A Design and Experiment on an Intelligent Fuzzy Monitoring System for Corn Planters

Abstract: When sowing summer corn without tillage, it is necessary to ensure that the furrow opener is free from straw congestion, and that the spacing of the sowing can be adjusted according to the breeds of corn and the preset seeding rate per acre. Based on the basis of the structural features of the newly developed no-tillage corn fertilizers, the study developed an intelligent fuzzy monitoring system for corn planters. The system facilitates automatic control of the spacing adjustment and the status monitor of the fertilizer tank, seed tank, and seeding orifice. According to the preset number of rows, line spacing, number of plants per acre, and seed germination rate, the control rate can be calculated through designing the surveillance software. The control rate is output to the fuzzy controller through the digital output module of the CAN bus. Fuzzy control is applied to the DC motor for stepless spacing adjustment to realize the stepless adjustment of the spacing. The system for video surveillance of the working status of a planter is developed, showing a real-time video image of the planter operation, and achieving an anti-congestion status monitoring of a no-tillage planting operation in a dusty environment. Through field trials, the detection accuracy was 91.4%. The seed-clogging fault-alarm accuracy was 96.0%. The entire system remained stable and reliable.

Key words: corn planters, stepless adjustment, plant spacing, fuzzy control, monitoring system, fault alarm

Introduction
The precision planter monitoring system in China has made some achievements after several years of development. After several years of development in China, some achievements have been made in precision planter monitoring systems, but there remain issues such as mediocre system operational reliability, high manufacturing costs, a low degree of modularity and inadequate adaptability, all of which restrict the wide application of precision planter monitoring systems. Currently, there are the following seeding performance detection methods exist in China and abroad: (1) manual inspection method, (2) photoelectric effect method, (3) piezoelectric effect method, (4) high-speed photography method, (5) strobe photography method and (6) machine vision detection method. According to information gathered by the authors at the 2011 agricultural machinery show held in Hanover, Germany, the wheat precision seeder’s monitoring technology for monitoring the precision of wheat seeders with regard to quantity as well as that of and the combine harvester’s harvesters in real-time monitoring technology for concerning seed quantity has become quite mature. The research focus has been transferred to the automatic control technology. The internationally advanced electronic monitoring systems for planters can not only show display the real-time planter working status, but also adjust and control the sowing amount of each per row, the number of grains per meter and the rotational speed of the seeder. For example, Germany HORSCH precision seeding machinery can make calibrate the same equal distances between any two seeds at a sowing speed up to 15 km / hour. The U.S.A. has been able to achieve intelligent navigation and autopilot functions in field operation processes. An autopilot system can be configured into various modes such as precision variable-rate fertilization mode, variable-rate spraying mode, and others for variable operating control modes. The application effect of an automatic navigation system is significant, thus easy for farmers engaged in large-scale commercial cultivation.
With the accelerated process of agricultural modernization, mechanization of agriculture will become the dominant mode of agricultural production. The trend of reducing labor and increasing automation is irreversible. The demand for farm machinery and equipment has been rendered rigid growth. At present, the overall development of China's agricultural mechanization has entered the intermediate stage from the primary stage, with the advanced stage being not far ahead approached at an increasingly marching progressive rate. Development of precision planting and precision fertilization is an inevitable path of agricultural mechanization and is the basis for harvest. Precision planting can help substantially save sowing seeds for sowing, save hours of thinking work thoughtful planning, or completely eliminate the thinning process, thereby improving crop’s the tidiness, health, nutrition, collective balance, and production of crops. Precision fertilization can save conserve fertilizer and protect the environment by meeting the exact fertilizing needs after measuring the soil nutrition level. In corn no-tillage sowing of corn, there is an urgent need to achieve a breakthrough in the whole entire process of mechanization, and to improve agricultural efficiency, and save on cost. In this study, based on the basis of the characteristics of the corn no-tillage corn sowing and fertilizing equipment, this study designed a corn planter operation monitoring system was designed. [delete comma] realizing to achieve the status surveillance over the status of automatic control of seeding spacing and over the positions of the fertilizer tank, [delete comma] and seed tanks, [delete comma] and as well as the seeding orifice.[1]

General System Design

Our system for monitoring the working status of a corn planter working status monitoring system consists of the following items: [insert bullets & delete commas]

- onboard computers,
- GPS receivers, digital cameras,
- a tilt sensor,
- a USB-CAN interface module,
- displacement sensors,
- an electronically- [delete hyphen] controlled stepless spacing regulator,
- a CAN bus analog input module,
- CAN bus digital input and output modules,
- a CAN bus pulse counting module,
- a seed tank sensor, a fertilizer tank sensor, a seeding orifice sensor.

