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Research on Control System of Corn Planter Based on Radar Speed Measurement

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Abstract: The intelligent control of precision planting can detect and regulate the operation quality of the planter in real time, which plays an important role in improving the operation quality of the planter and the yield of the corn. In this paper, the control system of a corn precision planter is designed to realize the operating quality monitoring and electric driving of the seed-metering device. The planting quality is calculated by the time interval between the neighboring falling seeds, instead of the plant spacing, to improve the operational efficiency of the system. At the same time, the forward speed of the planter is obtained by radar, which is used to accurately match the speed of the seed-metering device with the forward speed of the planter. The velocity error of the radar is analyzed, and the relevant relationship of the radar output frequency and forward speed is established. Comparative test results of this system and the JPS-12 test bench show that the detection performance of the system is reliable, and the maximum detection error of the quality parameters is less than 2.88%. Field experiments were carried out to verify the operational performance of the control system. Two speed sensors, radar and GPS, were chosen to study the effect of speed measuring on the performance of the control system. We found that speed measuring has a significant effect on planting performance. The qualified parameters of radar were significantly higher than those of GPS, at a forward speed of 6–12 km/h. The qualification feeding index (*QFI)* of radar was 0.51%, 0.67%, and 2.05% higher than that of GPS at speeds of 6, 8, 10, and 12 km/h. The precision index (*PREC*) of radar was 17.60%, 5.44%, 16.81%, and 17.30% lower than that of GPS. Therefore, the control system based on the radar speed measurement developed in this paper can significantly improve the operating quality of the planter.

Keywords: control system; corn planter; radar; planting uniformity

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1. Introduction

As the large-scale production process accelerates, crop planting is gradually developing from the pursuit of high yields to high efficiency [1]. Precision planting technology is developing rapidly, because it saves costs and improves production efficiency [2]. An intelligent control of a precision planter can detect operation quality and regulate the planter in real time, which can effectively improve the planter's operation quality [3]. Control technology and systems have become the key areas of research in the field of precision planting.

Intelligent control technology of a precision planter includes the detection of operation parameters and the regulation of planting quality [4–6]. Quality detection is mainly through the sensor, to record the operating qualified parameters. This facilitates the driver in mastering the planter and ensuring that the planter operates under the best working conditions. For precision planters, the key is to precisely adjust the rotational speed of the seed meter device to achieve uniform seed spacing.

The relevant control technologies in foreign developed countries are more complete. They are controlled and kept secret by leading enterprises. Ground wheel drive, hydraulic drive,

electric motor drive, and other drive methods are used by well-known agricultural companies, such as Agleader, Kinze, Horsch, Precision Planting, John Deere, and so on [7–10]. Precision Planting's stepper motor-driven "SpeedTube" planting system increases the planter's operating speed up to 16 km/h and maintains a good spacing consistency [7]. Case's Flexi-Coil variable planter adjusts planting spacing in real time by controlling the speed of the electro-hydraulic servomotor, according to the prescription [10]. In these countries, control systems have greatly assisted in improving the efficiency of planting production.

In Asian developing countries, such as China, the development of intelligent control systems for planters is relatively late in coming. The planting operation is mainly mechanical, relying on the experience of the manipulator, and is in an open-loop state that lacks the monitoring and feedback control of the operation status of the planter. Jia et al. used a concave photoelectric sensor to collect information on the seed suction of the platters. Working conditions of the whole metering device can be detected [11]. Xie et al. showed that the detection accuracy of infrared photoelectric sensors was easily affected by dust and the collision of falling seeds [12]. Moreover, when the sensor is mounted on the upper part of the seed guide tube, double-overlapping seeds cannot be separated in time, resulting in the sensor recognizing them as a single seed, and the counting accuracy is reduced. For this reason, he proposed a laser sensor monitoring method to counteract the negative effects of dust. Kamgar et al. used an encoder coupled with a transducer to monitor forward velocity. A mechatronics transmission system decreased both the miss index and the precision index [13]. Yang et al. tested an electric driving system and mechatronic transmission system in the precision seed metering of corn [14]. The electric and mechanical systems were, respectively, at the "insufficient" and "moderate" levels. He et al. described how a planter equipped with an electric driving control system had a significantly better planting quality compared with that using a mechanical transmission driving system under equivalent working conditions [15].

