Design of Intelligent Recognition System for Orchard Spraying Robot Path Based on Adaptive Genetic Algorithm

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Abstract. The problem of excessive pesticide spraying in orchards has caused a great risk of food safety. Because the traditional fueljet robot path recognition system has the problem of low path recognition accuracy, an adaptive genetic algorithm based orchard spray robot path intelligent recognition system is designed to improve the path recognition accuracy. Firstly, the hardware design of the path intelligent identification system is carried out, including the power supply module, the main control board module, the path identification module, the motor drive module and the wireless communication module. Through the division of these modules, the path intelligent identification of the orchard spray robot is realized. Then the design of the path intelligent identification system software system is adopted, and KEIL uVision4 is used as the development environment. The adaptive genetic algorithm is used to accurately identify the path and determine the path control scheme and direction adjustment scheme to improve the path recognition accuracy. Finally, the simulation experiment is compared with the traditional spray robot path recognition system. The intelligent recognition system of orchard spray robot based on adaptive genetic algorithm has higher path recognition accuracy and shorter recognition time.

Keywords: Adaptive genetic algorithm · Orchard spray robot · Intelligent path recognition system

1 Introduction

In the one-year key areas of the national medium- and long-term science and technology development plan and its priority themes, the development of agriculture requires the precise operation and informationization of agriculture [1]. At the “Digital Agriculture” Construction Strategy Seminar, the Ministry of Science and Technology proposed to implement the implementation of digital agricultural science and technology action with “precision agriculture” and “smart agriculture” as the entry point [2]. It can be seen that the implementation of precision agriculture, the widespread application of intelligent agricultural machinery, and the improvement of resource utilization and economic benefits will be the inevitable trend of agricultural development in this century [3]. Due to the long period of biological control and ecological

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control, weeds and pests and diseases in China's agriculture are still controlled mainly by chemical control [4]. China's pesticide and fertilizer production and application volume rank first in the world. The use per unit area is 2.6 times that of the United States, but the utilization rate of pesticides is only about 30%, the utilization rate of nitrogen fertilizer is only 30% to 35%, the utilization rate of phosphate fertilizer is only 10% to 20%, and the utilization rate of potassium fertilizer is only 35% to 50%. The long-term use and low utilization rate of chemical pesticides have brought serious ecological and agricultural product safety problems such as environmental pollution, chemical pesticide residue exceeding standards and weed resistance. In particular, the problem of excessive pesticide spraying in orchards has caused a great risk of fruit eating safety [5]. Therefore, based on the adaptive genetic algorithm, the path intelligent recognition system is designed for the orchard spraying robot. The orchard spraying robot uses vision sensor instead of human eye to acquire the video information of surrounding environment and convert it into data matrix. The computer replaces human brain to process and analyze the image in software and hardware, so as to realize the task of precise spraying fixed-point variable [6].

2 Hardware Design of Path Intelligent Identification System

2.1 Hardware System Framework Design

The intelligent identification system of the orchard spray robot path uses the idea of modular design in hardware system design. Each part is designed to be controlled by a special structure. The hardware system framework of the orchard spray robot path intelligent identification system is shown in Fig. 1.

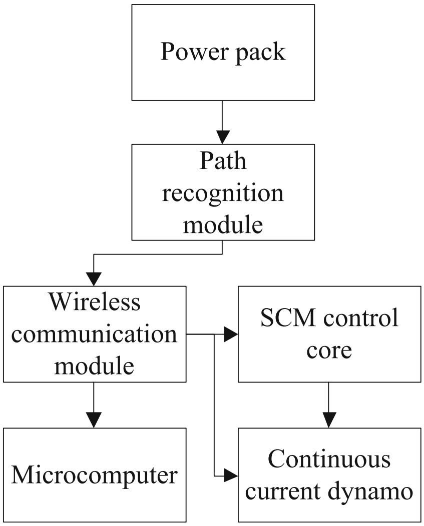


Fig. 1. Orchard spray robot path intelligent identification system hardware system framework

2.2 Power Supply Module

In the power supply module, each hardware component requires a different voltage to drive, and three different supply voltages need to be provided from the power distribution. The power supply is supplied to the main control board and signal processing board respectively, and the motor driving part is used to drive various motors in the intelligent path recognition system of orchard spraying robot. At the same time, for the anti-interference needs, the grounding pole of the battery should be designed separately.

