Design of Automatic Obstacle Avoidance Control System for Orchard Machine

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Abstract: Directing against the current complex operating environment of orchard operation machine and in order to reduce the labour intensity of workers, an automatic obstacle avoidance control system for orchard operation machine is designed. This control system takes the micro-controller as the core and collects the signal of surrounding environment. After the signal is processed and then compared by the host computer control system with the per-set alarm value, the control system will send commands to control the machine to start or not start the obstacle avoidance system, and meanwhile will control the braking and steering of orchard operation machine to adjust its operation and machine interfere with the next moving trajectory of orchard operating machine.

1. Introduction

China has a vast territory and diverse climates, with large amount of fruit tree planting area, wide varieties of fruit trees and abundant natural resources. China is the world's largest fruit production country. The area of fruit cultivation and output of fruits in China account for about 20% and 15% of that of the world respectively; from 1993 to present, the total area and total output of fruits have been ranking steadily the first in the world. The fruit industry is one of the pillar industries in China's rural economy and plays an important role in adjusting the agricultural industry, increasing farmers' income, and exporting and earning foreign exchange. However, there is still a certain gap between China's orchard operation machine and the developed countries; in the orchard operation there is also a manual labor mode. Therefore, this paper, aiming at the existing orchard operation platform, designs a kind of orchard operation platform obstacle avoidance system, which can effectively realize the autonomous operation of orchard operation machine and greatly relieve the working intensity and working pressure of the working staff. It is of great significance to improve work efficiency and realize the automation of agricultural machine in our country [1].

Autonomous obstacle avoidance algorithm abroad developed earlier, its application is not only more comprehensive, but also it has made a lot of valuable research results. Magnus Lindhe and OKhatib designed a clustered coordination obstacle avoidance algorithm and solved the problem of multiple obstacle avoidance obstacles [2]. M.naderi Soorki and his friends proposed a formation obstacle avoidance system, which realized automatic obstacle avoidance by editing the running route of the kinematic machine and combining formation configuration [3]. Guohua Ye designed a solution
algorithm for obstacle avoidance in multiple media systems, optimized the performance of automatic obstacle avoidance and solved the problem of multiple media interfering with each other [4].

At present, the development of the domestic automatic obstacle avoidance system has been relatively mature, but mainly used for intelligent vehicles, unmanned aerial vehicles and intelligent mobile robots. This article will be automatic obstacle avoidance system and orchard operating machine combined, you can make orchard operating machine in accordance with the preset mode in a certain environment free movement, thereby reducing the staff's participation and control, reducing the labor intensity of the orchard operators and realizing the automation and unmanned operation of the orchard. The advantages of orchard operation machine with automatic obstacle avoidance system can accomplish a variety of tasks in a complex, unknown environment, helping to improve the efficiency of orchard operations [5].

2. Structure of system
The system is composed of six modules: liquid crystal display (LCD) module, wireless transmission module, environment information acquisition module, numerical analysis module, driving module and single-chip microcomputer-based central processing module.

The system's working principal is shown in Figure 1. The single-chip microcomputer-based central processing module is the core of the automatic obstacle avoidance control system; the numerical analysis module is responsible for processing and analyzing the information collected by the environmental information collection module; the central processing module receives the transmitted information and sends the digital signal to the host computer control system through the lower computer control system the host computer control system receives the signal and then it is compared with the pre-set alarm , and accordingly the judgment therefrom will be reverted to control system of the slave computer to command the driving module to intervene in the running distance of the orchard operation machine and make adjustments for the following operation path of the orchard operation machine, and ensure the orchard operation machine make the correct movement adjustment for the complicated work environment.

