Research on Plant Control Robotic Wire Control Chassis Control System

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Abstract. In order to facilitate the independent operation of the wheeled plant protection robot, a wire-controlled chassis with wire control, modularization and generalization was designed and manufactured. The steering drive mode of the plant protection robot adopts front wheel drive rear wheel steering. The steer-by-wire system uses a steering motor to drive the steering gear and installs a corner sensor on the steering column to achieve closed-loop control of the steering. The throttle-by-wire system uses a PWM speed control method and uses a Hall sensor to achieve closed-loop speed control. The brake-by-wire system uses a dedicated drive to control the electric linear actuator for braking and closed loop control of the brake through the current loop. For the communication method, the CAN network is used to build the communication of each module. The results show that the line-controlled site can accurately follow the expected action value given by the decision-making system to ensure the accuracy and stability of the plant protection robot operation.

1. Introduction
The level of automation of plant protection machinery in China is low. Most of them are backpack and traction operation, which requires manpower to assist the operation. The efficiency is low and the waste is serious[1]. Therefore, to improve the automation level of domestic plant protection machinery and liberate people from the plant protection work with high labor intensity and bad working environment has become the most important thing to realize the modernization of agriculture in China. However, as the end-effector, the wire-controlled chassis is the basis to ensure the effective operation of plant protection robot. Therefore, in order to improve the automation level of plant protection machinery in China, it is particularly important to develop and design a line-controlled chassis which integrates steering, walking and braking[2].

The prototype of wire control technology came into being in the 1950s[3]. TRW in the United States and Kasselmann in Germany replaced the mechanical structure between the steering wheel and the steering wheel with corresponding control signals. In 2017, Tesla put forward a more innovative scheme for the layout of the wire control system, which simulates human driving behavior and achieves driverless driving from Los Angeles to New York. Domestic enterprises started online control technology relatively late, and the research of online control technology in major universities mainly stayed at the theoretical stage. On the basis of on-line steering control of Baidu UAV in 2017, combined with Road Hacker platform, the test of hybrid automatic driving of loop road and highway road conditions was realized for the first time in China[4]. The wire-controlled chassis is mainly composed of three systems: steering, throttle and brake. Among them, there are two main forms of steer-by-wire: 1 cancel the mechanical connection between the steering wheel and the steering wheel with corresponding control signals. In 2017, Tesla put forward a more innovative scheme for the layout of the wire control system, which simulates human driving behavior and achieves driverless driving from Los Angeles to New York. Domestic enterprises started online control technology relatively late, and the research of online control technology in major universities mainly stayed at the theoretical stage. On the basis of on-line steering control of Baidu UAV in 2017, combined with Road Hacker platform, the test of hybrid automatic driving of loop road and highway road conditions was realized for the first time in China[4].
System redundancy. The main suppliers at home and abroad are Bosch, TRW and Zhejiang Wanda. The throttle-by-wire has been developed so that the ECU can determine the opening and closing of the throttle, the amount of fuel injection, and the injection time interval based on the position of the accelerator pedal. The main suppliers abroad are Bosch, Continental and so on. Brake-by-wire has been developed into two types of EHB(Electronic Hydraulic Brake) and EMB(Electromechanical Brake System). Among them, EHB is more mature, with the advantages of small size, light weight, fast response speed and more flexible operation. The main suppliers at home and abroad are Bosch, Lianchang Electronics and Wanxiang Group[5].

Considering the high cost of wire-controlled chassis, the fact that suppliers do not retail and control protocols are not open to the outside world, it is necessary to design a low-speed automatic driving wire-controlled chassis for the autonomous operation experiment of plant protection robots.

2. TRANSMISSION SCHEME AND STEERING DRIVE SCHEME FOR REMOTE CONTROL CHASSIS

![Transmission system block diagram](image1)

![Model of the line control chassis](image2)

The steering drive mode of the plant protection robot adopts front wheel drive rear wheel steering. As shown in Figure 1, the transmission system of the wire-controlled chassis adopts the traveling motor and the reducer to drive to realize the chassis walking. The electric linear actuator is used to push the hydraulic Brake to realize the braking of the wire-controlled chassis, and the steering motor is used with the steering machine. The form is used to achieve the steering of the wire-controlled chassis. As shown in Figure 2, the steering part comprises 1 angle sensor, 2 steering motor, 3 coupling, 4 steering gear; the energy device is 5 battery pack; the throttle part comprises 6 walking motor, 7 speed reducer and 8 transmission front axle.