2.3 Main Control Board Module

In the control circuit, the STC12C5A60S2 single-chip microcomputer is selected as the core to form the main control board circuit, which is used to complete the signal processing and control functions of the intelligent identification system of the entire orchard spray robot path. In terms of output, it can complete two types of adjustable speed motor control output and non-speed control, which can control the control of two drive wheel DC geared motors; at the same time, it has an expandable port to facilitate later function expansion. The series of single-chip microcomputers support the program mutual transmission function and provide the basic support for the improvement of the running performance of the Orchard Spraying Robot Path Intelligent Recognition System. The main control board uses a 40-pin MCU with a total of 35 I/O interfaces. Among them, PO, P2 and P4.6 are used for input, a total of 17 ports, P1 and P3 are signals. The output part will be used for device control in the future. The main control circuit board has power input and power output interface, and provides voltage to circuit sensor circuit board of orchard spraying robot path intelligent recognition system through external power part. The start switch is used to control the circuit start of the main control board. The post-program download port is used to download and input the preset program of the orchard spray robot path intelligent recognition system. The signal flow chart of the main control board is shown in Fig. 2.

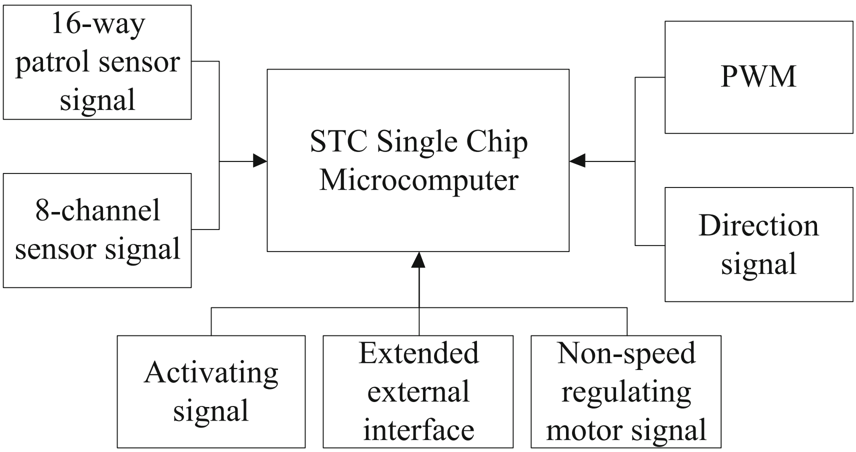


Fig. 2. Signal flow chart of the main control board

The line sensor input interface is mainly used to receive the road line sensor signal. In order to reduce the occupation of the MCU port, two 74HC245 bus driver circuits are used to form the multiplexing of the P2 port of the MCU, and the signal of the P4.4 port of the MCU is used for control. When P4.4 is low, the P2 port receives the low 8-bit signal QQQ-QQ7 of the 16-channel sensor. When P4.4 is high, the P2 port receives the high 8-bit signal of the 16-channel sensor QQ8-QQ15. The 8-channel sensor input interface can be used to connect optoelectronic, proximity or ultrasonic sensors. It can make the Orchard Spray Robot Path Intelligent Recognition System make full use of various sensors to detect external information to determine the distance from the target. The 4-channel sensor input interface uses the P0.0-P0.3 port of the single-chip microcomputer, and the socket J8-J11 is connected to 4 different sensors. The maximum detection distance is 30 cm, 1 m, 2 m depending on the model used. On the intelligent recognition system of orchard spray robot path, proximity switches are mainly used to detect whether some moving parts are in place, and the detection distance is generally less than 5 mm. There are 3 leads on the sensor, which are connected to the 3 pins of J8-J11.