Encoders or GPS are commonly used to detect speed for electric drive systems [16]. However, the accuracy of speed detection by encoders or GPS needs to be further improved. The encoder is mounted on the ground wheel, which causes the speed measurement to fail when the ground wheel slips. Meanwhile, GPS is susceptible to the operating environment, operating speed, and other factors that cause the speed measurement signal to drift. Additionally, the existing published studies on control systems for precision planters have unilaterally focused on planting quality detection or electric drives. An integrated system of precision seeder seed quality inspection and electric drives is needed for Asian developing countries.

In order to realize the integration of precision seeder seed quality detection and electric drives, and to provide a more accurate speed measuring method, we designed an intelligent system for a precision corn planter that integrates planting quality monitoring and electric driving for a seed-metering device. In particular, radar was used to obtain the forward speed, to precisely match the rotational speed of the seed-metering device with the forward speed. Moreover, comparative tests were conducted to verify the radar performance for speed measurement, by comparing it to GPS.

2. Materials and Methods

2.1. Design of the Control System

The control system based on radar speed measurement includes a main controller, terminal, radar, GPS, seed sensor, motor, and the motor driver, as shown in Figure 1. The motor and driver are able to be expanded according to the rows of the planter. The main controller adopts the STM32F103ZET6 control chip. Radar (Vansco 740030A, error of speed measuring <4 cm/s at an operating speed of 12 km/h) is used to obtain the forward speed of the planter. GPS (Guangzhou Xingyi Electronic Technology LLC, Guangzhou, China) is used to obtain the position of the planter, and it is also used in a comparison test of speed measurement. A seed sensor (Shandong Agricultural Mechanization Research Institute, Shandong, China) was installed in the seed tube of the planting unit to detect the quality

parameters. It is powered by 12 v DC. When the seeds pass through, the voltage of the signal pin changes from 12 v to 0 v. In order to ensure the accuracy of seed-falling judgment, the seed sensors were pretested. A motor (Times Brilliant Electrical LLC, Beijing, China) is used to drive the seed meter device. A driver (Times Brilliant Electrical LLC, Beijing, China) is used to control the speed of the motor. The main controller communicates with the terminal. This allows the terminal to be placed in the driver's cab, for easy access to the status of the planter. The radar and seed sensors transmit information to the controller through pulse signals. The driver communicates with the controller via a CAN bus.

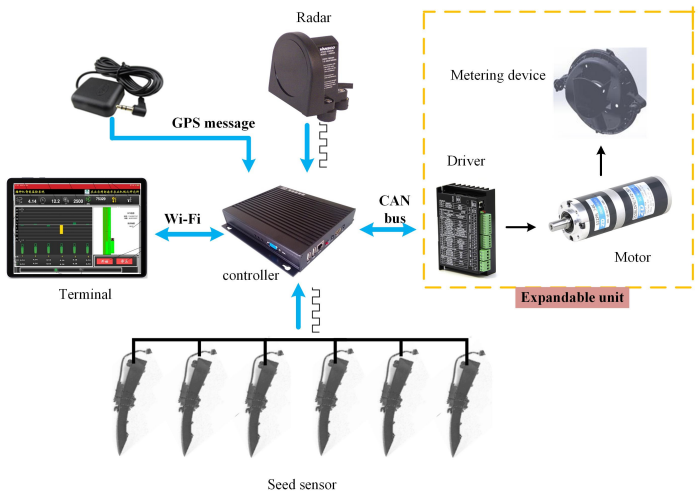


Figure 1. Components of control system for corn planter.

The control system of the planter based on radar speed measurement includes two functions. The first is the regulation of the rotational speed of the seed meter device: during operation, the controller obtains the operating speed in real time through tradar; then, based on the established matching relationship between the operating speed and the rotational speed of the seed meter, the controller sends a speed control command to the drive to reach the target spacing. The second function is planting quality monitoring: with a seed sensor installed in the seed guide tube to determine whether there is seed falling, the controller receives the pulse signal from the seed sensor and calculates the time difference of adjacent falling seeds, and then calculates the quality parameters (*QFI*, *PREC*) [17]. At the same time, the operation quality parameters of each row, as well as the operation speed, area, and position of the planter, are displayed on the terminal.

2.2. Description of the Hardware of the System

The hardware composition of the system is shown in Figure 2. It mainly includes a power supply, CAN, Wi-Fi, and seed sensor circuit.

The system operates with power supplied from the 12 v battery of a tractor. Anti-reverse diodes and filter capacitors were used before the power supply. An LM2596S-5.0 chip was used in the power supply circuit to convert 12 v to 5 v, which is supplied to the CAN circuit. An LM1117DT-3.3 voltage chip was used as a secondary step-down, to reduce the 5 v to 3.3 v. Similarly, filtering and decoupling circuits were added to provide stable voltage for the STM32F103ZET6 control chip.

