Remote monitoring system for maize seeding parameters based on Android and wireless communication

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Abstract: Most traditional maize seeding parameter monitoring devices use wired data transmission. The problems include wiring troubles, short transmission distances. And human-computer interaction display terminals are unique and usually customized rather than universal. A remote monitoring system for maize seeding parameters based on Android and wireless communication was developed in this study. The system used a single-chip microcomputer as the main controller and an infrared photoelectric sensor to capture seed information. The Android terminal application was used to set and display the seeder's seed parameter information and monitor it. The Air202 communication module enabled remote data transmission, while the Global Positioning System (GPS) monitored the speed of the planter. By establishing a message queue telemetry transmission (MQTT) cloud served as a data freight station, data reception, storage and forwarding can be performed. Seeding parameters can generate Excel spreadsheets in real-time for easy data processing and storage. In order to verify the reliability of the system, the seeding parameter monitoring comparison test and the multi-terminal remote monitoring test were designed. The results of the seeding parameter monitoring comparison test showed that the monitoring system of this study had higher monitoring accuracy. The maximum average relative error of seeding parameter monitoring was 0.4%, which had high monitoring accuracy. The multi-terminal remote monitoring test showed that the monitoring system of this research can adapt many types of Android terminals, realize the wireless connection, and realize remote synchronous monitoring at different distances. This study provides a reference for intelligent remote monitoring and intelligent agriculture on unmanned farms.

Keywords: remote monitoring system, maize seeding parameters, Android and wireless communication, remote synchronous monitoring, intelligent agriculture

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1 Introduction

Planting operations are a key step in agricultural production. The quality of planting has a huge impact on crop yields and indirectly affects agricultural economic benefits[1]. Therefore, accurate and timely monitoring of seeding quality can provide an important basis for seeding parameter adjustment, seeding equipment selection, and production forecasting. It is important to monitor changes in the performance of seeding operations[2-4]. Seed sensors are an important means to obtain seed information. Photoelectric sensors are the most common and are ideal for non-contact monitoring[5-7], which usually placed in the middle of the seed tube, consisting of a light-emitting element and a light-receiving element. Karimi et al.[8] developed and evaluated light-dependent resistors (LDRs), infrared (IR), and laser diodes (LD) sensing units. Okan and Ismet[9] developed a computerized measurement system that incorporates adhesive belts. Besharati et al.[10] established a test device for the development of an IR seed-sensor response that estimated the mass flow of various seeds based on received voltage, 1000-grain weight, and seed equivalent diameter. Kostićet al.[11] verified photosensor evaluation methods using data and image analysis under simulated conditions. Hao et al.[12] developed a compact instrument to quickly measure the performance and practical application of a seed meter. Wu et al.[13] designed a portable seed meter performance monitoring system with PLC and touchscreen as the core, which can set the parameters of the seed meter and detect its performance indicators in real-time. Sun et al.[14] designed a Cortex-M3-based no-till planter monitoring system, which can adjust the amount of fertilizer in each line according to the working speed of the machine during operation, and monitor the sowing and fertilization status in real-time. Che et al.[15] designed a seeding quality monitoring system based on a PIC microcontroller platform to monitor the seeding count, missed broadcast, and offline conditions. Huang et al.[16] proposed a seed-monitoring system based on GPS and general packet radio service (GPRS) that realized the remote transmission of seeding-quality information data. Karayel et al.[17] developed a high-speed camera system to measure the spacing and speed at which wheat seeds fall. The display of monitoring systems is dedicated, not universal, and has certain limitations[18-21].

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After understanding the current research status of the seeding parameter monitoring system, it is found that the seeding parameter monitoring system still needs improvement. The current monitoring system is mainly composed of sensors, a main controller and a terminal display. Generally, the main controller and the terminal display are integrated or connected by wires. The information processing unit and the display unit are inseparable, the wiring is troublesome, and the distance is limited. There is a one-to-one mode between the two, and it is impossible to achieve multiple terminals simultaneously display the monitoring results. The monitoring content is relatively simple, mainly based on the statistics of the seeding amount. When monitoring multiple single-combination planters, data communication and controller power supply need to arrange main lines and many branch lines, which is very cumbersome.