2.4 Path Identification Module

The path identification module is a key part of the orchard spray robot path intelligent identification system control system, which is the “eye” of the orchard spray robot path intelligent recognition system. The quality of the scheme is directly related to the orchard spray robot path intelligent recognition system can deny the road ahead, accurately identify the path information, and provide accurate parameter basis for path tracking to complete the high-quality automatic tracking function of the orchard spray robot path intelligent recognition system. There are several common ways to identify the specific scheme: Scheme 1: Using CCD camera tracking: CCD camera tracking, is to use the CCD camera to collect video image information of the road. It obtains a tracking method by transmitting the image of the front road surface to the microcontroller for processing, obtaining useful path information and then controlling the smart car for path recognition. The advantage is that it has a wide field of vision, can obtain a large amount of road image information, and has complete and comprehensive path information. It is forward-looking and can predict the changes of the road earlier and react quickly and in a timely manner. The disadvantage is that the hardware circuit is complicated, and the video image is separated and binarized. The image processing information is large and the speed is slow, which reduces the real-time control of the orchard spray robot path intelligent recognition system and is expensive. Scheme 2: Photoelectric sensor tracking: Photoelectric sensor tracking, is to use a series of LED diodes and receiver tubes to obtain path information. A light-emitting tube and a receiving tube form a pair, and the light-emitting diode emits light, which is reflected by the ground and received by the receiving tube. In practice, the ability of reflecting light is different because the ground in the working range is composed of green original paint floor and white positioning line. Different voltage values are formed in the receiving tube according to the light reflection condition, so as to determine whether the driving direction of the subsequent path needs to be adjusted. In combination with the actual environment, pre-arranged ground positioning is prone to breakage and discoloration. It is appropriate to consider the first option from the perspective of future practical use. However, considering that the design is currently only applied and practiced, it is not practical as an industrial grade product. Considering the cost and the actual working ability of the chip and platform, the second option is used for design and development [7].

In the design of the line detection circuit, the line sensor needs to be selected [8]. In the path control of the orchard spray robot path intelligent identification system, a photosensitive sensor device arranged in a line is selected. The signal difference caused by the difference in light intensity reflected by the light-emitting diodes on different color grounds is converted into a voltage change value to determine the path offset. In practical applications, the route should be pre-designed, and the vertical horizontal line should be set along the running path at a certain distance to facilitate the calibration of the entire sensor and the distance counting [9]. The sensor uses a 16-way line sensor. The main control board of the sensor signal processing board uses a 12 V power supply circuit for signal processing of the sensor signal processing board, and can be connected to the main control board through the power line. In the sensor signal processing board, the 16-way patrol line sensor sends the collected ground white strip information to the circuit board, and the collected information is first amplified, and the amplified signal is preset with a voltage value for comparison. After filtering, the required effective reflected signal is retained. After filtering, the effective signal is modulated into digital signal for feedback, which is controlled by the main control board. The light and dark changes represented by the signal indicate the positional relationship between the sensing element and the calibration path, thus providing a basis for path adjustment.

Since the voltage value caused by the direct feedback signal is small, a signal amplifying circuit is added to the circuit to amplify the signal for subsequent signal comparison. The ER first signal comparison circuit is connected to the reference voltage by using the LM324 to be connected to the voltage comparator, and the upper comparison result QQQ input is compared [10]. When the upper voltage value meets the predetermined value, the output high level is fed back to the control board, and when the upper voltage input value does not meet the predetermined value, the low level is finally output.

2.5 Motor Drive Module

The basic control principle in this control process is to adjust the average voltage by the duty cycle of the signal, and use the change of the voltage to control the operation of the DC motor. Two MOS tube drive circuits are provided in the circuit to drive the left and right wheel motors respectively. This circuit uses the IR2110 power driver integrated chip, which is a single-chip integrated driver module for dual-channel, gate-driven, high-voltage high-speed power devices with high reliability. The IR2110 input signal is the PWM pulse width signal sent by the main controller, and its output directly controls the on and off of the 75N75MOS tube. In the relay output circuit, L01 and L02 are connected to the DC motor, and the LDIR is the main control board. The left motor direction control signal is sent, and the common contact of the relay is controlled by the triode to operate. When LDIR is low, the relay normally open contact does not operate, the DC motor rotates forward; when LDIR is high, the relay normally open contact closes and the DC motor reverses; The relay circuit is used instead of the general MOS tube bridge circuit as the motor forward and reverse control circuit, which is mainly for the frequent start, stop and forward and reverse operation, the relay circuit is more reliable and safe.