The planter requires the independent detection and control of each row. Therefore, several motor drives are included herein that need to communicate with the main controller. Using a CAN bus makes it easy for the main controller to communicate with multiple motor drives. A VP230 isolated transceiver was chosen because of its excellent performance against electrostatic interference and voltage surges.

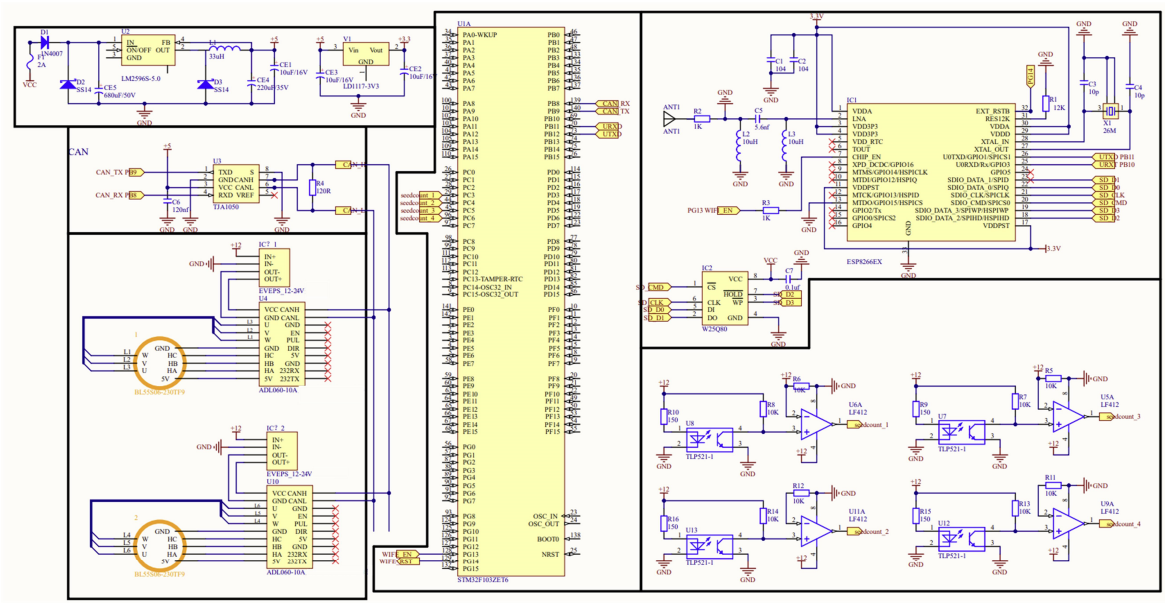


Figure 2. Main circuit diagram of control system.

2.3. Design of the System's Program

There are three functions of the controller: detecting the qualified parameters, controlling the rotational speed of the seed meter, and displaying the qualified parameters. To realize the above functions, the main program is executed as shown in Figure 3. The start of the system is controlled by the terminal. When you press the start button on the terminal, the system starts to work; otherwise, it is in a state of inquiry. The control system requires operators to input some parameters, such as the theoretical plant spacing, number of holes in the seed-metering device, transmission ratio, etc. When the control system is working, it first reads these parameters and stores them in a fixed register. After that, it receives a GPS message and extracts longitude and latitude information, to obtain the current position of the planter. By acquiring the frequency of the radar and the register value captured by the seed sensor, the forward speed and the quality parameters (*QFI*, *PREC*) of the planter are calculated. The target speed of the seed-metering device is calculated according to the obtained forward speed of the planter, which is sent to the driver by the CAN bus, so that the speed of the seed-metering device can be matched with the forward speed of the planter in real time. Finally, the forward speed, position, and quality parameters are sent to the terminal.

2.4. Calibration of the Speed Measuring of Radar

Radar speed measurement uses the Doppler effect: When the target approaches the radar, the reflected signal frequency is higher than the transmitter frequency. On the contrary, when the target is far away from the antenna, the reflected signal frequency is lower than the transmitter frequency. The relative speed between the target and the radar can be calculated by the change in frequency. According to the manufacturer, the installation height of the radar is 0.3–1 m. The installation height during this test was 0.8 m, as shown in Figure 4.