In response to the above problems, a remote monitoring system for maize seeding parameters based on Android and wireless communication was developed. After the information collected by the sensor is processed by the microcontroller unit (MCU), the resulting parameters are transmitted to the Android terminal application display through the remote communication module and the cloud server to realize real-time monitoring of the maize seeding parameters. The parameters monitored by the system are more comprehensive. In addition to counting the seeding volume, it can also count the seeding qualification rate and real-time plant spacing and other parameters to more accurately reflect the seeding status of the planter. Using wireless communication instead of wired communication can avoid the trouble of wiring. Real-time monitoring of multiple Android terminal devices can be realized at the same time. The controller and the display are no longer integrated, and a one-to-many or many-to-many communication mode is realized. This research is of great significance to the development of agricultural intelligence.

2 Materials and methods

The remote monitoring system for maize seeding parameters based on Android and wireless communication aims to achieve versatile remote monitoring through a non-unique terminal display. The traditional wired connection and close-range monitoring modes have been changed while changing the one-to-one mode of the control system and the terminal display. The system realizes the collection of seed parameters, GPS speed measurement, map positioning, remote communication, terminal application display, data storage and other functions.

2.1 Design of system information acquisition and calculation part

The entire monitoring system (Figure 1) includes a seed information capturing unit, a GPS speed acquiring unit, an information processing unit, a communication unit, an alarm unit, an MQTT cloud server, and an Android terminal. When seeding, the seed passes through the information capture unit, and a physical signal is converted to an electrical signal.

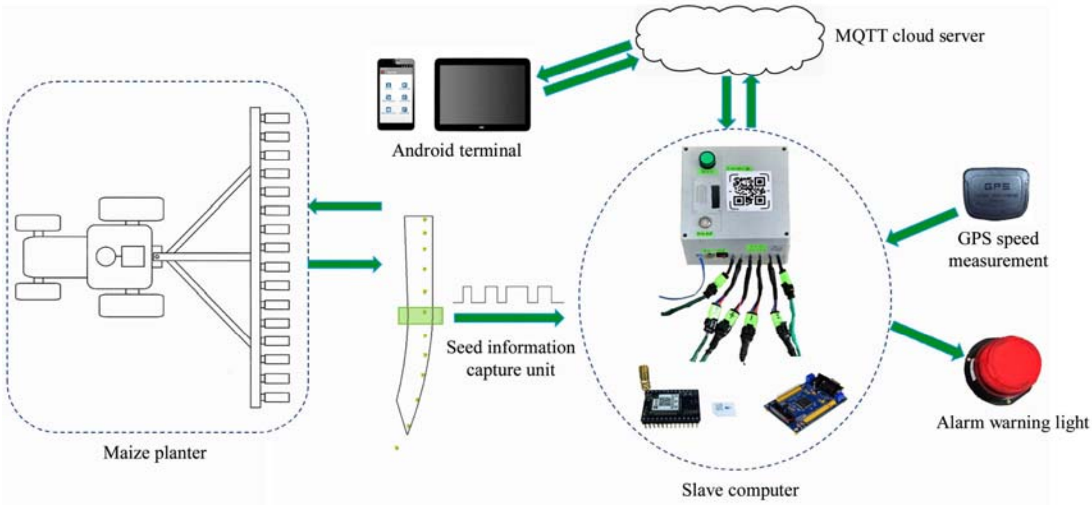


Figure 1 Overall composition of the monitoring system

At the same time, GPS obtained speed information, and the information aggregated to the information processing unit for calculation and analysis, and finally, all parameters were obtained. Then, use the communication unit to send the data to the MQTT cloud server according to the designed protocol. Finally, display in real-time on the Android terminal to complete the monitoring of the seeding parameters. Before planting, it was necessary to set the corresponding parameters on the monitoring app according to the parameters of the planter, including the number of holes and standard plant spacing of the seed meter. After the setting is completed, the data is sent to the cloud server and finally to the controller, and the corresponding variables are assigned to complete the parameter setting of the planter. At the same time, the controller will return the corresponding parameters to the app monitoring interface to form closed-loop monitoring to ensure that the parameters are set successfully. In the event of a failure, the information processing unit will control the alarm unit to give an alarm in time to remind the driver to stop and check.

