6	Piston rod length	252 mm
7	Outer diameter of cylinder sleeve	73 mm
8	Cylinder sleeve length	265 mm
9	Top dead center hinge joint length	625 mm
10	Bottom dead center hinge joint length	415 mm

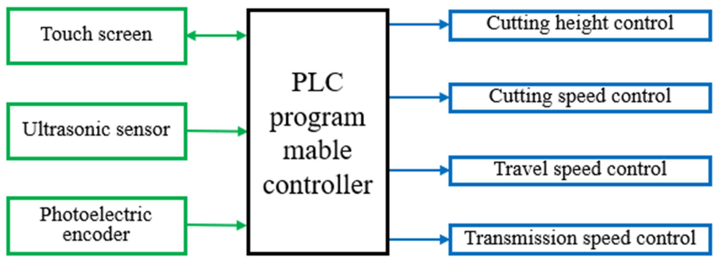

Figure 7. Hardware structure of the system.

is equipped with an A/D conversion module model XD-E4AD2DA to realize analog signal input. The man-machine interface adopted the TG765S-XT touch screen. Therefore, people can communicate with PLC through the Modbus protocol, which can realize the interaction between PLC controller and operator.

The height measurement part of the cutter adopts LM-112-010-DAC ultrasonic distance measuring sensor. The working principle is to convert the emitted acoustic signal into an electrical signal that can be received by 0~10 V, and use rays to form directional propagation. The time of the height signal reduces the time delay and enables the control commands issued by the system to be responded and executed faster. At the same time, in order to reduce the measurement blind area, its position should be installed above the cutter, and its height from the ground can be calculated by the Equation (1):

$$h = \frac{vt}{2} - h_0 \quad (1)$$

Where, h is the height of the cutter in m; v is the propagation speed of the ultrasonic wave in the air in m/s; t is the propagation time of the ultrasonic wave in the air in s; h_0 is the installation height of the ultrasonic sensor in m.

The height of the cutter can be adjusted within the range of 5~200 mm according to different harvest requirements. During operation, the system can adjust the cutter height of the harvester automatically through the electric push rod according to the preset stubble height. The parameters of the electric push rod are as follows: The maximum thrust of the electric push rod is 150 kgf, speed is 10~35 mm/s, and stroke of the push rod is 0~300 mm.

The control system of the harvester adopts 2500-line incremental photoelectric encoder to realize the measurement of walking speed, the cutting speed of the cutter and the speed of the conveyor belt. The system directly inputs the output pulse signal obtained by the encoder rotation measurement into the PLC controller and counts the pulse signal with the high-speed counter of PLC to obtain the measurement result. The actuator adopts a DC reduction motor and is equipped with a corresponding

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BLD series driver. The parameters of the reduction motor are shown in Table 4.

The PLC controller is used to set the height of the cutter and the speed ratio of each part according to the different planting methods and user needs. The control system detects the operating parameters of the working parts in real time during the harvesting operation, and automatically realizes the rapid matching control of the working speed of each part according to the forward speed and speed ratio parameters of the harvester. The main program control of the system is shown in Figure 8.

The system subroutine mainly realized the control of stubble height, cutter cutting speed, and conveying speed. Additionally, the PID controller was used in the program, which was mainly composed of Proportional unit (P), Integral unit (I), and Differential unit (D). Its control principle is shown in Figure 9. Among them: r(t) is the input signal; y(t) is the output signal of the controlled object; e(t) is the deviation signal of the r(t) and y(t), regarded as the input signal of the PID controller. The PID output signal δ(t) can be expressed by Equation (2):

$$\delta(t) = k_p \mathrm{e}(t) + k_i \int_0^t e(\tau)\,\mathrm{d}\tau + k_d \frac{\mathrm{de}(t)}{\mathrm{d}(t)} = K_p \left[\mathrm{e}(t) + \frac{1}{T_i} T_i \int_0^t e(\tau)\,\mathrm{d}\tau + T_d \frac{\mathrm{de}(t)}{\mathrm{d}(t)}\right] \quad (2)$$

Where, k_p is the proportional coefficient; k_i is the integral term coefficient; k_d is the differential term coefficient, T_i is the integral time constant, T_d is the differential time constant, and $e(t)$ is the deviation between the measured value and the set value.