The suggested formula for calculating the relationship between the forward speed and radar output frequency is as follows:

$$v = \frac{1.409 C f_D}{f_O \cos\theta} \tag{1}$$

where

f_D is the output frequency of the radar, Hz;
v is forward speed of the planter, km/h;

fo is the transceiver frequency, Hz, the standard transceiver frequency of 2.4125×10^{10} Hz;
c is speed of light (1.079×10^{9} kmh^{-1});
θ is the mounting angle.

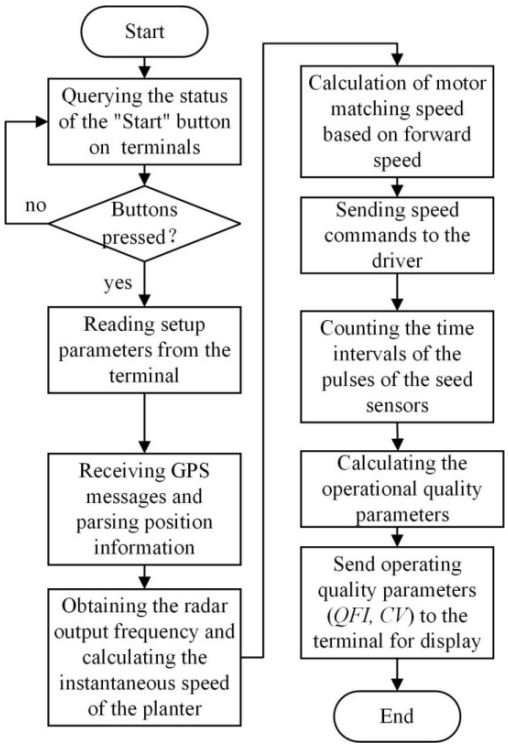


Figure 3. Program of controller.

Figure 4. The radar was mounted on the beams of the planter at a height of 0.8 m.

The output frequency is proportional to the forward speed. When using the standard transceiver frequency of 24.125 GHz, the frequency will be 33.6 Hz/kmh^{-1} at a 35° mounting angle. However, any error in the mounting angle will directly affect the radar accuracy. At 35°, an error of 1°approximately results in a 1% error in speed measurement. A post-installation calibration should be performed to remove any errors. Therefore, the measuring speed of the radar was calibrated before the test. The angle changes slightly during operation due to ground undulation. Considering that the angle is not easy to measure in real time, the angle in the calculation formula is removed and replaced by a correction factor α.

The equation for the forward speed v is as follows:

$$v = \alpha \times 27.32 \times 10^{-3} \times f_D \tag{2}$$

where

v is forward speed of the planter, km/h;

α is the correction coefficient;

f_D is the output frequency of radar, Hz.

The calibration tests were conducted at six speeds of 4.10, 6.20, 8.0, 10.1, 12.0, and 14.2 km/h, with three replications, based on the range of conventional operating speeds of the planter. The test results are shown in Table 1.

Table 1. Test results of radar calibration.

Forward Speed/kmh^{-1}	Theoretical Output Frequency/Hz	Actual Output Frequency/Hz			Mean Value of Actual Output Frequency/Hz
		Repeat 1	Repeat 2	Repeat 3	
4.1	85.67	66	77	90	77.67
6.2	129.55	108	114	138	120.00
8.0	167.16	142	156	172	156.67
10.1	211.04	190	181	198	189.67
12.0	250.74	239	225	252	238.67
14.2	296.71	276	265	293	278.00

It can be seen that there is an error between the actual and the theoretical output frequency at each speed. Considering the ground fluctuation in the field during operation, the angle of the planter changed slightly during operation. The uneven ground also has a certain impact on the reflection waves of the radar, which may cause an error in speed measurement. A linear regression was performed on the measured data, and the results are as shown in Figure 5. There is an obvious linear relationship between the forward speed and the radar output frequency, and the correlation coefficient is 0.9972. However, the radar output frequency and the forward speed are not a proportional function, which does not correspond to the instructions. This is because the results of multiple tests can only be achieved at a theoretical speed if each test is carried out under ideal conditions, which is almost impossible to accomplish in the field. In fact, in each test, there were errors between the results and the theoretical values. Therefore, the errors were minimized by multiple test calibrations, which led to a difference in the relationship obtained and the theoretical one, but this is more suitable for practical operation.

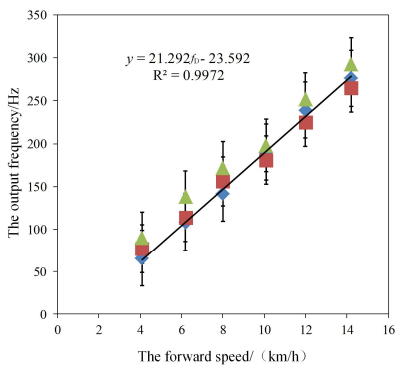


Figure 5. The relationship between the forward speed and the output frequency of the radar.

