Design and experiment of seeding performance monitoring system for suction corn planter

Kun Liu[1], Shujuan Yi[2*]

(1. *College of Electrical and Information, Heilongjiang Bayi Agriculture University, Daqing, 163319, China*;
2. *College of Engineering, Heilongjiang Bayi Agriculture University, Daqing, 163319, China*)

Abstract: To realize the highly precise and real-time monitoring of seeding performance in suction-type corn planter, and intelligent detection technology was presented. In this monitoring system, firstly, the sensor was designed based on the photoelectric technology. Meanwhile, in order to reduce the influence of dust in the field on the photoelectric sensor, the installation position of the sensor was changed to the space under the seed plate instead of the traditional position, that is, the middle of the seed tube. Secondly, the scattering angle of the highlighting light-emitting diodes was considered to calculate the spacing of transmitters to realize non-blind area detection. Last but not least, the peak-detection algorithm was utilized to increase the detection accuracy. Therefore, after a lot of the indoor and field experiments, the analysis shows that the detection accuracy of seeding quantity can reach 98.45%, alarm delay time under abnormal circumstances is not more than 2 s. Obviously, this system can meet the requirements of seeding completely and improve its reliability greatly.

Keywords: seeding performance, monitoring system, peak-detection algorithm, photoelectric detection
DOI: 10.25165/j.ijabe.20191204.4185

Citation: Liu K, Yi S J. Design and experiment of seeding performance monitoring system for suction corn planter. Int J Agric & Biol Eng, 2019; 12(4): 97–103.

1 Introduction

With the increasing of corn planting size and the improvement of the mechanization level, the precision seeding technology is developing rapidly. The suction corn precision planter is widely used by the agriculturally advanced countries such as Europe and the United State for its advantages of high seeding precision, high seeding efficiency, high emergency rate and no damage to the seeds. Recent years, the suction corn precision planter is popularized promptly in China. Take the suction corn precision planter for instance, during the seeding operation period, one aspect is that factors such as the vacuum degree of the metering device, the shape of seed suction hole, the seeds size and the structure and adjustment angle of the seed scraping device will lead to the reseeding or the miss-seeding. Another aspect is that for the no-tillage seeding operation, the residual straw stubble on the ground can easily block the seed tube and account for the broken lines, which affects the normal seeding. Additionally, with the vigorous promotion of the precision agriculture and the implementation of the policy of sharing agricultural machinery in China in recent years, to realize the precision seeding, the higher requirements have been put forward for the accuracy of seeding quantity. Therefore, detecting the seeding performance of the suction corn precision planter which includes the seeding quantity, and the abnormal circumstances such as the reseeding, the miss-seeding and the empty or blocked state of the seed tube is of great importance to reduce the loss of corn seeding, increase the yield and the efficiency, and ensure the grain yield of China[1-5].

Received date: 2018-12-17 **Accepted date:** 2019-05-13
Biographies: Kun Liu, MS, Associate Professor, research interests: agricultural mechanization engineering, Email: lak197807@163.com.
***Corresponding author: Shujuan Yi,** PhD, Professor, research interests: agricultural mechanization engineering. College of Engineering, Heilongjiang Bayi Agriculture University, Daqing 163319, China. Tel: +86-13836961877, Email: yishujuan_2005@126.com.

Currently, there are four main methods to detect the seeding performance of the planter at home and abroad, namely, machine vision method, piezoelectric effect method, capacitance detection method and photoelectric detection method. Machine vision method is a method which uses the high-speed camera to take the image of the seed plate in the metering device, and then through the image processing to analyze the situation of the adsorbed seed and the falling seed and finally calculate the seeding quantity, the reseeding and the miss-seeding situation. But because its disadvantages such as the complicated system structure, high device cost, the complex and time-consuming process of data extraction and processing, machine vision method isn't generalized widely. Piezoelectric effect method is a method which uses the falling seeds to collide the piezoelectric sensor and converts pressure signal into electric pulse signal, and then measures the time interval to detect the seeding performance. Because the installation angle is not so easy to determine that the collision position and strength are not uniform and the detection precision is not high. Capacitance detection method is a method which uses the medium change between the plates to cause the change of the capacitance. It's a new method which has advantages of high reliability, strong anti-pollution ability, non-contact measurement in recent years and applied widely in the detection of moisture content, liquid level and material level. However, the capacitance may be affected by the seed moisture content and the falling speed. In addition, the parasitic capacitance and stray capacitance which have the influence on the detection accuracy. Photoelectric detection method is one of the most widely used methods and it makes use of photoelectric sensor to convert the falling seed into the stable pulse signal. This method has advantages of simple structure, easy installation, fast detection speed, low cost and high accuracy[6,7].