There are three main steps for the adjustment and control of the traveling speed of the whole machine. In the speed control subroutine, firstly, the matching speed values of two controlled objects i.e. cutting speed and transmission speed, were set according to the measured value of walking speed. Secondly, two speed parameters were detected in real time, and the difference between the measured value and the set value was calculated to obtain

Table 4. Motor power parameters.

Serial number	Motor name	Voltage (V)	Power (W)	Reduction ratio
1	Travel motor	48	2000	20 : 1
2	Cutter motor	48	300	15 : 1
3	Conveyor belt motor	48	200	10 : 1

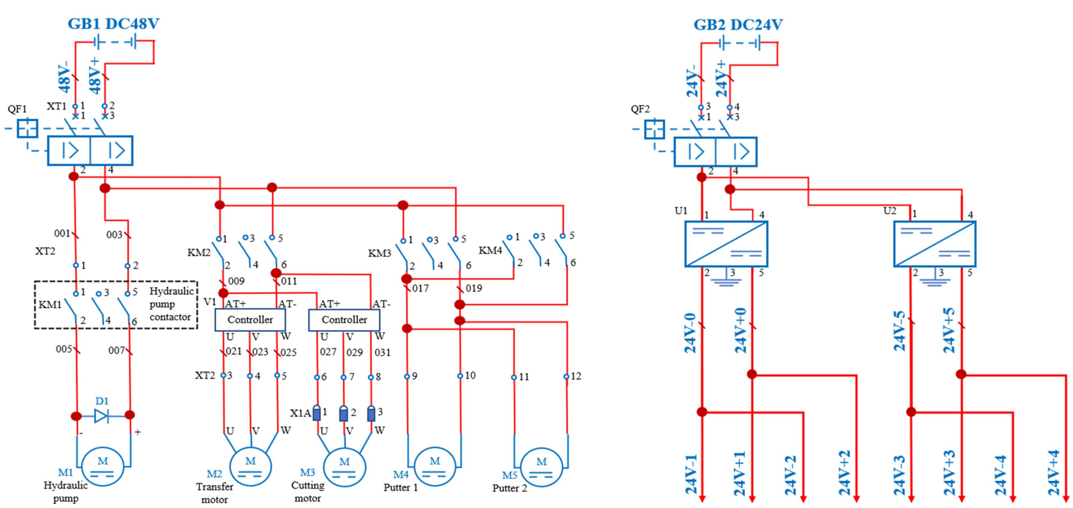

Figure 8. Main program control diagram of the system.

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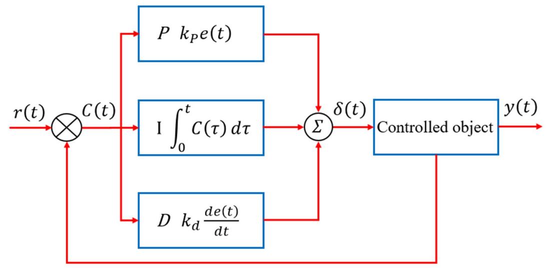


Figure 9. Schematic diagram of system subroutine control.

the deviation signal of each speed. Finally, the control signal was obtained through the PID algorithm, then, the motor driver controlled the speed of each motor to realize the fast and accurate adjustment of the cutting speed of the cutter and transmission speed. The flow chart of the speed control subroutine is shown in Figure 10 (b).