The relationship between the forward speed and the output frequency is:

$$v = 21.292 \times f_D - 23.592 \tag{3}$$

The forward speed of the planter can be calculated based on the equation obtained by the calibration test.

2.5. Rotational Speed Control of the Seed-Metering Device

The speed of the seed-metering device was regulated according to the forward speed. Therefore, it is necessary to establish the equation for the radar output frequency and the rotational speed of the motor. The relationship between the forward speed and the rotational speed of the seed-metering device has been clarified in existing article [17]. Combined with Equation (3) in this study, the equation for calculating the rotational speed of the motor and the radar output frequency was established as follows:

$$n_D = \frac{5000 \cdot i}{3 \cdot S_{ref} \cdot L} \times (21.292 \cdot f_D - 23.592) \tag{4}$$

where

n_{D} is the motor speed, r/min;
S_{ref} is the theoretical plant spacing, obtained from the setting parameters, cm;
L is the number of holes, obtained from the setting parameters;
i is the deceleration ratio, obtained from the setting parameters.

2.6. Detection of Planting Quality Parameters

The detection of planting quality parameters was achieved by using a photoelectric sensor placed inside the seed guide tube. The controller received the time difference (Δt) between two adjacent pulse signals. According to China National Standard GB/T 6973-2005 (2005) [18], it is necessary to statistically analyze the actual plant spacing based on intervals of 0.5 times the theoretical plant spacing. The *QFI* and *PREC* were calculated based on the frequency of the actual plant spacing occurring within each interval. Since the planting quality parameters were calculated based on frequencies, the calculation relationship between the time difference (Δt) and plant spacing can be disregarded. Instead, the time difference (Δt) was directly analyzed based on intervals of 0.5 times the theoretical time difference (Δt_{i_ref}), to simplify the calculation steps of the control system and improve operational efficiency. The theoretical time difference (Δt_{i_ref}) can be obtained from the theoretical plant spacing and the instantaneous speed of the planter, as Equation (5).

$$\Delta t_{i\_ref} = \frac{3.6 \times S_{ref}}{100 \times v_i} \tag{5}$$

where

v_{i} is the instantaneous speed of the planter acquired by radar, km/h;
S_{ref} is the theoretical planting space, obtained from the setting parameters, cm.

2.7. Test Arrangement

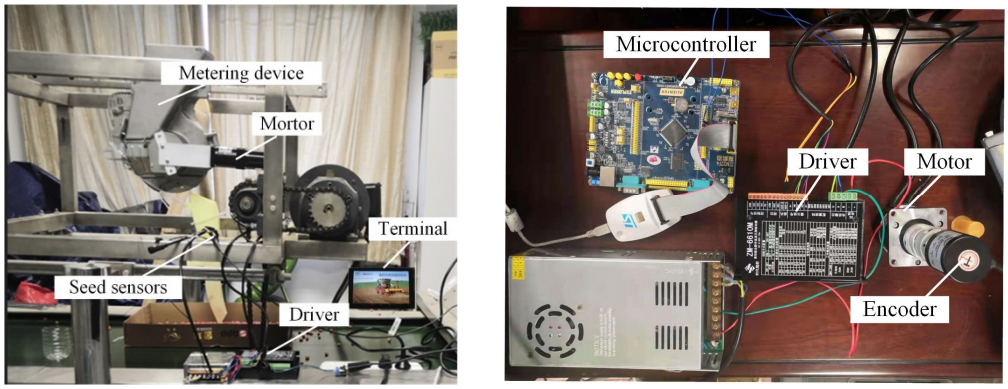
Laboratory tests can accurately control a single variable and eliminate the interference caused to indicators by a complex field environment, making it easy to evaluate various functions of the control system [19]. Laboratory tests for the accuracy of quality parameters detection and rotational speed of the motor control were performed. It was inconvenient to obtain the forward speed by radar during the laboratory test, so it was set to a fixed value in the control system program.

Field experiments were carried out in the experimental station of the Nanjing Institute of Agricultural Mechanization, Ministry of Agriculture and Rural Affairs, in June 2023. The weather was sunny, and the lighting was fine. The field was relatively flat, without straw mulching. The soil in the test site was classified as loam soil, which was composed mainly of light and medium loam; soils are generally weakly acidic. The soil was treated to a depth of 15 cm by rotary tillage.