2.6 Wireless Communication Module

Zigbee is a wireless data transmission network platform consisting of up to a wireless data transmission module, which is very similar to the existing mobile communication CDMA network or GSM network. Each Zigbee network data transmission module is similar to a base station of a mobile network, and can communicate with each other throughout the network [11]. The distance between each network node can range from the standard 75 m to hundreds of meters or even several kilometers. The entire network can also be connected to other existing networks. Compared with other solutions, this technology has the advantages of large network capacity, short delay, reliable communication and low power consumption. Therefore, in the design of the orchard spray robot path intelligent identification system, the ZKM101B communication module was selected to realize wireless network transmission. ZKM101B wireless transmission converter can complete two-way wireless data communication between devices and devices based on RS232 and RS485 bus, realize one-to-one communication between one host and multiple slaves. It completely replaces the traditional RS232 and RS485 cables, and the specific functions can be configured according to the user's choice.

3 Design of Path Intelligent Identification System Software System

3.1 Software System Development Environment

In the software development, the KEIL C51 standard C compiler is used to provide the C language environment for the software development of the 8051 microcontroller while retaining the efficient and fast assembly code. The C51 compiler's capabilities continue to grow, allowing you to get closer to the CPU itself and other derivatives. Starting with uVision2, the C51 has been fully integrated into the integrated development environment of uVision2. This integrated development environment includes: compiler, assembler, real-time operating system, project manager, debugger. The uVision2 IDE provides a single and flexible development environment for them. In programming we used KEIL uVision4 as the development environment.

3.2 Accurate Path Recognition Based on Adaptive Genetic Algorithm

Software design and program development for path recognition control scheme using adaptive genetic algorithm. Adaptive genetic algorithm is a computer to complete the control activities described by people in natural language. The adaptive genetic algorithm has many good characteristics. It does not need to know the mathematical model of the genetic object in advance, so it is especially suitable for the control of complex nonlinear systems that are difficult to establish mathematical models. The establishment of the rules is to transform the experience into corresponding variables. It has strong resistance to transformation and performs well in controlling nonlinear hysteresis system. It has the advantages of fast system response, small overshoot and short transition time. Since the processing is classified in the form of establishing rules in processing, the processing speed is faster. In composition, it can be divided into three parts: genetic input, genetic operation, and genetic judgment output. This kind of algorithm is very practical in dynamic and complex environment conditions and practical application environments where obstacles are not fixed. In the adaptive genetic algorithm, it is necessary to convert the exact value that needs to be input into the applicable amount required by the genetic controller rule, the domain of the quantitative value, the lighting level and the quantization factor, and the value of the variable and the inheritance of the membership function is completed. As long as the genetic operation link is based on the established rules combined with the corresponding logical relationship, the logical reasoning process is completed, and the inference result is output. The magnitude of the output is obtained by inference of the genetic relationship equation, not an exact value. Therefore, the genetic output is subjected to de-geneticization, converted into a clear amount within the domain, and then scaled into a precise control. Common methods of de-generization include weighted average method, center of gravity method, and summation method.

In practical applications, the most widely used is the PID control mode. In the process of adjustment, the physical meanings of proportional, integral and differential are mainly applied, and the errors in the actual control are controlled and adjusted to achieve the control objectives. Where r(t) is the actual input value in the entire system; y(t) represents the actual output value; e(t) is the amount of error between the input and output values in the system, which can be expressed by Eq. 1:

$$e(t) = r(t) - y(t) \tag{1}$$

u(t) is the system control signal output by the PID regulator, and is the output value of the controller obtained after the controller performs the PID operation on the error signal. The mathematical formula for its control law is shown in Eq. 2:

$$u(t) = K_p\left[e(t) + \frac{1}{T_1}\varsigma_0 e(t)dt + T_D\frac{de(t)}{dt}\right] \tag{2}$$