- a gear speed sensor
- and other components.

The CAN bus module is embedded with microcontrollers. Therefore, the onboard computer and CAN bus modules constitute a distributed systems via the CAN bus. The topology of the whole entire system is shown in Figure 1 [2-6].

The GPS receiver monitors the planter’s travel speed, latitude and longitude of the planter. Data is transferred through the USB interface to the onboard computer. Latitude and longitude data are transferred via system software into plane coordinates x and y, which can be used to calculate the acreage.

A digital camera is used to capture video images, which are sent via a the USB interface and transmission lines to the onboard computer, enabling the a real-time display of the planter’s work status of the planter. [delete period] so that the tractor driver of the tractor can know be aware of what is happening happening behind the tractor vehicle without looking back.

The tilt sensor is used to monitor the planter’s working or shipping mode of the planter, which helps the system software determine which programs to execute.

The displacement sensor monitors the position of the electronically controlled stepless spacing regulator. The onboard computer collects information and compares it with the desired seeding rate, calculates the deviation, and outputs a motor-control signal to drive the stepless spacing regulator in accordance to with the unit’s walking speed of the unit, which in turn outputs the desired shaft speed and realizes the adjustment of variable sowing spacing.

The fertilizer tank sensor is used to monitor the residue in the fertilizer tank. If the residue in the tank amount is too
little insufficient, the sensor will send alarm information. The seed tank sensor is used to monitor the remaining amount of seed in the tank. If the remaining amount of seed is too small, the sensor will send alarm information. The seeding orifice sensor is used to monitor whether possible blockage in the orifice is blocked. If there is abnormal situation is abnormal at the seeding orifice within, the sensor will send alarm information. The speed sensor is used to generate the rotation pulse of the drive shaft of the spoon-plate seeder. The onboard computer counts the pulses via the CAN bus pulse counting module. If the pulse signal is abnormal, the onboard computer will determine whether there is ground wheel slip slippage, based on the basis of the planter traveling speed of the planter.

The tilt sensor, the displacement sensor, the fertilizer-tank sensor, the seed-tank sensor, the seeding-orifice sensor and the speed sensors are all connected to the onboard computer through the CAN-bus analog input module, and CAN-bus digital input modules, plus CAN cables and USB-CAN interface, respectively. The topology of the monitoring system is shown below.

Fig. 1 Topology of the planter monitoring system

System Hardware Design

An onboard computer is installed in the tractor cab. When working in the fields, the tractor travels at a high ambient temperature with heavy vibrations and dust. From the viewpoint of reliability and durability for onboard use, the an industrial touch tablet computer is selected, as the onboard computer with having the following specifications,:

- CPU: Onboard INTEL Atom N450, 1.66GHZ,
- LCD Type: TFT,
- screen size: 12.1 ",
- and resolution: 1024 × 768.

A spoon-plate corn seeder is used to connect to the planter system for precision seeding. The running of the spoon seeder is driven by the a ground wheel and the a transmission device. When the planter is travels moving, the ground wheel rotates, which drives thereby driving the rotation of a hexagonal shaft through the transmission device of the sprocket and chains. The hexagonal shaft drives the rotation of the spoon-plate seeder through the sprocket and chains. A gear-speed sensor is installed to on an one end of the hexagonal shaft, to monitoring monitor the output state of the per-second-speed pulse signal per second and conducting signal processing. In this way the working status of the seeder can be known determined. Together with the planter travel speed of the planter, the ground wheel slippage ratio can be known calculated. The installation of the gear-speed sensor onto the planter is shown in Figure 2.