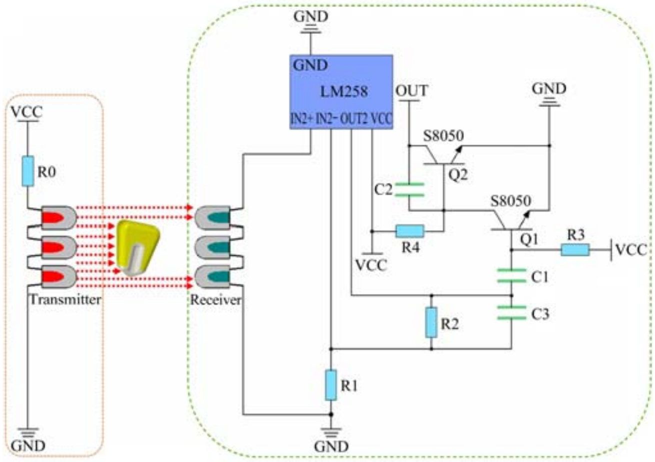


Figure 2 Optoelectronic sensor circuit design

To capture seed information, an infrared radiation photosensor (Figure 2) was installed in the middle of the seed tube to count and time the seeds. The time interval is determined by detecting the edge signal on the Channel of the microcontroller timer (TIMx_CHx). When the edge signal transitions (rising edge/falling edge), the current timer value (TIMx_CNT) is stored in the corresponding channel's capture/compare register (TIMx_CCRx) to complete capture. Figure 3 shows the capture and seeding parameter calculation criteria of the seed signal.

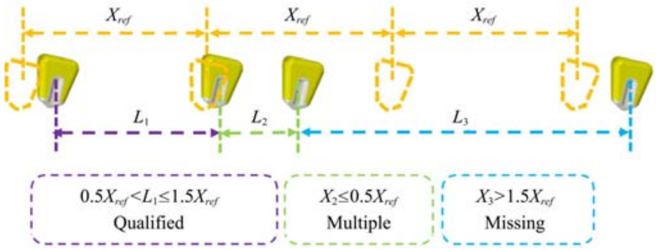
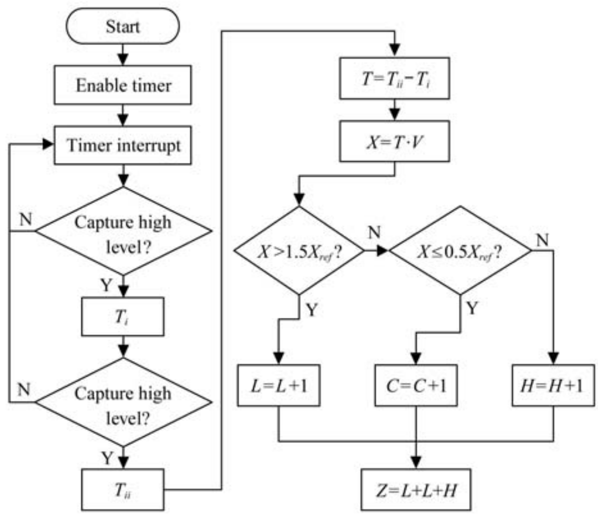


Figure 3 Seed signal capture and PWM shaping

The calculation process (Figure 4) is based on the standard test method ISO 7256-1 developed by the International Standards Organization (ISO) (1984)[22].



Note: $T_{ii}-T_i$ is the time between two adjacent signals; L is the seeding missed quantity; C is the seeding of multiple quantities; H is the seeding qualified quantity; Z is the total amount of sowing.

Figure 4 Obtain and calculate seeding parameters

This method has been adopted by the Chinese national standard as GBT 6973-2005 (China National Standard, 2005)[23].

