Design of Electric Steering Wheel for Agricultural Machinery

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Abstract: Aiming at the automatic steering control system of agricultural machinery, this paper puts forward the method of using S7-200 intelligent PLC of Siemens company as the core controller, which uses the high-speed pulse signal output by the controller to control the stepper motor to drive the rotation of the steering shaft, realizes the automatic steering through the control of the motor speed and steering, uses the encoder to detect the rotation angle of the steering shaft to realize the feedback control, and selects the touch screen to realize the user interaction scheme.

1. Introduction
In recent years, in the Northeast Plain and North China Plain, agricultural automatic navigation technology has been widely used and expanded. Some research results show that the agricultural automatic navigation technology can effectively reduce farming overlap and contralateral error, improve the straight-line driving ability of agricultural machinery, and improve the operation accuracy\cite{1}.

There are two ways of agricultural automatic steering: solenoid hydraulic steering and electric steering. The electric steering wheel is mainly driven by electric motor, which is characterized by compact transmission and easy installation, small change range of agricultural machinery steering system and relatively low transformation difficulty. The agricultural electric steering wheel is one of the main directions for the future development of agricultural automatic navigation technology \cite{2}.

2. Overall design
In the process of system design, the design is based on the instruction of rotation angle which is sent by on-board computer to PLC. The state, mode and other settings of PLC are controlled by the touch screen. When the system is in the automatic driving mode, the controller updates the data of rotation angle and rotation speed sent by the on-board computer every 100ms. When the controller receives the new data, it calculates immediately, not only whether the input result is valid, but also the difference value according to the real-time position fed back by the encoder. Finally, the compensated value is converted into pulse signal and output to the stepper motor driver. The stepper motor driver drives the stepper motor to rotate, and the stepper motor drives the steering wheel to rotate through gears, so as to achieve accurate angle control. The encoder detects the real-time position of the steering wheel and feeds it back to the controller, which then processes the feedback value, and finally sends a series of real-time data such as the processed value to the on-board computer and touch screen to realize the closed-loop control. The overall design structure of the system is shown in Figure 1.
3. System mechanical structure design
Through the investigation of the existing electric steering wheel in the market, we know that the current electric steering wheel can be divided into two kinds of schemes: motor drive and motor direct drive. The mechanical structure mainly includes the steering wheel, motor, angle measuring device, transmission mechanism and fixed device. Through the control of the controller, the original steering wheel can be replaced to realize the automatic steering of agricultural machinery [3-4]. The two schemes are shown in Fig. 2 and Fig. 3.

Through the research and market investigation at home and abroad, the main advantages and disadvantages of the two schemes are summarized: the motor driven electric steering wheel of scheme 1 has low requirements for motor, and can meet the requirements of torque and accuracy of the system through motor reducer, but the structure is complex and the installation is not convenient; scheme 2 has simple installation of direct motor driven electric steering wheel, large motor torque High precision, but the motor technology is complex, expensive, difficult to maintain, high power requirements.

According to the characteristics of agricultural machinery, the motor drive type is selected. After redesigning the fixing and driving mode of the motor, and adding encoder to measure the angle of rotation, a new scheme of motor driven electric steering wheel is designed, as shown in Figure 4.
Figure 4 Structure of electric steering wheel of agricultural machinery
1. Steering wheel; 2. Steering shaft; 3. Steering shaft gear; 4. Encoder gear; 5. Step motor gear; 6. Encoder; 7. Safety coupling; 8. Step motor; 9. Steering shaft shell; 10. Fixed frame

4. Control system design

4.1 controller selection
S7-200 smart Siemens specializes in the upgrading of S7-200 products for the Chinese market. The reasons for using this PLC as the electric steering wheel controller of agricultural machinery are as follows:

(1) This PLC is equipped with Siemens special high-speed processor chip, which can execute instructions quickly. Compared with the small PLC produced by other manufacturers, it is far ahead, and can meet the high-speed data exchange with on-board computer and its own high-speed operation.

(2) The CPU module itself integrates Ethernet interface, and can communicate and network with other CPUs, on-board computers and touch screens by using network cable, which saves the cost of special communication cable and is economical and convenient.