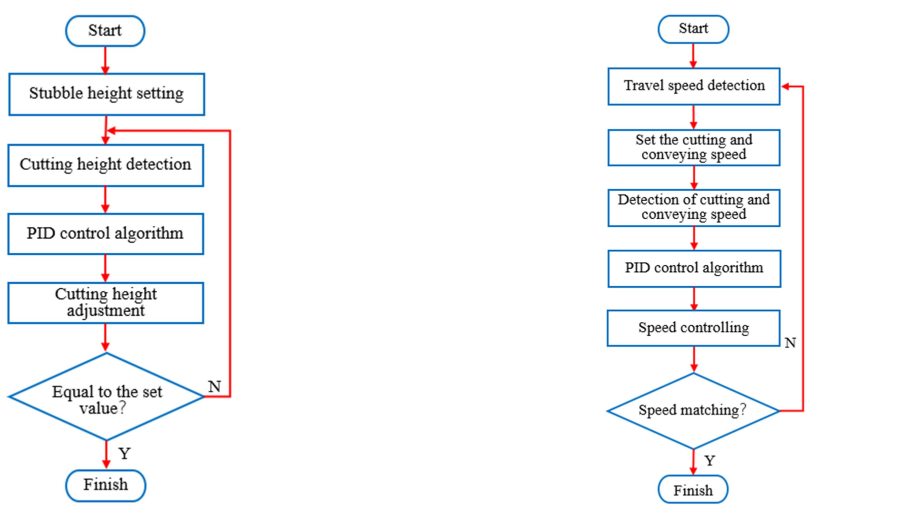
RESULTS AND DISCUSSION

Small Green Vegetables Combine Harvester and Man-Machine Interface

The human-machine interface is an interface that realizes the interaction between the PLC and the operator. It can convey the operator's control intention conveniently, and then the PLC accepts and executes the corresponding instructions. It mainly includes data display, parameter setting, start and stop buttons, indicator lights, and other components. The corresponding input buttons, input boxes and display boxes are shown in Figure 11. During the harvester working, users can set relevant parameters freely according to their needs through the setting boxes of speed and height, and the system will automatically display the measured data on the touch screen interface.

Performance Testing of the Whole Machine

Based on theoretical analysis, this paper firstly selected the purchased parts and



(a) Flow chart of height control subroutine **(b)** Flow chart of speed control subroutine

Figure 10. Flow chart of program control.

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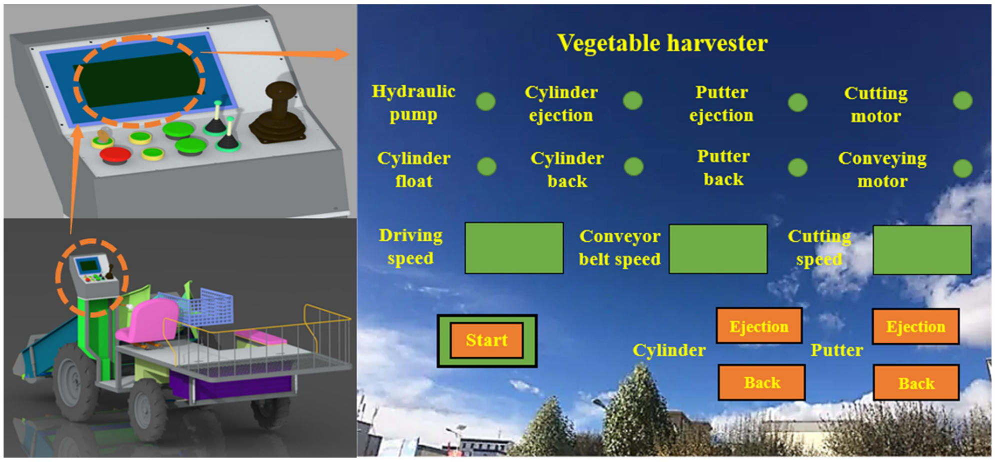

Figure 11. Human-machine interface of vegetable harvester.

standard parts such as the rear axle, conveying motor, electric push rod, and so on. Secondly, a three-dimensional model of the whole machine was drawn by Creo software. Finally, the machined parts were delivered to Wuxi Yuetian Agricultural Technology Co., Ltd. for processing and debugging after drawing and reviewing. The processing of the prototype, prototype, and function display of the prototype are shown respectively in Figure 12.