Though the photoelectric detection method has many advantages, once the detection blind zone or a certain dust that covers the surface of sensor may lead to the detection accuracy decreasing or false alarm. Hence, some advanced methods have been presented based on the photoelectric detection method. For example, Japan's Ahmad and his team presented to use 22 pairs of the laser transmitters as the light source[8]. But the laser is the straight beam, which is difficult to realize the non-blind zone detection and especially its installation is very complicated. In addition, Canada's Hamed Farahani proposed the photoelectric reflection method. That is, the transmitter and the receiver are located in the same side to reduce the working surface. Obviously, this method may account for the light cross-interference. Last is the self-cleaning dust removal device designed by Ji Chao based on a rotary transparent dust cover to prevent the sensor from dust influence, but this self-cleaning device itself affects the seeds passing and isn't convenient to maintain for the long-term use[9-13].

To realize the high-precision and the all-weather detection, in this paper, three super-bright light emitting diodes are taken as the transmitter and three photosensitive resistors are used as the receiver based on its high-sensitivity characteristics. In addition, three pairs of photoelectric tubes are on the crossed and opposed position to ensure the no-blind area detection. For the pulse signal of the seed falling obtained, a kind of advanced peak-detection algorithm is used to count the accurate seeding quantity and judge the abnormal situation in real time. Consequently, the result data are transmitted to the host computer to show and alarm.

2 System structure

The hardware part of the monitoring system is composed of the host computer and the slave computer, as shown in Figure 1. To simplify the installation structure and improve the transmission efficiency, the monitoring system uses the wireless communication mode between the host computer and the slave computer. The communication modules are the DL-22, 2.4G Zigbee with the communication range of 1500 m. In the case of the slave computer, it is primarily responsible for detecting and signal processing based on MCU STC12C5A60S2. Firstly, the seeding performance detection uses the photoelectric tubes to detect the seed falling and get the pulse signal. Secondly, the peak-detection algorithm which processes the signal to obtain the seeding performance. Finally, the empty state alarm of the seed box uses the capacitance approach switch to judge the seeds position and alarm. In addition, for the host computer, the touch LCD processor realizes the alarm, parameters setting and display based on the data received.

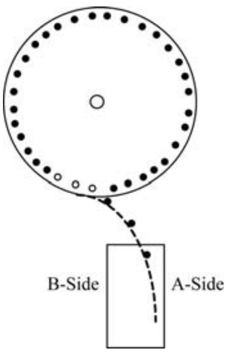


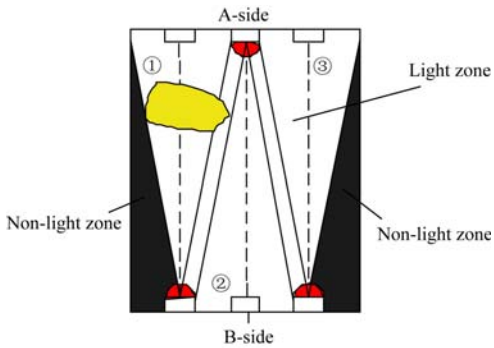
Figure 1 System structure diagram

3 Seeding monitoring sensor design

3.1 Photoelectric detecting equipment

Considering the working conditions of the seeding operation, such as large temperature difference, high-dust and strong vibration, photosensitive resistor is used as the receiver with its spectral characteristics which the photosensitive resistor with the different materials has the different sensitivity towards the lighting with different wavelength. Therefore, the photosensitive resistor with Lead sulfide, its relative sensitivity can be more than 90% at the wavelength of 540 nm. To prevent from the influence of high-dust, the super-bright light emitting diodes are taken as the transmitter and the photosensitive resistor as the receiver. In addition, the installation position of the sensor is changed to the space under the seed plate, which cannot only reduce the dust influence, also avoid the seeds' bouncing in the seed tube to affect the detection accuracy.