Figure 2 Gear-speed sensor

![Figure 2 Gear-speed sensor](image)

Figure 2 shows that a set-of measuring gear with 60 teeth is installed on the outer end of the hexagonal shaft. A magneto-resistive sensor is installed facing the gear’s circumference of the gear. Whenever the gear rotates by a pitch, the sensor converts the movement into an approximate sine wave signal and outputs it. The signal is filtered and amplified into a pulse signal. For every circle in which the gear rotates, the sensor outputs 60 pulses. The measuring gear is a of the driven gear type, which means meaning that when the hexagonal shaft rotates, the measuring gear rotates. Therefore, by monitoring measuring the rotational speed of the gear, the speed of the spoon-plate seeder can be calculated. The monitoring system uses the CAN bus pulse-counting module to count measure the pulse signal output by the gear-speed sensor.

When the counting result of obtained from the pulse-counting module is C, the measuring gear’s pulse-number per-circle output of the gear by from the speed sensor is P,
the counting time is \( t \) seconds, and the measuring gear speed is \( n \) (r / min), the following equation is established:

\[
C = \frac{P \cdot t \cdot n}{60}
\]

When \( t = 1s \) and \( P = 60 \), \( C = n \).

By Rearranging Equation (1), the formula to measure the gear speed is becomes

\[
n = \frac{60C}{P \cdot t}
\]

Formula (2) shows that if the counter counts the pulse signal in \( t \) seconds, the measuring gear speed \( n \) of the measuring gear can be calculated.

In this paper study, the GPS receiver receives the planter's traveling speed of the planter and its positioning information. With the assistance of the a HOLUX GR-213U, GR-213U built-in satellite receiving antenna and the a third-generation GPS receiver chip designed by SiRF, the GPS receiver communicates with other electronic devices through the USB interface. With the its built-in rechargeable battery, the receiver stores satellite data such as satellite signal status and the last recorded location, date and time. The receiver collects position information every 0.1 second, and performs an update every second.

3.1 Coordinate calculation of planter’s GPS positioning of planter

The onboard computer receives GPS location information and planter's the traveling speed of the planter through the USB interface. Based on the basis of the set number of rows, row spacing, number of plants per acre and seed germination rate, the control amount can be calculated through by self-developed software. The control amount information is sent via the CAN-bus digital output module output to the fuzzy controller, which performs fuzzy control over the DC motor of the stepless spacing regulator, thereby achieving stepless the requisite adjustment of spacing.

The linear displacement sensor inside the stepless spacing regulator monitors and adjusts the position information. The information which is sent to the onboard computer via the CAN bus analog input module. The computer performs the calculation calculates of the displacement error and the error rate of change in errors of in the stepless spacing regulator.

3.2 Fuzzy control algorithm of stepless spacing regulator

The key of to precise adjustment by a stepless spacing regulator is the displacement accuracy of the slider on the regulator slider. This type of regulator...
is a nonlinear system, characterized by a pure-time delay phenomenon. Lag errors occur with classical control methods. The fuzzy control does not need to establish a mathematical model of a controlled object. The system’s robustness of a nonlinear delay system is suitable for the control of a nonlinear delay system thereof. Therefore, fuzzy control is a good choice for a stepless spacing regulator.

3.2.1 Structure of the fuzzy controller of the stepless spacing regulator

The fuzzy controller of the stepless spacing regulator uses the regulator-slider displacement errors and the error’s changing rate of the errors as input. The output variable is the DC motor’s control value. The structure of the fuzzy this controller of the stepless spacing regulator is shown in Figure 4.