In order to test the energy consumption, instantaneous current and motor heating of the harvester under no-load and normal operation, the energy consumption and motor heat generation of the harvester during normal operation for 2 hours were tested. The results of the test every 15 minutes are shown in Tables 5 and 6, respectively. Besides, the instantaneous current situation under various working conditions is shown in Table 7, and the parameters of the oil cylinder and electric push-pull rod are shown in Table 8.

It can be seen from Table 5 that the proportion of electricity consumed by the prototype for two hours of normal operation is 23%, which means the control of power consumption is very good. Also, it can be seen from Tables 6, 7, and 8 that the prototype can well meet the electrical energy demand under various working conditions, and the heat generation of the motor is controlled well. Additionally, the strokes of the oil cylinder and the electric push-pull rod fully meet the needs of the header in harvesting operations.

(a) Processing process **(b)** Prototype **(c)** Function display

Figure 12. Prototype of self-propelled intelligent small green vegetables combine harvester.

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Table 5. Power consumption parameters.

Project	Time	15min	30min	45min	60min	75min	90min	105min	120min
Start End	14:30 16:30	93%	91%	88%	86%	84%	81%	79%	77%

Table 6. Motor heating parameters.

Measurement object	15 min	30 min	45 min	60 min	75 min	90 min	105 min	120 min
Chassis drive motor (℃)	34	40	43	47	49	52	53	54
Conveying motor (℃)	40	48	51	51	52	50	50	51
Cutting motor (℃)	52	61	65	65	64	62	63	62

Table 7. Current variation parameters.

Project	Current value A_1	Current value A_2	Current value A_3	Average value A
Stop state (Ah)	0	0	0	0
Starting state (Ah)	7.4	6.6	8.4	7.47
Accelerating state (Ah)	64.9	45.6	60.3	56.9
Conveyor start (Ah)	3.6	3.8	3.4	3.6
Cutter start (Ah)	6.5	5.7	6.3	6.2
Hydraulic start (Ah)	93.5	93.2	90.0	92.2
Full speed (Ah)	26.2	21.7	27.6	25.2

Table 8. Parameters of oil cylinder and electric push-pull rod.

Measurement object	Distance (mm)	Rise time (s)	Lifting speed (mm s^{-1})	Descent speed (mm s^{-1})
Lift cylinder	207	7.78	26.60	25.37
Electric putter	100	22.40	4.46	4.52

Harvest Experiment of Small Green Vegetables in the Field

The field harvesting performance test of the prototype was carried out by taking the Chinese little greens grown in the greenhouse during the harvest period as the test object. In addition, it should be noted that the terrain in the facility greenhouse is flat and the relevant parameters of the greenhouse are as follows: The width of the shed door is 2 m, height of the shed door is 1.95 m, width of the headland is 1.1 m, width of the ridge is 870 mm, height of the ridge is 100 mm, width of the lower ridge is 130 mm, The width of the upper ridge is 280 mm, and center distance of the ridge is 1,200 mm. The test instruments include tape measure, toolbox, electronic scale, etc. The natural growth, prototype structure and field harvest performance test of the whole machine are shown in Figure 13.

In this experiment, firstly, a ridge of small green vegetables was selected randomly in the greenhouse. Then, the length of the test area was established as 40 m, and a measurement area was drawn every 10 m. Additionally, considering that the harvester was unstable at the beginning of work, the experimental data such as the weight of collected vegetables and the weight of residual and dropped vegetables were recorded in the last three survey areas. As a result, the harvesting efficiency and operation loss rate obtained by recording the

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(a) Appearance of small green vegetables to be harvested

(b) Harvesting process and effects

(c) Structure diagram of intelligent harvester prototype

Figure 13. Harvest performance test of small green vegetables in the field.

test results and calculations are shown in Table 9.