The no-blind zone detection is a novelty in this paper. To improve the detection accuracy and avoid the seeds falling outside the detection zone, the type and installation position of the photoelectric tube is chosen and computed to realize the no-blind zone detection. Firstly, the transmitter and the receiver are crossed and opposed, as shown in Figure 2. According to the vertical distance of the photoelectric tube and the scattering angle of the transmitter, the installation position can be determined to ensure the light zone and no interference of light.



Note: The red area is the transmitter and ①②③ are three receivers.

Figure 2 Photoelectric tubes distribution diagram

According to the analysis of the seed dynamics, most of seeds will fall along the tangent direction of the seed plate at the same point[14,15], as shown in Figure 3. Therefore, the side with two receivers of the sensor is fixed on A-side to ensure that all seeds can pass through the light zone.

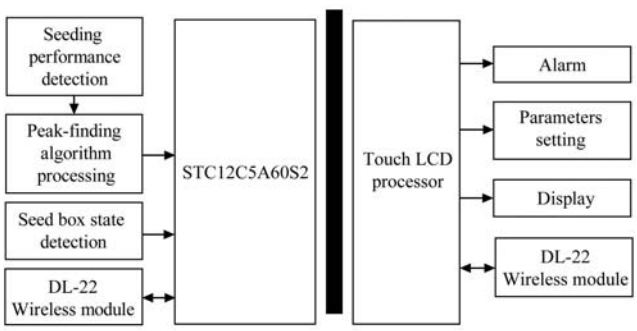


Figure 3 Schematic diagram of seed falling

The photoelectric sensor is shown in Figure 4. Firstly, the photosensitive resistor MG41-22 is connected with a 200kΩ resistor R4 in series. Secondly, when the light of transmitter shines the photosensitive resistor, its resistance will become very small and the divided voltage of each photosensitive resistor is about 0.27 V. Thirdly, when a seed passes the light zone, the light will be shadowed to cause the resistance of photosensitive resistor very large, and the divided voltage can be up to 2.8-5.0 V.

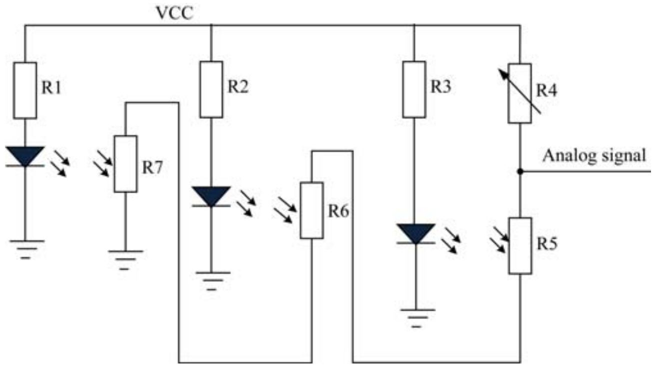


Figure 4 Photoelectric tubes connection diagram

3.2 The signal processing based on peak-detection algorithm

The second novelty is to use the peak-detection algorithm to process and analyze the pulse signal, then get the seeding performance. Firstly, the obtained analog signal (voltage) is sent to the P1.0 port of MCU STC12C5A60S2, namely, the high-speed A/D conversion port. Through the serial assistant, the digital signal converted can be shown in Figure 5.

```
FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF E1 AD 76 3B 03 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 06 19 2A 3A 49 5F 98 C4 DF EE F7 FB FD FE
FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
FF FF FF FC DA B1 82 53 1F 00 00 00 00 00 01 13 26 35 44 53 79 AE D3 E7 F2 F9 FC FE FE
FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
```

Figure 5 Partial digital signals of seeds falling in the serial assistant

It is clear that the digital signal keeps in FF when no seed passes, once a seed passes, the value begins to decrease rapidly from FF to 00 and then quickly returns to FF. After several tests, it can be found that the number of actual falling seeds is always slightly more than the number of value-changing, and the deviation is about 6%. By analyzing the reason, when two seeds fall at the same time, namely, the reseeding, will result in the situation which the value decreases a little from FF and rise rapidly to FF. It's difficult to count the accuracy seeding quantity through judging the changing of the digital signal.

