The adoption of automatic navigation technology for row-followed no-till seeding in China

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1. Introduction

Conservation agriculture (CA), which can decline soil erosion and increase yields, has formed a series of mature technologies and equipment in China after years of study and development. It is well known that CA has the standing stubble and root system of the crop in the underground during row-followed no-till seeding, which results in the blocking issue of machine and high labor intensity. To avoid these problems, the approach that integrating agricultural machinery with measurement and control, navigation and other technologies to realize the automation, intelligence and precision of CA production was proposed. In the past decades, numerous smart technologies have applied at CA. The objective of this paper is to review the application progress of Automatic Navigation Technology (ANT) applied at row-followed no-till seeding in China, especially for wheat row-followed no-till seeding in north China plain where summer maize and winter wheat are cultivated in sequence.

2. PRINCIPLE OF ANT APPLIED AT ROW-FOLLOWED NO-TILL SEEDING

Generally, in north China plain where annual maize-wheat rotation, wheat seed spacing, maize standing stubble row spacing, and maize root system radial radius are 20 cm, 60 cm, 3~5 cm, respectively. In addition, the maize stubble will be uprooted when the furrow opener is within 5 cm of the maize root system radius, which indicates that the lateral deviation of the no-till seeder in row-followed operation is only ±5 cm. If the deviation exceeding ±5 cm, the furrow opener is easy to meet with maize stubble, which will cause blockage or shutdown of no-till seeder, and seriously negative effect on seeding. To sum up, although it is difficult to achieve the required accuracy only by manual operation, but ANT could be a promising technology to solve the problems. The principle of ANT applied at row-followed no-till seeding is shown in figure 1, the no-till seeder guided by ANT can avoid the maize stubble row and seed wheat between two maize stubble rows. Consequently, this way can improve the precision and efficiency of row-followed no-till seeding.

3. ANT APPLIED AT ROW-FOLLOWED NO-TILL SEEDING

According to the principle of navigation, ANT includes mechanical touch navigation, machine vision navigation, GNSS navigation, laser navigation, compass navigation, etc. Currently, the ANT applied at row-followed no-till seeding mainly includes touch type ANT, machine vision type ANT and GNSS type ANT. The basic structure of ANT applied at row-followed no-till seeding mainly information collection module, control module, monitoring module and execution module (Fig. 2).

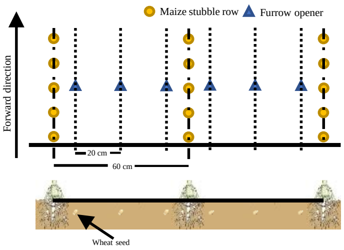

Fig. 1. Principle of ANT applied at row-followed no-till seeding

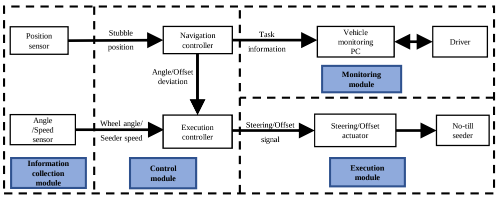

Fig. 2. Basic structure of ANT applied at row-followed no-till seeding

Table 1. Performance comparison of three types ANT applied at row-followed no-till seeding

ANT type	Advantages	Disadvantages
Touch type	1. Simple mechanism. 2. Low cost.	1. Labile detection signal. 2. Low precision.
Machine vision type	1. Real-time path planging. 2. High precision.	1. Time-consuming. 2. Easily affected by enviornment.
GNSS type	1. High precision. 2. Widely allications increasing.	1. High cost. 2. Easily affected by weather. 3. Non-real-time path planning

3.1 TOUCH TYPE ANT

The basis of touch type ANT is the detection device of stubble row, which is designed according to crop cultivation characteristics. The detection device generates path signal and transfers to control center when the seeder is in operation. Then control center calculates steering signal and controls the actuator to complete operation of stubble avoidance. The actual wheel angle was fed back to the control center to form a closed-loop control. The Vehicle monitoring PC is monitoring the module which adjusts navigation real-time parameters and responds to the failure of machine in unexpected risky situations. Wei et al. (2005) proposed an automatic guidance system based on electro-mechanical servo following stubble. He et al. (2007) presented an automatic guidance system based on touch type and compass type navigation. The test results showed that the maximum offset of the two guidance system was 6cm when tractor speed was less than 1m/s.

3.2 MACHINE VISION TYPE ANT

The machine vision type ANT is a non-contact technology to acquire the relative location information between the seeder and the stubble row. During no-till seeding operation, visual sensor is directly mounted on the no-till seeder to collect images of stubble row and sends to control center. Then, control center calculates the offset signal according to seeder speed and guides offset actuator movement to realize row-followed seeding without contacting maize stubble. Chen et al. (2008) presented a navigation line detection algorithm for the maize stubble row without stubble residues coverage between rows. The tests showed that the processing time of a 640×480 pixels image was less than 0.1s. Li et al. (2009) designed a no-till seeding navigation control system to perform row-followed no-till seeding operation. The maximum error angle of tracked signal was 1.5°. Chen et al. (2018) proposed a method to detect maize stubble row with maize residues covering between rows and designed a row-followed control system to realize stubble avoidance and furrow opening operation. The field experiment revealed that the furrow openers could effectively avoid the maize stubble when the seeder speed was less than 1.2 m/s.

3.2 GNSS TYPE ANT

The GNSS type ANT is not a non-contact technology either, but it obtains the absolute position information of the machine (Liu et al., 2018). The control center compares the current position information received from GNSS sensor with the previously specified navigation path information and generates steering signal. After receiving the steering signal, steering actuator moves to achieve stubble avoidance and row-followed no-till seeding. Nowadays, research on GNSS type ANT in China mainly concentrated in path planning, navigation control, etc. In addition, GNSS ANT is not fully applied at agricultural production in China. To be specific, GNSS ANT is separately applied in tillage, seeding, field management and harvesting in agricultural mechanization production. Moreover, due to the seeding precision and growth environment, the maize stubble row is not a straight line. Consequently, row-followed seeding operation needs real-time path planning according to the electronic map containing maize stubble position information. To sum up, the key to the realization of row-followed no-till seeding based on GNSS type ANT is the advance acquisition of electronic map containing stubble absolute position information.

Table 1 shows the performance comparison of three types ANT applied at row-followed no-till seeding.

4. PROSPECT

Automation, intelligence and precision is the future development direction of CA. ANT is a key technology in smart agriculture technologies, which has been gradually applied at CA over the past years in China. However, actual field operating environment is complex, since it could have natural illumination, uneven crop growth and other obstacles potentially affecting application of ANT in row-followed no-till seeding. Therefore, based on analyzing the present research situation, it is suggested that the future research can be considered from three aspects: (1) Optimizing conventional algorithms and exploring new algorithms for stubble detection. (2) Further improving ANT control system to achieve great performance in complex farmland environment; (3) Developing a real-time and rapid acquisition technology for electronic map containing stubble absolute position information.

5. CONCLUSIONS

On the foundation of summarizing the principle of ANT applied at row-followed no-till seeding, the adoption of ANT for row-followed no-till seeding in China was introduced in detail in this paper. Then this paper has prospected the future development directions of ANT in row-followed no-till seeding. This paper intended to provide a reference for the development of ANT for CA.