The DC motor of the stepless spacing regulator has only the on-and-off modes during work while running. Hence, it is not adjustable. In the fuzzy control, the Mamdani Model needs to divide the control value into several levels during the fuzzy process. Different levels of control value have different adjustment values, which thereby requires requiring the controller to be adjustable. The fuzzy control has a new model for fuzzy control: the Sugeno Model. The latter part of the fuzzy rule of this model can be in the form of a function or a constant, in which 1 is for on, and 0 for off. This which matches the two-end control state of the DC motor on the stepless spacing regulator. Therefore, the control of the DC this motor on the stepless spacing regulator uses the Sugeno Model. The slider displacement error of the stepless spacing regulator is denoted by $e_s$, referring to the difference between the actual measured value of the slider displacement and the set value. The slider displacement error ranges between [-1, 1], the fuzzy domain being [-5, 5]. The quantization factor $k_e = 5$; the changing rate of slider displacement error ranges between [-0.5, 0.5], the quantization factor $k_{e'} = 10$.

(1) Selecting the overlapping rate and overlapping robustness of the membership function

In the fuzzy model, the shapes of the fuzzy-rule former membership function include triangles and bell shapes. The fuzzy domain being $[0.5, 0.5]$ for the membership function. The overlapping rate of the membership function is usually bigger than the overlapping rate, generally ranging between 0.3 and 0.7.

The higher the values of the overlapping rate and the overlapping robustness are, the higher the fuzziness of the fuzzy control system can be. Therefore, the system that has a vague relationship between the values can be better controlled. The low overlapping index is suitable for systems with clearer correlations between input and output. To enable the fuzzy control system to operate more smoothly, a mature overlapping rate and overlapping robustness should be chosen. In this project, the overlapping rate of the membership function for the slider displacement error of the fuzzy control system is 0.25 to 0.4, when the overlapping robustness is 0.5. The overlapping rate of the membership function of the displacement error changing rate is 0.33, the overlap robustness being 0.5.

(2) Fuzzy subsets of input variables

To reduce the amount of calculation, in this study, the shapes of the membership functions of the slider displacement error and the error changing rate
The slider displacement error has seven fuzzy variables:
1. PB (positive big), [Editor CJR’S Note: In formal academic rhetoric, “large” is a better word than “big.”]
2. PM (positive medium),
3. PS (positive small),
4. ZE (zero),
5. NS (negative small),
6. NM (negative medium), and
7. NB (negative big).

The slider error rate has five fuzzy variables:
1. PB (positive big),  
2. PS (positive small),  
3. ZE (zero),  
4. NS (negative small), and  
5. NB (negative big).

(3) Control of on/off output

The motor control value of the stepless spacing regulator is \( U_s \). The [This DC motor control has only two states: on and off.]

When the constant of the latter part of the zero-order Sugeno model is 1, it means designates connecting connection to the DC motor, \([edit comma & insert semi-colon; and whereas, [insert comma] 0 \) means designates off the DC motors with 0, which thereby matches matching the two statuses states of the motor control in the stepless spacing regulator. In this way the fuzzification of the motor control value of the stepless spacing regulator is settled.

(4) Direct reasoning of the fuzzy rules and defuzzification

In the fuzzy logic theory, the inference of the fuzzy rules is generally the a synthesis and calculation depending on the fuzzy relation \( R \). This way method has problems, \([insert comma] including \) a long computing time, a large amount of computer memory, inconvenience in modifying the fuzzy rules, etc. This system uses software real-time software online for reasoning, which uses a single-point fuzzy set to make render the exact amount of the input signal fuzzy, \([delete comma] and \) applies the direct method to reasoning about the fuzzy rules. Suppose that there are two fuzzy control rules:

\[
R_1 : \text{if } x = A_1 \text{ and } y = B_1 \text{ then } u_1 = f_1 \\
R_2 : \text{if } x = A_2 \text{ and } y = B_2 \text{ then } u_2 = f_2
\]

where \( A_i \) and \( B_i \) are the former fuzzy set, and \( f_i \) is the latter constant. Assume that the current input is \( x = x_0, y = y_0 \). First obtain the degree of belonging to which these two inputs belong to the former conditions \( A_i(x_0) \) and \( B_i(y_0) \). Then the former matching degree of the entire rule can be calculated, \([delete period & insert colon]\):

\[
\alpha_i = A_i(x_0) \land B_i(y_0)
\]

(3) The overall reasoning result \( u_0 \) is derived from the weighted average of \( u_1 \) and \( u_2 \). \([delete period & insert colon]\):

\[
u_0 = \frac{\alpha_1 u_1 + \alpha_2 u_2}{\alpha_1 + \alpha_2}
\]