Based on MATLAB, after importing the digital data, the partial spectral curve is shown as Figure 6.

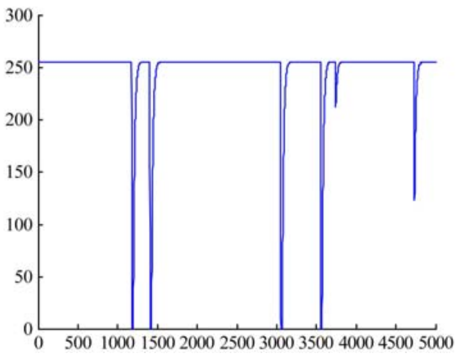


Figure 6 Partial spectral curve

Through the curve, it's clear that the problem which counts the seeding quantity and judges the seeding situation can be regarded as the peak-finding problem of asymmetrical spectra. At present, the common peak-detection algorithms include the direct finding method, the general polynomial fitting method and Gaussian fitting algorithm[16,17]. To solve the problem of FBG reflection spectrum, such as adaptive detection algorithm and Gauss fitting algorithm based on the index correction are proposed. Considering these factors which the waveform of the pulse signal is affected little by noise and is one kind of the asymmetric spectral, therefore, Gaussian fitting peak algorithm[18-20] is used to process the signal and get precise seeding quantity.

According to the Figure 6, after A/D conversion on the analog signal, it's clear that the waveform can be described by the data (x_i, y_i) (i=1, 2, 3…N) of a type of Gaussian functions. Namely,

$$y_i = y_{\max} \times \exp\left[-\frac{(x_i - x_{\max})^2}{S}\right] \tag{1}$$

where, $y_{\max}$, $x_{\max}$ and S represent the peak height, peak position and half width of the Gaussian curve, respectively.

Take the natural log of both sides of Equation (1), we can obtain:

$$\ln y_i = \ln y_{\max} - \frac{(x_i - x_{\max})^2}{S} \tag{2}$$

$$\ln y_i = (\ln y_{\max} - \frac{x^2{}_{\max}}{S}) + \frac{2x_i x_{\max}}{S} - \frac{x_i^2}{S} \tag{3}$$

Assume that,

$$\ln y_i = z_i,\ \ln y_{\max} - \frac{x^2{}_{\max}}{S} = b_0,\ \frac{2x_{\max}}{S} = b_1,\ -\frac{1}{S} = b_2$$

Then Equation (2) becomes a quadratic polynomial fitting function:

$$z_i = b_0 + b_1 x_i + b_2 x_i^2 = (1 \quad x_i \quad x_i^2)\begin{bmatrix} b_0 \\ b_1 \\ b_2 \end{bmatrix} \tag{4}$$

Consider all data and measurement errors ε_i, the expressed matrix form as follows:

$$\begin{bmatrix} z_1 \\ z_2 \\ \vdots \\ z_n \end{bmatrix} = \begin{bmatrix} 1 & x_1 & x_1^2 \\ 1 & x_2 & x_2^2 \\ \vdots & \vdots & \vdots \\ 1 & x_n & x_n^2 \end{bmatrix}\begin{bmatrix} b_0 \\ b_1 \\ b_2 \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_n \end{bmatrix} \tag{5}$$

Written briefly as: $Z_{n\times1} = X_{n\times3}B_{3\times1} + E_{n\times1}$

In the case that the total error E is not considered, according to the least square principle, the generalized least squares solution of the matrix B composed by the fitting constant b_0, b_1, b_2 can be obtained[21-24]:

$$B=(X^TX)^{-1}X^TZ \tag{6}$$

Consequently, according to Equation (3), the parameters $y_{\max}$, $x_{\max}$ and S can be obtained and determine the number of the effective peaks, then finally calculate the accurate seeding quantity. In this paper, take the example of a waveform with 39 grains, the number of the counting points (* in green) obtained by the peak-detection algorithm is also 39, as shown in Figure 7.

3.3 Detection of abnormal seeding situation

3.3.1 Detection of reseeding and miss-seeding

Through recording the time interval between two adjacent seeds Δt, based on "Single seed (precision) planter experimental method" to judge whether the reseeding or the miss-seeding. This criterion states that:

$$\begin{cases} v\Delta t > 1.5\overline{d} & (miss-seeding) \\ v\Delta t \le 0.5\overline{d} & (reseeding) \end{cases} \tag{7}$$

where, v is the planter speed; $\overline{d}$ is the theoretical planting spacing.