Transform it to get the transfer function:

$$G(S) = \frac{U(S)}{E(S)} = K_P\left(1 + \frac{1}{T_{1S}} + T_D s\right) \tag{3}$$

KP is the proportional coefficient in the PID controller, T1 is the integral time constant of the controller, and TD is the differential time constant of the controller. The schematic diagram shows that the system is a closed-loop control system, and the role of the PID controller plays a linear adjustment role. The process of controlling is to input the expected value r(t) into the controller, and detect the actual output y(t), and then compare the two, the error value is obtained by comparison and fed back to the control device with the signal e(t). If the deviation value is 0, the current working status is normal and no adjustment is needed. If the deviation value is not 0, then the PID controller performs adjustment, and the output control signal U(T) adjusts the control object. Through continuous information comparison, the orchard spray robot can be guaranteed to follow the normal route.

3.3 Route Control Scheme

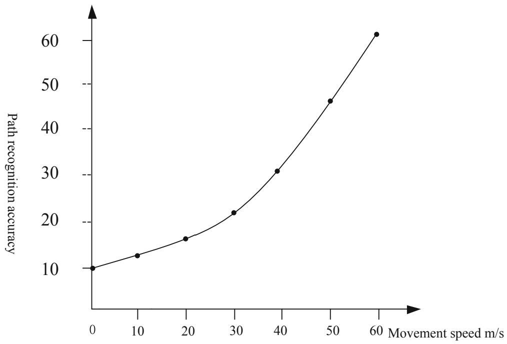
In the orchard spray robot path intelligent recognition system, the tracking function is realized by the detection signal reflected back by the line sensor installed under the trolley to determine the relative position between the current car and the fixed track. Select a word line on the sensor arrangement, which is perpendicular to the direction of advancement in the horizontal plane. In the distribution of the photoelectric sensor probes, according to the principle of equal-angle division, the non-equidistant arrangement is performed according to a certain angle relationship, so that the input and output results are close to a linear relationship. Because the design environment is relatively simple, the offset can be accurately determined for different feedback signals. Here, the adaptive genetic algorithm is selected on the algorithm [12].

3.4 Direction Adjustment Scheme

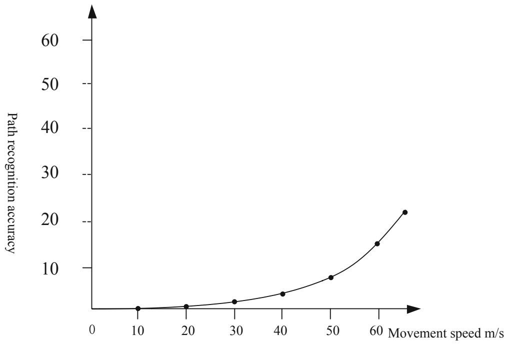
The two front wheels of the trolley are the driving wheels, each equipped with a DC geared motor to drive the car forward. When the current advancing direction deviates from the fixed direction, the sensors distributed on both sides feedback back different detection signals according to the magnitude of the deflection angle, and have a set of codes formed by different high and low levels. When the signal is fed back to the main control chip, according to the different codes, the angle between the trolley axis and the feedback back to the high-level sensor position is determined, and the adjusted input amount is determined to pass through the two PWM wave output ports of the chip at the same time. By changing the duty cycle and controlling the average voltage per unit time, and changing the motor speed, the rotation speed of the driving wheels on both sides is different, so as to adjust the movement state of the orchard spraying robot [13].