![Control system structure diagram](image)

Figure 1 Control system structure diagram

The automatic obstacle avoidance control system for orchard operation machine in this paper can accurately identify the machine operating environment around the operation machine in orchard, autonomously control the machine to start or not start the obstacle avoidance system, make different obstacle avoidance measures for different work environments and obstacles, and then realize the orchard operation automation [6].
3. Design of system hardware

The hardware of the automatic obstacle avoidance system is mainly environmental information acquisition module, numerical analysis module, based on the micro-controller's central processing module and the host computer-controlled liquid crystal display module, the operating module. Environmental information acquisition module is mainly composed of ultrasonic detectors and infrared distance measurement sensor. The ultrasonic sensors can maintain good distance measurement performance under the conditions of low brightness, dust and other undesirable conditions, and are insensitive to color and light intensity, with the advantages of fast detection speed, simple structure, and reliable data processing, easy not to be damaged etc [7]. However, the ultrasonic energy emitted by the ultrasonic sensor is strong. When multiple ultrasonic sensors are used together, they interfere with each other and the position of the object is not accurately detected [8]. In order to get a more detailed and accurate environmental information, we use the ultrasonic sensor and the infrared distance measurement sensor. Due to its advantages of high measurement accuracy and fast speed, the infrared distance measurement sensor can effectively make up for the disadvantages of multiple ultrasonic sensors interfering with each other [9].

In the orchard machine driving process, ultrasonic sensors and infrared distance measurement sensors continue to detect orchard operating machine around the operating environment, and sends the collected data information to the numerical analysis module, the system uses math software, such as maple, to process the detected data and send it to the MCU-based central processor. The lower computer control system continuously reads the state data of the surrounding environment collected by the sensor (generally, the analog quantity), and converted to digital signal feedback to the host computer. Host computer control system to read the data will be received by the environment information and set the warning value to compare and give the next crew control system commands. lower computer control system and then according to this command to explain the corresponding timing signal directly control the corresponding equipment to achieve the system obstacle avoidance function.

The ultrasonic sensor is mainly composed of transmitter unit, receiver unit, control unit and power supply unit. SCM makes the output impulse through the external pin P1.0, pulse signal and ultrasonic drive Circuit series, in the push-pull mode with ultrasonic sensor emission ultrasonic. In order to increase the distance measurement range, we can amplify the oscillation signal and then add it to the ultrasonic sensor. The receiver unit is composed of transducer and amplifying circuit. The transducer is used for receiving ultrasonic wave to generate mechanical vibration to convert it into electric energy. The control unit mainly completes the control of the overall system work, such as controlling the transmitter to send the ultrasonic wave, judging whether the receiver accepts the ultrasonic wave, identifying the accepted ultrasonic wave size and so on. The power section mainly provides energy for the system's work. In this article, HC-SR04 ultrasonic sensor was adopted and thereby it can make a detailed detection to the landform [10].

In this paper, the infrared emission tube TLN103 and receiving tube PT370 were adopted, where The farthest transmitting distance of the transmitting tube is 1m and the transmitting angle is ±80°,the receiving angle of infrared receiver tube is ±45°.The device uses two infrared rangefinder sensors, different transmitting circuits transmit pulsating infrared light of different frequencies, filter out the interference of ambient light in the receive frequency selection, and to prevent the interaction between different devices. The infrared emitting diode used in this device is driven by a pulsating DC current that is proportional to the power and current, so adjusting the current can change the detection range of the ambient information acquisition module [11].

For the purpose of acquiring enough detailed data, we made a detailed configuration for the installation position of sensor. In order to ensure that the sensor can systematically and comprehensively collect the surrounding environment information, a pair of infrared range-finder sensors are installed in front of the machine and the different transmitting frequencies are adopted to to measure the obstacles in front of the machine. Additionally another pair of ultrasonic sensors are
installed on the left and right sides of the machine, responsible for measuring the obstacles on both sides of the machine [12].