If

$$X>1.5X_{ref} \quad (1)$$

Counted as missing;

If

$$X\leq0.5X_{ref} \quad (2)$$

Counted as multiple, the rest are qualified.

where, X is the real-time seeding seed spacing, cm; X_{ref} is the seeding theoretical seed spacing, cm.

By calculation:

$$X=\frac{250TV}{9} \quad (3)$$

where, T is two consecutive seed intervals or pulse periods, s; V is the planter forward speed, km/h.

Calculate the corresponding probabilities:

$$l=\frac{L}{Z}\times100\% \quad (4)$$

$$c=\frac{C}{Z}\times100\% \quad (5)$$

$$h=\frac{H}{Z}\times100\% \quad (6)$$

where, l is the miss rate, %; c is the multiple rate, %; h is the qualified rate, %.

To accurately obtain the speed of the planter, a UB-355 GPS receiver (Shanghai Jidu Information Technology Co., Ltd, Shanghai, China) was used for speed measurement. The speed-accuracy is 0.1 m/s, the maximum signal update frequency is 10 Hz, the cold start time is within 26 s, and the hot start time is 1 s. The working temperature was −40°C to 80°C, and the performance met the requirements of the work. The GPS receiver used RS232 serial communication and was converted to TTL and STM32 serial communication.

After obtaining the GPS information, the speed is obtained and the speed of the seeder is determined as:

$$V=1.852\times K_n \quad (7)$$

where, K_n is the unit of speed dedicated to sea navigation, kn. GPS can directly obtain the real-time data of K_n.

The Air202 communication module (Shanghai Hezhou Communication Technology Co., Ltd, Shanghai, China) was used as GPRS module, which can be used in an open source environment or with an AT command. Message queuing telemetry transport (MQTT) is a message protocol based on a binary message-based publish/subscribe programming mode. It was proposed by International Business Machines Corporation (IBM) and has become the Organization for the Advancement of Structured Information Standards (OASIS) specification. This simple specification is ideal for IoT scenarios that require low power and limited network bandwidth. An MQTT server, or "broker," can be an application or a device. It is located between the message publisher and the subscriber. It can accept network connections from customers, accept application information published by customers, process subscribe and unsubscribe requests from clients, and forward application messages to subscribed customers. With the MQTT cloud server, remote subscription and release of control system data can be realized to enable remote monitoring.

2.2 Design of system terminal app human-computer interaction

The Android mobile terminal app human-computer interaction program is developed based on Android Studio and programmed in the Java language. Its design includes four parts. First, add the monitoring object part, mainly by scanning the two-dimensional code to add the monitoring object. Multiples can be added, and each Air202 device has a unique two-dimensional code, known as the international mobile equipment identity (IMEI). Second is the display interface, including the parameter input, result display, and dynamic curve drawing. The curve drawing adopts a chart library, an Android app called AChartEngine, which has a powerful drawing function. The app monitoring parameter display interface (Figure 5) applies to the four-row maize planter, including the positioning and satellite map display, which is convenient for obtaining a real-time position.

When the seeder is properly seeding, the seeding unit in the planter image is displayed in green, and if the seeding fails, it is displayed in red. This is very convenient for the planter driver and can detect and eliminate planting errors in a timely manner. The standard seed spacing is shown in wide sky blue lines, which makes it easy to observe fluctuations in real-time seed spacing and visually reflect changes in seed spacing. The app has four layouts to draw the parameter curve of each line, and these can be arbitrarily scaled. The third part is for data receipt and updating. The app receives data from the MQTT cloud server in real-time through the network to update the display interface. Fourth, data is exported to generate the Excel file, using the tool-class library jxl.jar, which can create and edit Excel tables, including attributes and format. Through this, the seeding parameters obtained by the app can be instantly added to the Excel table for later data processing and storage. Figure 6 is a brief program flow for the App interface update.