3. Results and Discussion

3.1. Lab Tests for Quality Parameter Detection and Rotational Speed of Motor Control

The quality parameters of the control system were tested on the JSP-12 test bench with two fixed speeds of 8 and 10 km/h (Figure 6a). The seed sensor was mounted in the seed tube at the lower end of the seed-metering device. When the number of dropped seeds reached 250, the terminal displayed the planting quality parameters. Meanwhile, planting quality parameters were obtained under the same test conditions using the JSP-12 precision planting test bed [20]. The planting quality detection of the test bed adopted the principle of image recognition. The reliability of the planting quality detection of the control system designed in this study can be determined by comparing it with that in the experimental benchmarking.



(**a**) (**b**)

Figure 6. Lab tests for quality parameter detection (**a**) and motor speed control (**b**).

In addition, the speed control accuracy of the drive motor was determined by installing an encoder on the drive motor. Four forward speeds, 6, 8, 10, and 12 km/h, were selected for testing. Under a gear reduction ratio of 36, 24 planting holes, and a target plant spacing of 25 cm, the corresponding rotational speeds of the motor were set at 600, 800, 1000, and 1200 r/min. A microcontroller was used to acquire the rotational speed from the encoder and compare it with the theoretical speed of the motor, as shown in Figure 6b. During the tests, once the drive motor attained its rated speed, the speed information was sampled every 1 ms a total of 20 times, and the average of the 20 samples was calculated to determine the actual speed of the drive motor.

The test results show that, at a forward speed of 8–10 km/h, the maximum error of the quality parameters between this system and the JPS-12 lab bench did not exceed 2.88% (Table 2). However, at a forward speed of 10 km/h, the error between the two was relatively larger. At a forward speed of 10 km/h, the system identified 248 seeds, which was 2 seeds less than the actual number [21]. The reason for this discrepancy may be that the test bench uses a photoelectric sensor. When two seeds fall simultaneously, with a very short time difference in their trajectories, the photoelectric sensor considered them as one seed and could not differentiate them, resulting in an omission error. On the other hand, the JSP-12 lab bench utilized image recognition, which can relatively accurately identify seed numbers, even if the time difference between the falling of two seeds is very small, as long as their trajectories do not completely overlap. Therefore, the detection accuracy of the image method was higher than that of the photoelectric method. However, due to the need for an embedded camera and exposure device, which occupy a large space, it cannot be installed in narrow planting tubes. Hence, photoelectric sensors are more widely used in the quality detection systems of planters in the field.

Table 2. Comparison of quality parameters between designed control system and JSP-12 test bench.

Forward Speed/ kmh^{-1}	Qualified Parameters	This Study	JPS-12 Test Bench	Error/%
8	Number of seeds	250	250	0.00
	QFI/%	97.27	97.65	0.39
	MI/%	1.42	1.44	1.39
	PREC	2.86	2.91	1.72
10	Number of seeds	248	250	0.80
	QFI/%	96.23	96.89	0.68
	MI/%	2.5	2.43	2.88
	PREC	4.68	4.81	2.70

The mean value of the rotational speed of the motor for 20 times is shown in Table 3. The error of the rotational speed of the motor was less than 0.76% under the four forward speeds, indicating that a high regulation accuracy was obtained.

Table 3. Test results of the rotational speed of motor.

Forward Speed/kmh^{-1}	Theoretical Speed/ (r/min)	Real Speed/(r/min)	Error/%
6	600	604.62	0.76
8	800	805.11	0.63
10	1000	1000.21	0.02
12	1200	1202.14	0.18

3.2. Field Tests for Operation Performance of the Control System

The control system was installed on a corn precision planter produced by Shandong Dahua Agricultural Machinery Co., Ltd. (Jining, China), and the planter was connected with four planting units as shown in Figure 7. Zhengdan 958, which is commonly used in maize seeds, was selected; the planting distance was set at 20 cm, and the forward speed was 6, 8, 10, and 12 km/h. The maize variety had a 1000-seed weight of 332 g, and a moisture content of 13%. The seeds were graded before use; the dimension parameters of 1000 seeds were measured, with the average length and width of seeds being 11.2 mm and 8.9 mm, respectively. After the experiment, the seeds were picked out for plant spacing collection. According to China National Standard GB/T 6973-2005 (2005) [18], the *QFI* and the *PREC* were used as indexes to evaluate the performance of the control system.