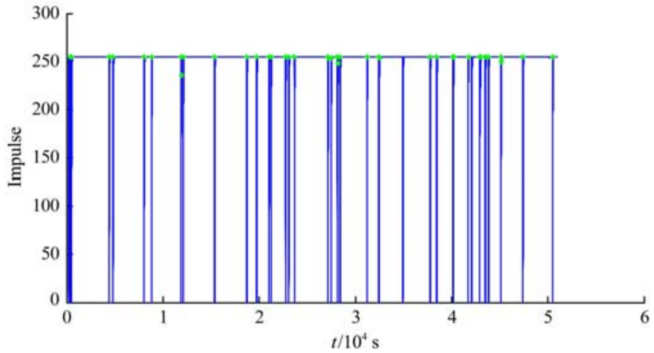


Figure 7 The peak value points obtained by peak-detection algorithm

When the planter operates normally, the speed is common 6-10 km/h and the theoretical planting spacing for the corn is basically 20 cm. Thus, when Δt >180 ms, it can be counted as the miss-seeding, that is, when the time difference between two peaks detected is more than 180 ms; when $\Delta t \le 36$ ms, it can be counted as the reseeding.

3.3.2 Detection of empty and blocked state of the seed tube

According to the criterion of the miss-seeding Δt >180 ms, the alarm time of the empty state of the seed tube is set to 540 ms, that is, when the digital value is less than 0EH (0.27v) lasts 540 ms, the empty alarm will be started. Conversely, when the digital value is more than E4H (4.47v) lasts 540 ms, the blocked alarm will be started.

3.4 Detection of seed box state

The LJC30A3-H-BY capacitance approach switch is used to detect the empty state of the seed box. By adjusting the installation height and turning the knob on the sensor, the alarm distance of empty state can be determined. Consequently, when the seeds in the box are below the set position, the high-level signal is given to the MCU and the system alerts.

3.5 Wireless communication

Assuming the address for every seed box and seed tube, the host computer protocol is shown in Table 1. Table 2 is the uploading data protocol of the slave computer.

Table 1 Host computer protocol

Head marks	Object address	Instructions	Data	Tail marks
	The host computer address	FF (Data collecting)	00	
	00	FE(Start)	00	
FC	00	FD (Normal stop)	00	ED
	00	EE (Abnormal stop)	00	
	The host computer address	FB (Confirmation)	00	

Table 2 Slave computer protocol

Head marks	Object address	Source address	Signal type flag	Normal and Abnormal data				Tail marks
FC	64H	Slave computer address	Normal F0	empty01 blocked02	00	00	00	ED
			Abnormal 0F	Seeding quantity				

According to the communication protocols, the slave computer is mainly responsible for initialization settings, collecting the photoelectric signal, the signal processing and sending the result to the host computer through the wireless module.

3.6 The host computer functions

The host computer uses the touch LCD processors and includes three modules which is namely the real-time data module, the data statistics query module and the parameters setting module. The main interface is shown in Figure 8.

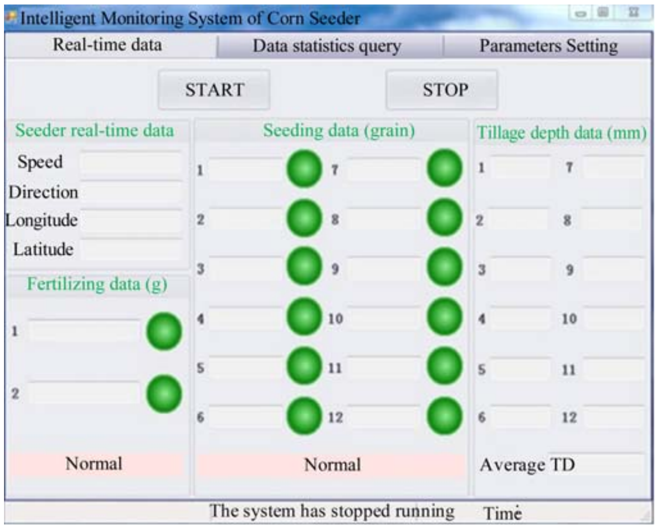


Figure 8 Real-time data interface

4 Experiments

4.1 Experiment preparations

Experiments use a two-row dynamoelectric planter (Figure 9, 10) which Heilongjiang Bayi Agricultural university developed independently. A small motor system with the gear meshing is equipped on each seeding device, which can drive the seed plate to rotate. By adjusting the motor speed regulator, the seed plate rotation speed is changed respectively. Considering the actual operation speed is about 6-10 km/h, the rotation speed of the seed plate can be calculated at 15-25 r/min.