As shown in Table 9, the average loss rate of small green vegetables harvested is 4.22% and the machine can harvest 0.16 hectares of small green vegetables per hour. Therefore, the self-propelled intelligent vegetables harvester can reduce the intensity of manual work and improve the harvest quality and efficiency. Additionally, it can be concluded that the intelligent control system adopted in this design realizes the self-adaptive matching of cutter height, walking speed and conveying speed, and the cooperation of header self-adaptive device and reciprocating cutter effectively ensures the accuracy of cutting height and the improvement of the cutting.

CONCLUSIONS

Starting from the planting mode of small green vegetables, a self-propelled intelligent vegetables harvester was designed. The header adopts a profiling roller with a diameter of 100 mm and a grounding length of 900 mm, which can reduce the pressure of the soil while ensuring efficient cutting operations. At the same time, the header lifting mechanism composed of two hydraulic cylinders is used to precisely and quickly adjust the height of the header. In addition, the chassis adopts the pure electric drive of the intelligent battery management system based on BMS technology, which realizes the intelligent balance matching of power. Through the PLC control system, the fast-matching response of each working part

Table 9. Measurement table of harvest efficiency and operation loss rate.

Serial number	Project	Test results			Average value	Variance
		1	2	3		
1	Test time (s)	62.5	59.1	60.9	60.8	1.930000
2	Harvest efficiency (hm^2/h)	0.156	0.165	0.159	0.16	0.000014
3	Weight of Collected vegetables (kg)	26.46	26.25	26.85	26.52	0.061800
4	Weight of residual and dropped vegetables (kg)	1.29	1.15	1.08	1.17	0.007633
5	Loss rate (%)	4.60	4.19	3.87	4.22	0.089267

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is completed, which improves the speed of signal processing. The operator can define relevant parameters through the human-computer interface to adapt to different harvesting needs.

The prototype was tested for performance and field harvesting tests, and the power consumption and motor heating were good. Additionally, the intelligent control system operated normally, and the rotational speed of each working part can be optimally adapted. This study also tested the relevant parameters of the harvester under normal operation and found that the average harvesting efficiency was 0.16 ha/h and the average loss rate was 4.22%. Besides, the proportion of electricity consumption of the harvester in two hours was only 23%. Therefore, the self-propelled intelligent combine harvester for small green vegetables improves the harvesting efficiency and quality of small green vegetables, and fully meets the harvesting standards of these products.

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ایجاد ساختار و سامانه کنترل کمباین خودرو برای یک سبزی کوچک سبز

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چکیده

به منظور بهبود برداشت مکانیزه و هوشمند سبزیجات سبز کوچک، یک دستگاه کمباین خودرو برای یک سبزی کوچک با توجه به روش کاشت و نیازهای زراعی آن طراحی شد. چنین وسیله‌ای می تواند به طور همزمان نیازهای عملیات برداشت مکانیزه برای برش، بستن و انتقال و جمع آوری سبزیجات سبز کوچک را تامین کند. علاوه بر این، این مدل از شاسی درایو الکتریکی(electric drive chassis) سامانه مدیریت باتری هوشمند مبتنی بر فناوری BMS استفاده می کند که تطبیق تعادل هوشمند(intelligent balance matching) نیرو را محقق می سازد. این دروگر سامانه کنترل هوشمند کنترل شده توسط PLC را برای تشخیص خودکار سرعت حرکت دستگاه، ارتفاع وسیله برش و سرعت انتقال (transmission speed) و غیره را به‌کار می گیرد تا تطابق سریع هر قسمت کار را تحقق بخشد. نتایج نشان داد که نسبت مصرف برق ماشین برداشت در دو ساعت ۲۳% با میانگین راندمان برداشت ۰.۱۶ هکتار در ساعت بود. همچنین، میانگین نرخ تلفات در طول کارکرد معمولی دروگر ۴/۲۲% بود. این پژوهش یک مبنای مرجع برای برداشت مکانیزه هوشمند سبزیجات سبز کوچک فراهم می کند.

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