4. Software Design of System

4.1. Software program design

The entire control system is based on the SCM's smart obstacle avoidance machine and C source program. First, the sensor module detects the front and both sides of the machine, they can identify whether there is obstacle or obstruction or not. When the machine approaches to obstacle, the sensor will read the time interval between signal sending and receiving, and then identify the distance between machine and obstacle (Adjusting the sliding rheostat can adjust the maximum detection distance of ultrasonic sensor, adjusting the current can adjust the maximum detection distance of infrared distance measurement sensor). The sensor module transmits the measured data to the numerical analysis module, the numerical analysis module lists the mathematical physics equations based on the measured data, and makes the mesh generation for the space; afterwards the initial conditions are given by observing the data. The numerical solutions at the grid points are obtained by solving these partial differential equations by approximate analytical method (series solution method, successive approximation method) and numerical solution method (giving approximate values of solutions at discrete points), following the numerical solutions are transmitted to the display module and the central processing module. In the case of there is no man-made intervention, the machine moves according to the optimal solution of numerical analysis. The machine, in the process of moving, triggers the sensor modules to detect the obstacle in the front and on both sides and measure the distance, in the meantime, the numerical analysis module constantly adjusts the mechanical walking till the machine avoids the obstacle; afterwards the machine will run normally and close the obstacle avoidance system subprogram. The software flow chart is shown in Figure 3 as follows.

![Figure 2 Flow chart of control system](image-url)

\[\text{Start} \rightarrow \text{Initialization} \rightarrow \text{Mechanical operation} \rightarrow \text{Measure distance and display} \rightarrow \begin{cases} \text{N} & \text{Is there any obstacle?} \\ \text{Y} & \text{Establish a mathematical model} \\ \text{Drive machinery to avoid obstacles} \end{cases} \rightarrow \text{Start obstacle avoidance system} \rightarrow \text{Numerical Analysis of measurement data} \rightarrow \text{End of obstacle avoidance system} \]
4.2. Obstacle avoidance algorithm
The sensors used in this system are ultrasonic sensors and infrared rangefinder sensors. The ultrasonic sensors uses the acoustic reflection principle and transmits the acoustic wave signal via the sensor in the process of measurement; when encountering with obstacle, the ultrasonic wave, when being transmitted in air, will reflect back immediately and the receiver will receive the reflected ultrasonic waves. Therefore, the time difference between transmitting and receiving of ultrasonic wave can be used to determine the distance between the machine and the obstacle:

\[ s = v \cdot \frac{t}{2} \]  

(1)

Where \( v \) is the transmission velocity of ultrasonic wave in air; it is approximately \( 340 \text{m/s} \) at the normal temperature, \( t \) is the time difference between the transmitting and receiving of signal.

The infrared distance measurement is to use the trigonometric survey principle to achieve distance measurement [13]. The infrared distance-measuring sensor transmits the infrared beam according to a certain angle; when the infrared light beam hits the object, it will be reflected by the object, the emitted light beam therefrom is detected by the sensor board, so the offset value can be obtained. By using the trigonometry theorem, the following geometric relationship can be obtained:

\[ D = \frac{f(X + L)}{L + fc \cdot \tan(90^\circ - \alpha)} \]  

(2)

Where \( D \) is the distance from the infrared sensor to the target object, \( f \) is the focal length of the filter, \( L \) is the offset value, \( X \) is the center distance, \( \alpha \) is the emission angle, and \( c \) is the transmitting velocity of infrared in air \( c = 3 \times 10^8 \text{m/s} \). As for the schematic diagram of infrared distance measurement, see Figure 3 as follows.

A pair of ultrasonic sensors and infrared distance-measuring sensors are placed in front of the machine and on left and right sides of the machine to measure and identify the distance of obstacles around the machine; where the steering time and angle of the machine can be decided according to the distance between the machine and obstacles[14].

5. Conclusions
In this paper, in view of the complicated operating environment of operation machine in orchard and the shortage of automatic control system in operation machine in orchard, an automatic obstacle
avoidance system for operation machine in orchard is designed. It takes SCM as the core, collects and processes the information acquired by the sensor, and then controls the operating condition of operation machine in orchard and intervene the next moving trajectory of operation machine in orchard. This automatic obstacle avoidance control system in this paper has great significance for the automatic development of orchard operation machine.

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