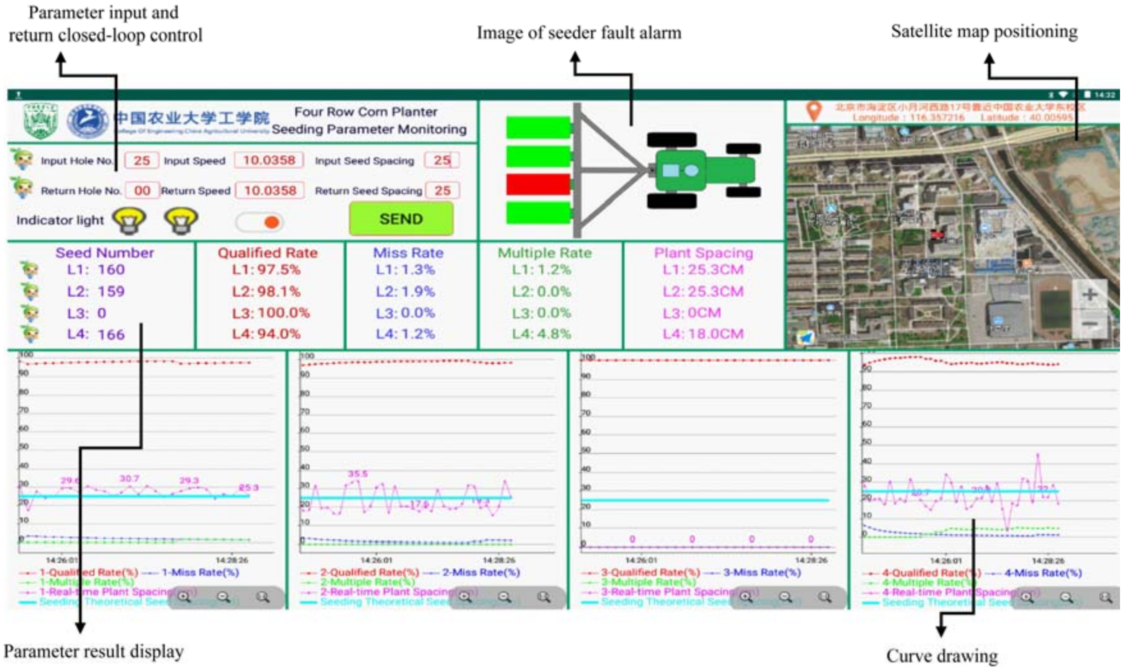


Figure 5 Seeding parameter monitoring app design

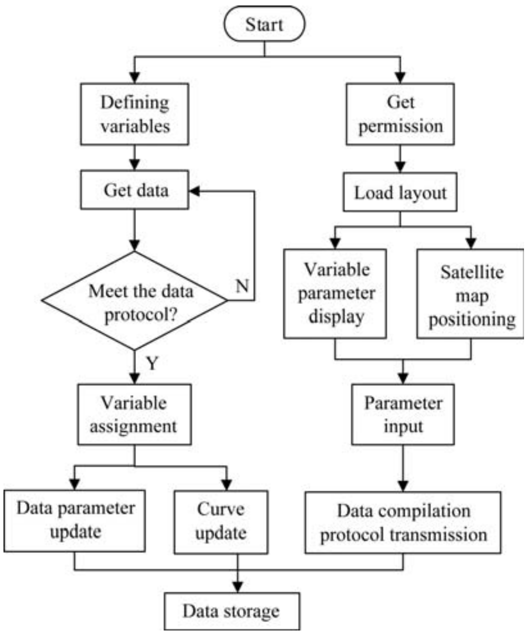


Figure 6 App interface update brief program flow

2.3 Experimental verification

2.3.1 Seeding parameter monitoring comparison experiment

The seeding parameter monitoring comparison test is to verify the reliability of the monitoring system. Compared with the seeding parameter detector developed by the College of Engineering, China Agricultural University (Figure 7), Hao et al.[12] verified that the seeding parameter detector has high monitoring accuracy. The air suction type meter is selected as the monitoring object, and the seeding theoretical seed spacing is set to 25 cm. Tested at different speeds of 5 km/h, 6 km/h, 7 km/h, 8 km/h, 9 km/h and 10 km/h, three tests were repeated for each speed. The test results are listed in Table 1.