Figure 9 Sensors installation

Figure 10 Speed regulator and the fan

The air suction is simulated by the negative pressure generated by the fan which is adjusted by the fan regulator, and the negative pressure meter can display the pressure value.

According to the shape and size, all corn seeds are classified into three kinds, that is, the small round, the big flat and the oval. The indoor experiments will investigate the effect of seed shape and size on the detection accuracy.

4.2 Indoor experiment

4.2.1 Normal seeding experiment

The experiment conditions are assumed that the seed plate rotation speed is at 20 r/min and the negative pressure is at 5 kPa. After the indoor experiment, the experiment data of the seeding quantity for three kinds of seeds are shown in the Table 3.

Table 3 Indoor experiment data for different shape seeds

Group		Tube 1		Tube 2	
Small round	1	Actual	121	Actual	125
		Detection	119	Detection	126
		Accuracy/%	98.3	Accuracy/%	99.2
	2	Actual	101	Actual	105
		Detection	103	Detection	105
		Accuracy/%	98.1	Accuracy/%	100
	3	Actual	136	Actual	134
		Detection	138	Detection	136
		Accuracy/%	98.6	Accuracy/%	98.5
Big flat	1	Actual	148	Actual	145
		Detection	145	Detection	144
		Accuracy/%	98	Accuracy/%	99.3
	2	Actual	220	Actual	221
		Detection	219	Detection	221
		Accuracy/%	99.5	Accuracy/%	100
	3	Actual	201	Actual	197
		Detection	199	Detection	194
		Accuracy/%	99	Accuracy/%	98.5
Oval	1	Actual	201	Actual	186
		Detection	200	Detection	188
		Accuracy/%	99.5	Accuracy/%	99
	2	Actual	331	Actual	327
		Detection	327	Detection	330
		Accuracy/%	98.9	Accuracy/%	99.1
	3	Actual	211	Actual	208
		Detection	210	Detection	206
		Accuracy/%	99.5	Accuracy/%	99
Total		Actual	3318		
		Detection	3310		
		Accuracy/%	99.8		

The experimental results show that the deviation between the actual value and the detection value is not more than 3%, and the total seeding accuracy can reach 99.8%. It's clear that the effect of seed shape and size on the detection accuracy can be neglected.

4.2.2 Alarm delay experiment

Firstly, the empty and blocked experiment of the seed tube are tested, that is, closing the speed regulator to make the empty state or using something to obstruct the seed tube to make the blocked state. Through the repeated experiments, the alarm delay time is shown as Table 4. In the case of the empty box detection, when the seeds separate from the sensor the alarm comes.

4.2.3 The reseeding and the miss-seeding experiment

Firstly, take the seed Tube1 as the experiment object and select 100 grains of small round corn seeds, the negative pressure of the fan is adjusted to 8 kPa which is easy to occur the reseeding to do the reseeding experiment. Secondly, adjusting the negative pressure of the fan to 3 kPa which is easy to occur the miss-seeding to do the miss-seeding experiment. Then the reseeding and the miss-seeding experiment data are shown as follows.

From the Table 5, we can see that the detection accuracy of the reseeding and the miss-seeding is almost 100%. Specially, for the third group which the actual and detection value are different, one of the holes has three grains of seeds. The peak-detection algorithm can't tell three peaks, but in practice, to ensure the qualification percent, this situation which three grains of corn seeds are inhaled on the same hole occurs scarcely.