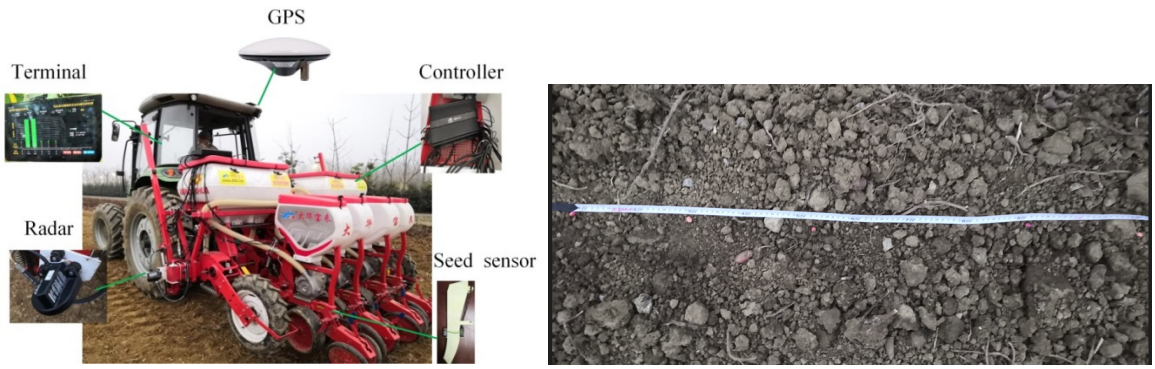


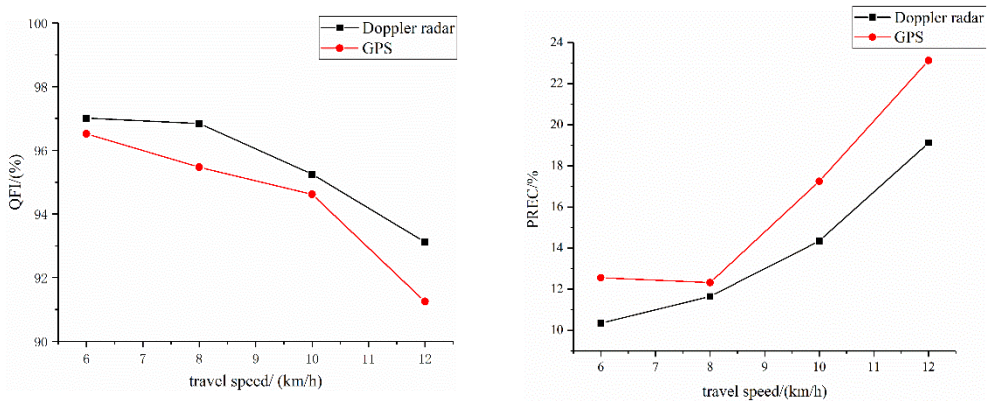
Figure 7. The planter and its driving system for field tests.

Based on the previously established relationship between the radar output frequency and the forward speed of the planter, radar can be utilized to obtain the forward speed of the planter. Moreover, a comparative experiment was conducted to highlight the advantages of radar for speed measurement. In this experiment, two speed measurements, GPS and radar,

were used to obtain the forward speed of the planter. Currently, GPS is commonly used as the speed measurement in research related to electric-driven planting systems. Ding et al. compared two speed measurement methods, GPS and an encoder, and the results showed that GPS had a better accuracy, especially when the operating speed was higher [22].

The use of GPS to obtain the forward speed can be achieved by a program modification of the controller. Originally, GPS was included in the control system for the implementation position of the planter. GPS also has the function of measuring speed. In the modified program, besides position information, speed was also extracted, so that a comparison between the two speed measurement methods could be realized.

The test results are shown in Figure 8. The *QFI* of the radar is better than GPS at the conventional operation speed of the planter of 6–12 km/h (Figure 8a). At speeds of 6, 8, 10, and 12 km/h, the *QFI* of the radar was 0.51% and 1.44%, 0.67% and 2.05% higher than that of GPS, respectively. Similarly, the *PREC* showed that radar was better than GPS (Figure 8b). Under different operating speeds, the *PREC* of radar was smaller. At 6, 8, 10, and 12 km/h, the *PREC* of radar was lower by 17.60%, 5.44%, 16.81%, and 17.30%, respectively.



(**a**) (**b**)

Figure 8. The *QFI* (**a**) and *PREC* (**b**) of the control system at speeds of 6, 8, 10, and 12 km/h.