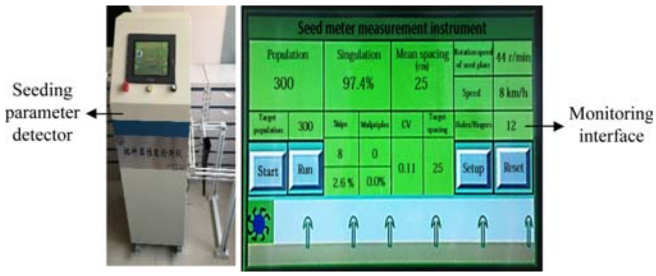


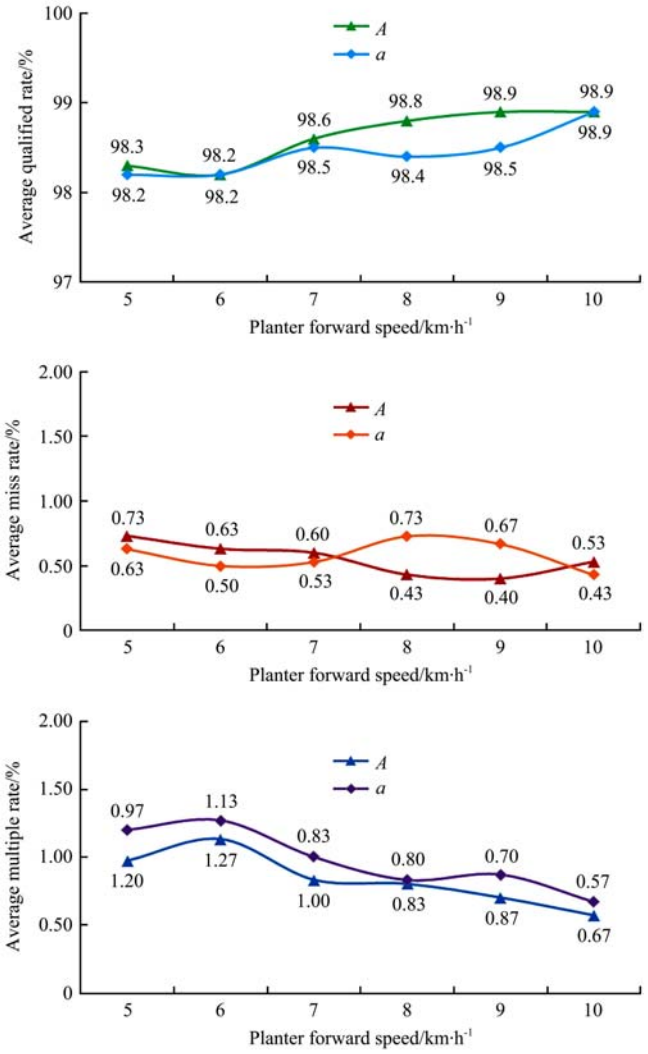
Figure 7 Seeding parameter detector

Table 1 Seeding parameter monitoring comparison experimental data

Speed /km·h^{-1}	Seed number	Qualified rate/%		Miss rate/%		Multiple rate/%	
		A	*a*	*A*	*a*	*A*	*a*
5	500	98.1	98.2	0.6	0.5	1.3	1.3
	500	98.5	98.3	0.8	0.8	0.7	0.9
	500	98.3	98.0	0.8	0.6	0.9	1.4
6	500	98.0	98.1	0.7	0.4	1.3	1.5
	500	98.3	98.5	0.5	0.5	1.2	1.0
	500	98.4	98.1	0.7	0.6	0.9	1.3
7	500	98.8	98.3	0.4	0.7	0.8	1.0
	500	98.4	98.5	0.9	0.3	0.7	1.2
	500	98.5	98.6	0.5	0.6	1.0	0.8
8	500	99.0	98.7	0.3	0.5	0.7	0.8
	500	98.9	98.5	0.4	0.7	0.7	0.8
	500	98.4	98.1	0.6	1.0	1.0	0.9
9	500	98.7	98.2	0.4	0.8	0.9	1.0
	500	99.1	98.7	0.3	0.5	0.6	0.8
	500	98.9	98.5	0.5	0.7	0.6	0.8
10	500	98.9	99.1	0.6	0.3	0.5	0.6
	500	99.0	98.6	0.4	0.6	0.6	0.8
	500	98.8	99.0	0.6	0.4	0.6	0.6

Note: *A* is the monitoring system of this study; *a* is the seeding parameter detector.