Table 4 The alarm delay time

Group	Seed tube/empty	Seed tube/blocked	Seed box/empty
1	1.22"	1.11"	1.47"
2	1.30"	1.20"	1.36"
3	1.28"	1.18"	1.40"

Table 5 Reseeding and miss-seeding experiment data

Group1	Tube 1			
	Reseeding (8 kPa)		Miss-seeding (3 kPa)	
1	Actual	16	Actual	7
	Detection	16	Detection	7
	Accuracy/%	100	Accuracy/%	100
2	Actual	16	Actual	7
	Detection	16	Detection	7
	Accuracy/%	100	Accuracy/%	100
3	Actual	17	Actual	6
	Detection	16	Detection	6
	Accuracy/%	94	Accuracy/%	100

4.3 Field experiment[25]

The field experiment was tested in Jiamusi Shuguang farm in August 2017.

Experiment planter: air-suction type no-tillage planter;

Experiment seeds: Sidan19.

The detection parts of the slave computer are installed on the seed box (Figures 11 and 12). The length of each ridge is about 170 m, and the speed of the planter is 6-10 km/h, the planting distance is about 20-25 cm. The weather is drier, the light is strong and the dust is large. The seeding performance parameters are as shown in the Tables 6 and 7.

Based on the result above, the seed quantity accuracy of the monitoring system can reach 98.45%. In addition, the reseeding and the miss-seeding detection were not affected by the field condition. The host computer can display the alarm information no more than 2 s when the abnormal situation occurs.

Figure 11 Detection devices installation

Figure 12 Seeding experiment in the field

Table 6 Seeding quantity of the field experiment

Group	Items	Tube1	Tube2
1	Actual	837	806
	Detection	849	818
	Accuracy/%	98.6	98.5
2	Actual	842	813
	Detection	858	826
	Accuracy/%	98.1	98.4
3	Actual	843	810
	Detection	854	823
	Accuracy/%	98.7	98.4

Table 7 Performance parameters of the field experiment

Seeding quantity accuracy	Reseeding detection accuracy	Miss-seeding detection accuracy	Alarm delay time
98.45%	99.4%	99.6%	< 2 s

5 Results and discussion

Compared with the indoor experiment, the seeding performance in the field is slightly lower than the indoor. Considering these factors, such as the fiercely vibration, high dust and the unstable power supply, it is possible to cause the different between the indoor and the field experiment. Moreover, in the field experiment, most of the detection value is higher than the actual value, the reason is that some seeds aren't picked out to make the actual seed quantity reduce during picking up the seeds and counting in the field. In short, based on the experiment verification of the field, the seeding performance monitoring system can completely satisfy the actual operation requirements.

6 Conclusions

In this paper, using the photoelectric detection method to detect the seeding performance, and improvements have been made in four aspects as follows, that is, the selection and installation of the photoelectric sensor, non-blind zone detection, the peak-detection algorithm for the signal processing and the wireless communication transmission. After the indoor and the field experiment, the results show that the detection accuracy of seeding quantity can reach 98.45%, reseeding detection accuracy is 99.4%, miss-seeding detection accuracy is 99.6%, and alarm delay time under abnormal circumstances is not more than 2 s, which conforms to the operation criterion and completely meets the actual requirement. In addition, the visualization and touch surface of the monitoring system is convenient for the drivers to operate. In conclusion, the research work in this paper can effectively improve the working efficiency of the planter and the agricultural mechanization level.

Acknowledgements

We acknowledge that this work was financially supported by Three Horizontal-Three Vertical Support Project of Heilongjiang Bayi Agricultural University (TDJH201803), Key Scientific Research Project of Heilongjiang Agricultural Reclamation Bureau (HNK135-06-08).

[References]