4 Simulation Test

The design of the path intelligent recognition system of the orchard spray robot based on adaptive genetic algorithm is realized by the design of hardware system and software system. In order to verify the path recognition accuracy of the path intelligent recognition system of the orchard spray robot based on the adaptive genetic algorithm, a simulation experiment was designed. In the course of the experiment, an orchard was used as the experimental object, the path intelligent identification system of the orchard spray robot based on the adaptive genetic algorithm was verified by the pesticide spray of the orchard spray robot based on the adaptive genetic algorithm of the orchard spray robot accuracy. In order to ensure the validity of the experiment, the traditional spray robot path recognition system is compared with the path intelligent recognition system of the orchard spray robot based on adaptive genetic algorithm to observe the

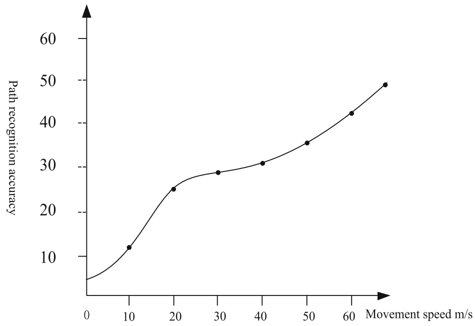


(a)Recognition accuracy of orchard spray robot path intelligent recognition system based on adaptive genetic algorithm

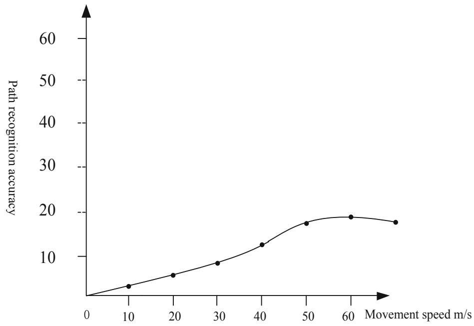


(b)Recognition accuracy of path recognition system for traditional orchard spraying robot

Fig. 3. Comparison of the first path recognition accuracy



(a)Recognition accuracy of orchard spray robot path intelligent recognition system based on adaptive genetic algorithm



(b)Recognition accuracy of path recognition system for traditional orchard spraying robot

Fig. 4. Second path recognition accuracy comparison

experimental results. The path recognition accuracy of the traditional spray robot path recognition system and the path intelligent recognition system of the orchard spray robot based on the adaptive genetic algorithm is shown in Fig. 3 and Fig. 4.

Experiments show that the path intelligent identification system of the orchard spray robot based on the adaptive genetic algorithm is compared with the traditional spray robot path recognition system, the path recognition accuracy of the orchard spray robot's path intelligent recognition system based on adaptive genetic algorithm is higher.

In order to further verify the effectiveness of the system, the intelligent recognition time of the traditional system and the orchard spray robot in this system is compared and analyzed, and the comparison result is shown in Fig. 5.

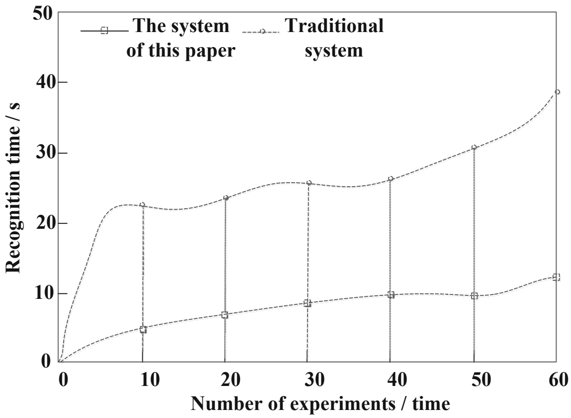


Fig. 5. Comparison of time between two systems

According to Fig. 5, the intelligent recognition time of the orchard spray robot system is within 10 s, while the intelligent recognition time of the orchard spray robot in traditional system is within 40 s. This indicates that the intelligent recognition time of the orchard spray robot is less than that of the traditional system.

5 Conclusion

Due to the problems of low accuracy and long recognition time in the traditional intelligent path recognition system of orchard spraying robot, this paper designs an intelligent path recognition system based on adaptive genetic algorithm for orchard spraying robot, which can broaden the working range of orchard sprayer, improve spraying accuracy and improve work efficiency. It can also improve the level of Agricultural Mechanization in China, which has very important practical significance and broad prospects for the development of precision agriculture in China.

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2. College-level Scientific Research Projects 《Design of Intelligent Sorting Equipment for Fruits and Vegetables》 (201820)

3. Design of Intelligent Robot for Fruit and Vegetable Agriculture Management in Nantong City Science and Technology Project JC2018148

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