Through the analysis of the test data, it was found that the monitoring system of this study was basically close to the monitoring result of the seeding parameter detector. Figure 8 is the average of the seeding parameters for each speed.



Not: *A* is the monitoring system of this study; *a* is the seeding parameter detector.

Figure 8 Average seeding parameters at each speed

2.3.2 Multi-terminal remote monitoring test

In order to verify the remote monitoring function of the research monitoring system and the adaptability to various android terminals, four different models of android tablets were tested in four locations. The parameters and location of the tablet are listed in Table 2. Figure 9 is the test bench.

Table 2 Android tablets parameters and location

Tablet number	Brand	Model	Size (inches)	Location	Distance from control box
I	TouchWo	TD173	17.3	China Agricultural University in Beijing	2 m
II	HuaWei	JDN-W09	8.0	China Agricultural University in Beijing	10 m
III	XiaoMi	MI PAD2	8.9	Shandong University of Technology in Zibo	380 km
IV	HuaWei	M5	10.1	Northwest A&F University in Yangling	970 km

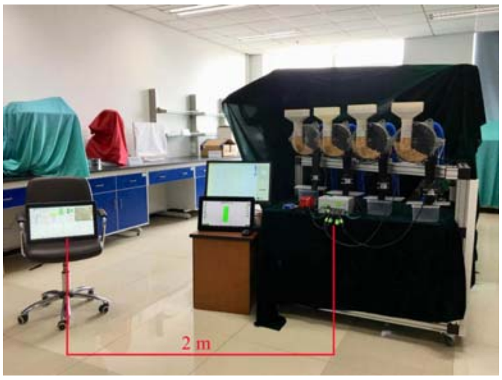


Figure 9 Seeding monitoring electric drive test bench

The test was repeated 5 times, set the fourth line of the test bench to fault as a comparison, and one of the test results was selected as a demonstration. Figure 10 is the app result display interface. Figure 11 is the terminal tablet computer result display. It can be seen that the monitoring system of this study can realize simultaneous online monitoring of remote multi-terminals, and the app has good adaptability. It can be used normally on android tablet terminals of different brands and different sizes.

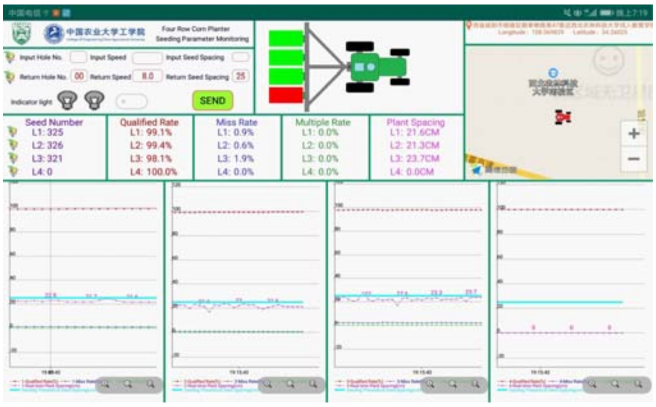
3 Results and discussion

Through experimental tests, the seeding parameter monitoring system designed in this research had a good working performance. The results of the seeding parameter monitoring comparison experiment showed that the monitoring system of this study was similar to the monitoring result with the higher precision monitor, it can be seen that the curve change of average qualified rate, average miss rate and average multiple rate was basically similar at 5 km/h, 6 km/h and 7 km/h of the planter speed. At 8 km/h and 9 km/h, the average miss rate is slightly different, but the error is not large, and the maximum average error is only 0.3%, and the multiple rates are basically similar. At 10 km/h, the average qualified rate, average miss rate and average multiple rate of the two monitoring are basically the same. The increase in speed has a certain impact on the accuracy of monitoring, but the error caused by this impact is not large. The maximum average error of the two monitoring systems is 0.4%. Therefore, the monitoring system of this study has a similar high-precision monitoring performance as the seeding parameter detector. Although there is a certain deviation at high speed, the error is extremely small and does not have a major impact on the monitoring results. It can meet the actual needs.