[1] Wang C H, Li W G. Based on MCU control pneumatic type no-till planter monitoring system. Transactions of the CSAM, 2013; 44(51): 56–59. (in Chinese)
[2] Ahmad A, Al-Mallahi, Kataoka Takashi. Monitoring the flow of seeds in grain drill using fiber sensor. 4th IFAC Conference on Modeling and Control in Agriculture, 2013; pp.311–314.
[3] Qi J T, Jia H L, Li Y. Design and test of fault monitoring system for corn precision planter. Int J Agric & Biol Eng, 2015; 8(6): 13–20.
[4] Xia L M, Wang X Y, Geng D Y, Zhang Q F. Sliding Monitoring System for Ground Wheel Based on ATMEGA16 for No-Tillage Planter—CT246. 2010 CCTA, 2011; 531–537.
[5] Abdolahzare Z, Mehdizadeh S A. Nonlinear mathematical modeling of seed spacing uniformity of a pneumatic planter using genetic programming and image processing. Neural Computing and Applications, 2018; 29(2): 363–375.
[6] Liu Y H. The research of electromagnetic vibrating cotton intensive cotton planting equipment. Qingdao: Shandong University of Science and Technology, 2005. (in Chinese)
[7] Young S L, Pierce F J. Precision planting and crop thinning. Automation: The Future of Weed Control in Cropping Systems. Springer, 2013; pp.99–124.
[8] Li D, Geng D Y, Ma B T, Li Q H, Wang Z W. Research on the performance monitoring system of maize precision planter. Agricultural Machinery Research, 2013; 35(11): 71–74. (in Chinese)
[9] Zhao M Q, Hu Y W, Liu Y Q. Measurement and analysis on vibration characteristics of pneumatic seed metering device of no-till seeder. Transactions of the CSAE, 2012; 28(26): 78–83. (in Chinese)
[10] Song P, Zhang J X. The real-time monitoring system for the performance of precision planter. Journal of Agricultural Machinery, 2011; 2: 71–74. (in Chinese)
[11] Liu J Y, Liu F, Zhang P J. Design of monitoring system for air suction seeder metering device. Agricultural Machinery Research, 2015; 9: 143–146. (in Chinese)
[12] Xia L M, Wang X Y, Geng D Y, Zhang Q F. Performance monitoring system for precision planter based on MSP430-CT171. 2010 CCTA, 2011; pp.158–165.
[13] Li L X, Hao Z M, Yang W, Xia X Y, Wang J H. Design of seeding performance detection system for precision seeder. Agricultural Engineering, 2012; 8: 16–19. (in Chinese)
[14] Su W, Wang F L. Study on pneumatic system of vacuum seed planter. Journal of Northeast Agricultural University, 2012; 43(5): 61–64. (in Chinese)
[15] Zhou L M, Zhang X C, Yuan Y W. Design of capacitance seed rate sensor of wheat planter. Transactions of the CSAE, 2010; 26(10): 99–103. (in Chinese)
[16] Liu W Z, Zhao M Q. The performance theory analysis and experiment. Transactions of the CSAE, 2010; 26(9): 133–138. (in Chinese)
[17] Scholkmann F, Boss J, Wolf M. An efficient algorithm for automatic peak detection in noisy periodic and quasi-periodic signals. Algorithms, 2012; 5: 588–603.
[18] Chen Y, Yang X, Liu H L. Processing FBG sensing signals with exponent modified Gaussian curve fitting peak detection method. Spectroscopy and Spectral Analysis, 2016; 36(5): 1526–1531.

[19] Slodzinski R, Hildebrand L, Vautz W. Peak detection algorithm based on second derivative for two dimensional ion mobility spectrometry signals. Peak Detection Algorithm based on Second Derivative Properties. Springer, 2015; pp.342–354.

[20] Bödeker B, Vautz W, Baumbach J I. Peak finding and referencing in MCC/IMS-data. International Journal for Ion Mobility Spectrometry, 2008; 11(4): 83–87.

[21] Adam A, Ibrahim Z, Mokhtar N, Shapiai M I, Cumming P, Mubin M. Improving EEG signal peak detection using feature weight learning of a neural network with random weights for eye event-related applications. Sādhanā, 2017; 42(5): 641–653.

[22] Rai H M, Trivedi A, Chatterjee K, Shukla S. R-peak detection using daubechies wavelet and ECG signal classification using radial basis function neural network. Journal of the Institution of Engineers, 2014; 95(1): 63–71.

[23] Hao W N, Chen J Y. Peak position detection-based acquisition algorithm of multiple access interference resistance. China Satellite Navigation Conference (CSNC), 2016; 2: 29-46. (in Chinese)

[24] Lomaliza J-P, Park H. Improved peak detection technique for robust PPG-based heartrate monitoring system on smartphones. Multimedia Tools and Applications, 2018; 77(13): 17131–17155.

[25] Zhou L M, Wang S M, Zhang X C, Yuan Y W, Zhang J M. Seed monitoring system for corn planter based on capacitance signal]. Transactions of the CSAE, 2012; 28(13): 16–21. (in Chinese)