3. WIRE-CONTROLLED CHASSIS CONTROL SYSTEM

![Control schematic of the wire control chassis](image3)
The battery pack is placed in the middle of the chassis structure to facilitate the supply of power to each electronic module. Figure 3 shows the decision layer outputs the expected value of the next action to the execution layer. The VCU in the line control site will perform linear control of the brake, throttle and steering according to the input information of the sensor. The steering is realized by the VCU sending a command to the drive of the steering motor, the drive drives the steering motor to rotate, and the steering motor is connected to the steering gear through the universal joint, thereby transmitting the torque of the steering motor to the steering gear through the coupling. To push the rear wheel for steering[6]. The realization of the walking is also to send a command to the drive of the traveling motor through the VCU, thereby controlling the traveling motor to rotate, the motor reducer is placed at the front center, and the power is applied to the driving wheel through the front axle. When the speed of the plant protection robot is too large and requires braking, the ECU sends a command to the electric linear actuator, and the electric linear actuator action changes the flow direction of the hydraulic oil in the hydraulic circuit, thereby controlling the hydraulic cylinder action to push the brake pad to clamp the driving wheel to generate the brake effect.

3.1. Steering control system for wire control chassis

As shown in the figure 4: the upper computer gives the VCU a command to rotate the target angle $\alpha_{\text{aim}}$, and the VCU controls the steering motor of the steering wheel by the drive of the steering motor. At the same time, the steering angle sensor is mounted on the steering column to feed back the actual rotation angle $\alpha$ and the target. The transfer $\alpha_{\text{aim}}$ comparison yields a deviation $\Delta \alpha$, which is input to the VCU, and the controller will adjust the corresponding rotation angle according to the positive and negative deviations of the deviation. When the deviation is positive, the steering motor rotates forward, and vice versa; when the deviation value is large, the controller outputs a PWM (pulse width modulation) square wave with a large duty ratio[7]. At the same time, the angle sensor will also monitor the corner size in real time and compare it as the input amount and the deviation set threshold, the current steering control will also end. The VCU is the control system, the steering mechanism is the actuator, the steering motor is the controlled object, and the transfer sensor is used as the feedback measuring device. These four parts constitute the closed-loop servo steering system.

![Figure 4. Steering control schematic](image_url)

Based on the above principle, it is proposed to use DC servo motor as the steering motor. The interface description of the corresponding driver is shown in Figure 5. The CAN bus communication method makes the vehicle wiring simpler, more efficient and more reliable. Each serial port command sent by the VCU to the drive is composed of 10 bytes. The mode selection of the drive is shown in Figure 6. Here we plan to select the mode of the speed position and write the corresponding address against the corresponding communication protocol. The control flow is as follows:

- Send reset command.
- Waiting for 500ms.
- Send mode select command to put the drive into a mode.
- Wait500ms
- Send a data command in the mode that has been entered (This instruction is sent periodically, with a minimum interval of 1ms and a recommended interval of 10ms).
Figure 5. Steering motor drive interface description

The commands that the driver feeds back to the VCU mainly include the following three types: 1. Sending current, speed, position and other information; 2. Sending CTL1 and CTL2 port level status to the outside; 3. Sending online detection feedback.

3.2. Throttle control system for wire control chassis

In order to ensure the uniformity of application of plant protection robots during farm operations, it is necessary to ensure the ability of cruise control under complex road conditions. Therefore, we use a DC48V, 3KW travel motor with speed feedback, the drive speed signal is 0-5V analog, using pulse width modulation (PWM) method, the constant DC voltage is modulated into a variable size and polarity. The DC voltage is used as the armature voltage of the motor. Since the accuracy of the motor speed is very high, and the load of the motor changes greatly during the operation, the speed closed-loop control is adopted, and the method realized by using the DC brushless motor can measure the signal of the Hall signal line, obtain speed and travel distance information [8].

As shown in the figure 6: when the VCU receives the target speed $V_{aim}$ issued by the host computer, it sends a command to the driver to control the speed of the traveling motor, and uses the photoelectric encoder as the speed measuring component to realize real-time measurement of the motor speed and obtain the motor speed information $V_i$. Feedback to the VCU to form a closed loop speed control system.

![Throttle control schematic](image)

Figure 6. Throttle control schematic

3.3. Brake control system for wire control chassis

In order to ensure that the plant protection robot accurately decelerates or brakes during the operation[9], for the brake system of the wire-controlled chassis, we add an electric linear actuator to replace the pedal action of the person on the basis of the traditional hydraulic Brake system, and the corresponding work The flow is shown in Figure 7. The electric linear actuator action pushes the hydraulic oil in the cylinder into the brake caliper along the hydraulic line, and then tightens the hub to achieve braking.

In order to realize the closed-loop control of the line control, the driver of the model AQMD3610NS-A is used, and the braking torque and the current are used to realize the feedback of the braking torque through the current feedback. The method has the advantages of fast response speed, light weight, no complicated hydraulic system and convenient maintenance, and the corresponding schematic diagram is shown in Figure 8.
4. CONCLUSION

Taking the self-operating plant protection robot as the research object, the transmission mechanism, steering drive mode, steering, walking and braking of the wire-controlled chassis are designed and manufactured, and the closed loop control of the position loop, speed loop and current loop are applied respectively. The test results show that the line control site can accurately execute the output command of the decision-making layer, realize the stable closed-loop control of the traveling motor and the steering motor, and the fast response control of the braking system. It has the characteristics of modularization and intelligence to ensure the operation of the plant protection robot’s flexibility and stability of driving.

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