A variance analysis was performed on the effects of forward speed and speed measurement on the *QFI* and *PREC*, as shown in Table 4. The results demonstrate that both the speed measurement method and forward speed have significant influences on the *QFI* and *PREC*. The influence of forward speed is extremely significant ($p < 0.01$). The decrease in the qualified index with an increase in operating speed was determined by the performance of the planter itself. As the planter's rotational speed increased, the time for seed filling and clearing decreased, leading to a significant reduction in the desired plant spacing. Furthermore, with higher forward speeds, seeds hitting the ground at higher velocities were more prone to bouncing, resulting in a decrease in the *QFI* and an increase in the *PREC* [23].

Table 4 shows that using radar speed measurement yielded better planting quality parameters compared to GPS speed measurement, and it reached a significant level. This indicated that a control system utilizing radar speed measurement achieves a better planting quality. The reason behind this is that radar measures the instantaneous speed of the planter based on the Doppler effect, while GPS measures the average speed of the planter based on positioning information. The output frequency of GPS information is 10 Hz, which means it provides only 10 speed measurements within 1 s. On the other hand, radar can obtain instantaneous speed measurements within a set time period, which could be a few milliseconds. In this program, the speed measurement of radar was set to be obtained every 20 ms. Within the same time frame, radar can acquire more precise speed information, which is more accurate for controlling the rotational speed of the motor. Saadat et al. pointed out a slipping rate between 6.08% and 8.77% for different precision planters [3]. Yang and Ding et al. stated the mechanical ground wheel driving systems unsuitable

for high-speed planting, and the planting quality deteriorated with increasing operating speeds. But they did not consider the effect of the speed sensor on the electric drive system [14,22].

Table 4. A variance analysis of the effects of forward speed and speed measurement methods on the *QFI* and *PREC*.

Source of Variation	*QFI*				*PREC*			
	Sum of Deviation Square	Degree of Freedom	F Value	*p* Value	Sum of Deviation Square	Degree of Freedom	F Value	*p* Value
Speed sensor	2.376	1	11.330	0.044 *	11.956	1	12.303	0.039 *
Speed	24.755	3	39.343	0.007 **	119.439	3	40.967	0.006 **
Error	0.629	3			2.915	3		
Total	72,242.961	8			1955.975	8		

Note: * means reaching the level of significance ($p < 0.05$), ** means reaching the level of extreme significance ($p < 0.01$).

Additionally, GPS calculates speed based on position information, which can be affected by signal interruptions or position drift, thus impacting the accuracy of speed measurement. Radar avoids these issues and achieves a better operational performance. However, it should be noted that radar calculates forward speed based on the frequency of reflected waves from the ground, and surface coverings in the field can potentially affect the accuracy of speed measurement. In this experiment, the surface is relatively flat after tillage treatment, which mitigates the negative impact of these factors. For surfaces covered with crop residues, further research is needed to investigate the accuracy of Doppler radar speed measurement.

4. Conclusions

We have designed a precision planter control system that incorporates planting quality detection and the controlling of the rotational speed of the seed-metering device. The system utilized radar to measure the forward speed of the planter, thereby improving the accuracy of speed measurement and the precision of controlling the rotation speed of the seed-metering device. The system employed a distributed control architecture using the CAN bus, allowing the independent control of motors on each planting unit. This enables the system to be easily applied to planters with different rows. Furthermore, in the algorithm for planting quality detection, a statistical time difference method is used, instead of plant spacing, to calculate planting quality parameters, significantly improving the execution efficiency of the controller.

We conducted calibration tests on the radar to establish the relationship between forward speed and the radar output frequency. We tested the precision of the motor speed control through lab experiments, and the error between the actual and theoretical motor speeds at forward speeds of 6, 8, 10, and 12 km/h did not exceed 0.76%. This indicates that the system can achieve high-precision motor speed control. Additionally, compared to the JPS-12 lab bench, the maximum error in planting quality parameters obtained by the designed system was less than 2.88%.

Field tests were conducted on the control system. The results show that the speed measurement method and forward speed significantly influence the *QFI* and *PREC*. Among them, the effect of forward speed on the *QFI* and *PREC* reached an extremely significant level ($p < 0.01$). When the system utilized radar, the qualified indexes obtained at the conventional forward speeds of 6–12 km/h were significantly better than that obtained by GPS. At forward speeds of 6, 8, 10, and 12 km/h, the *QFI* processed with radar was 0.51%, 1.44%, 0.67%, and 2.05% higher, respectively, compared to GPS. The *PREC* processed with radar was 17.60%, 5.44%, 16.81%, and 17.30% lower, respectively. This indicates that a control system utilizing radar speed measurement can achieve a better operational performance.

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