(3) 6ES7 288-1st20-0aa0 integrates two channels of high-speed pulse output, with a frequency of up to 100 kHz. Compared with other small PLCs, it also has obvious advantages. It also supports a variety of motion modes and has powerful motion control functions.

(4) S7-200 smart ST20 is priced at about 700 yuan in the market, with low price, powerful function, superior performance and high cost performance.

4.2 System program framework
The main body of the controller program is divided into main program, reference sub program, automatic driving sub program, high counter sub program and motion control sub program. Among them, the high counter subroutine and the motion control subroutine are the module subroutines generated according to the needs in the software tools. They can be used as commands in the main program and the ordinary subroutines. In this way, the program functions are modularized. Each scanning cycle only scans the main program and the called subroutines, and the subroutines that are not called are not scanned. In this way, the scanning cycle can be greatly shortened, while The programming idea is clearer,
debugging is convenient, and the main structure of the program is shown in Figure 5.

4.3 system circuit diagram
The system circuit is the basis to ensure the normal operation of each equipment, which needs to be connected with the working principle of each equipment in combination with the program requirements.

First, the tractor battery (DC12V) is connected to the power input of power module sy-0940s2406 through the knife switch. The power module provides stable DC 24V voltage output. PLC, stepper motor driver zd-2ha860, touch screen tpc7062tx, encoder e6b2-cwz5b can be directly powered by DC 24V, and four motor phase lines of stepper motor can be connected with the corresponding interface of stepper motor driver. According to the characteristics and program requirements of the controller, port q0.0 is a high number pulse output port, which is connected with the step motor driver pul +, port q0.1 is a moving direction output port, which is connected with the step motor driver dir +, port q0.2 controls the motor to be locked, which is connected with the step motor driver ENA +, and the step motor drivers pul -, dir - ENA - connect GND, i0.0 port and i0.1 port are orthogonal A / b pulse input ports of controller high-speed pulse input, which are connected with out a and out B of encoder, touch screen is connected with RS485 port of controller through RS485 data line, and i0.3 port is connected with system emergency stop button. The system wiring diagram is shown in Figure 6.
4.4. The design of touch screen main control interface

Four display windows (operation status, driving mode, setting position, real-time position) and four keys (parameter seeking, mode, pause, stop) are set in the main control interface. The operation status, driving mode and real-time position windows are only displayed according to the command of the controller and cannot send data to the controller. The setting position window can be sent to the register of the controller through the touch screen keyboard. Write the new value, and the controller will make corresponding processing according to the value. Four keys can directly control the corresponding intermediate relay in the controller. The controller will make corresponding according to the status of the intermediate relay, and the operation effect is shown in Figure 7.

![System wiring diagram](image)

**Figure 6 System wiring diagram**

4.5. The design of touch screen parameter seeking interface

The parameter seeking interface is specially set for the parameter seeking subroutine in the program. There are three ways to find the reference point in the parameter seeking subroutine, which can be selected by the touch screen button, and there are two display windows to display the current way to find the reference point and the current position (the current position is the memory position of the corresponding controller, only for reference). The completion of the reference point finding is also confirmed by the button.

![Touch screen main control interface](image)

**Figure 7 Touch screen main control interface**
5. Conclusion
The electric steering wheel of agricultural machinery is an actuator designed for the automatic navigation and driving system of agricultural machinery, using Siemens S7-200 smart PLC as the controller. The controller calculates and processes the position data of the on-board computer or touch screen, converts the reasonable position data into the pulse number to drive the stepping motor. The stepping motor drives the steering shaft of the steering wheel through the gear, so as to control the travel route of the agricultural machinery. The encoder is used to measure the angle, feed back the real-time position, compensate the difference, and ensure the position control accuracy.

At present, the actuator of the agricultural machinery automatic navigation driving system on the market is expensive, only the motor price is more than 8000 yuan, the whole system is more expensive, and the whole actuator designed in this paper is only about 1500 yuan, which greatly reduces the cost of the whole agricultural machinery automatic navigation driving system, and reduces the investment of farmers in production equipment.

Finally, through the use of physical objects to build the system, and repeated debugging, the final test results meet the requirements of agricultural machinery automatic navigation driving system to the actuator.

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