For the control rules formed by \( m \) pieces of fuzzy conditional phrases, the overall result \( u_0 \) is

\[
u_0 = \frac{1}{m} \sum \alpha_i u_i
\]

3.3 Software design and anti-jamming measures of the computer control system

The system software uses the visual programming language Delphi 7.0 to program in the Windows XP environment. The HMI is the "simulate real" interface, which is shown in Figure 7.
In Figur 7, left-click the computer-shaped icon, and the screen will pop up sowing a parameter-setting window. Left-click the icons to the right of each selection in the setting window, and a parameter selection list will appear. After left-clicking the appropriate parameters have been left-clicked, the parameter selection list disappears. The parameter selection list disappears.

When setting the right appropriate seeding parameters, left-click on the icon “确定”, and then, the sowing parameter setting window will disappear.

4 Experiments and Analysis

On May 23, 2011, after the experimental production of the four-row planter was finished in the prototype modular planting unit, field tests were conducted to examine the planter’s mechanical performance and monitoring systems of the planter in the plots of belonging to the Yiyuan Agricultural Machinery Manufacturing Co. Company in Qingyun, Shandong Province. Through the tests, improvements were made on the ditching forms, metering device selection, installation dimensions of the components, and the detection effect of the sensors.

On June 16th, 2012, after the improvements on the prototype were finished, planting tests were run on the Yiyuan Company’s plots of Yiyuan Agricultural Machinery.
Manufacturing Co. in Qingyun, Shandong Province and in the nearby smaller pieces of fields in Dongxin Township after the wheat harvest. Wheat stubble left in the test fields were in of different various heights, different straw mulch, and varying humidity had been left in the tested fields. Three types of seeders were tested: (1) the passive-driving roller-driven mechanical-seeding type, (2) furrow-opening-disc-rollover type, and (3) rotary-knife-furrow-rollover-seeding type. The technical parameters tested and compared included furrow-opening performance proficiency, planting precision, stepless-spacing regulating regulation performance, consistency of seeding depth, seed damage, soil-covering performance proficiency, and monitoring system operations working performance. According to the examination results by from the Quality Supervision and Inspection Station of Agricultural Machinery Products of Shandong Province, the detection accuracy for counting corn seed number was 91.4%; the seed-clog fault-alarm accuracy rate was 96.0%; the fertilizer-clog fault-alarm accuracy was 95.5%. The results indicate that the entire system was stable and reliable.

5 Conclusions Summary

(1) The distributive monitoring system of for monitoring planting status developed in this study has the following features: it

- achieves bidirectional information transfer between upper and lower PCs;
- it can monitors spoon-plate speed, and status of fertilizer tank and seed tanks;
- it sends audible alarms;
- it has real-time display of actual planting spaces;
- it can realize enables real-time control and regulating regulation of spacing; and
- can show displays real-time video of the planter during the planting process.

(2) The intelligent stepless spacing regulator developed in the this study realizes satisfies the precision requirements for corn precise sowing and regulating on precise the spacing of corn regulating. The device can achieve stepless spacing regulating regulation of manually- and electronically-controlled automatic seeding, in which the transmission ratio ranges from 0.8 to 3.1 (corresponding to the spacing 15 ~ 50cm). The regulator uses a micro-motor to perform implement stepless CVT, which enables the planter to change speed steplessly during work operation.
References
[1] Huang Guangqun, Han Lujia, Liu Xian, and Yang Zengling. Establishment of an evaluation system for integrated agricultural mechanization engineering technology [J]. Transactions of the Chinese Society of Agricultural Engineering, 2012, (16): 74—79. (in Chinese with English abstract) [Editor CJR’s Note: Since this bibliographic information is a translation, I have improved the English therein. However, if it had already been published this way—with the errors— I would not revise it. This comment also applies to other entries, below.]


[12] Li Tai-we, Li Hong-wen, He Jin. Design of 2BMF-5 Type No-till Wheat Planter in Ridge-field. Journal of Agricultural Mechanization Research.2008,(10):50-