The advantages of multi-terminal remote monitoring tests show that the monitoring system of this research can realize remote monitoring of multiple android terminals at the same time, with no need to connect wires, the terminal display does not need special customization, and it has better adaptability and versatility than similar products. The app can be installed arbitrarily on Android tablets of different brands and sizes. The data transmission is stable and reliable, and there will be no data loss problems. The data transmission success rate is 100%. The app display interface will update relevant data parameters in real-time, the curve will be drawn in real-time, and the satellite will be positioned in real-time. The monitored data can be stored in real-time, which is convenient for later analysis and processing. It can alarm in time if there is a failure, and the success rate of the failure alarm is 100% to ensure the normal planting operation. The test once again verifies the high accuracy of the monitoring system, which meets the requirements of planter monitoring.

a.

b.

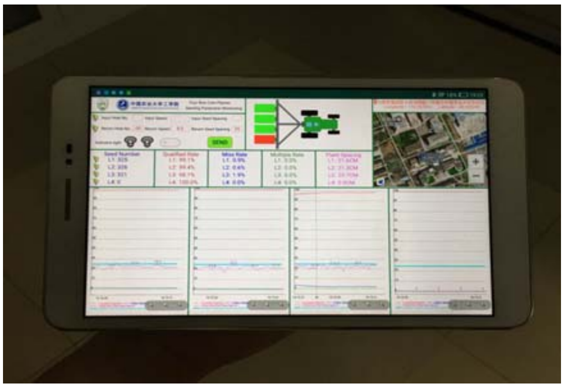


c.

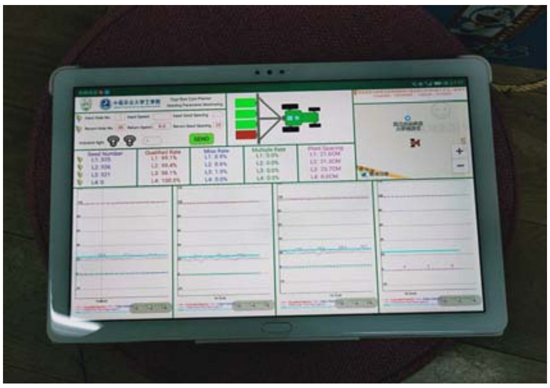
d.

Figure 10 App result display

a. At China Agricultural University in Beijing. Distance: 2 m, Longitude: 116.357812°, Latitude: 40.00523°



b. At China Agricultural University in Beijing. Distance: 10 m, Longitude: 116.357812°, Latitude: 40.005242°



c. At Northwest A&F University in Yangling. Distance: 970 km, Longitude: 108.069829°, Latitude: 34.26025°

d. At Shandong University Of Technology in Zibo. Distance: 380 km, Longitude: 117.996089°, Latitude: 36.809924°

Figure 11 Terminal tablet computer result display

4 Conclusions

A remote monitoring system based on Android and Wireless communication was established. The monitoring system has high monitoring accuracy, and the system can realize wireless remote monitoring of multiple android terminals. It is not limited by distance. No data was lost during data transmission. The app can be applied to different types of Android devices. The human-computer interaction interface can input and display seeding parameters, and the results can be displayed more intuitively by drawing curves. The data results can be stored in real-time, and the fault can be alarmed in time, simultaneously it can be displayed on the app interface. The system has strong versatility and can provide great help for the seeding monitoring of planters, and at the same time provide a reference for the development of smart agriculture.

Acknowledgements

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