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Study of Fuzzy Control Technology Application in Wheat Precision Seeding

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Abstract: In this study, in order to further improve the accuracy and reduce the error in wheat sowing , the study be based on the theory of fuzzy control and the PID control mode, puts forward a design idea of fuzzy control of stepper motor, to use stepper motor instead of the land wheel driving sowing. Single chip microcomputer as the core of control system, The information sent by the Bluetooth module for wireless and through man-machine interface setting seeding parameters and real-time display of sowing condition. The effect on the design of two dimension fuzzy controller by using SIMULINK simulation, good, can effectively improve the accuracy and stability about wheat seeding.

Key word: Fuzzy control, precision seeding, PID, microcontroller, bluetooth, stepper motor

INTRODUCTION

The performances of seeder directly affects the productivity and the emergence rate of seedlings. The seed metering device acts as seeder's core and it plays an important role in seeding quality (Zhang and Zhao, 2008). Based on current control system for international crop planting of investigation, research, analysis, this study presents an automatic control for seeding, using AT 89C52 as CPU. In this system, stepping motor drives seed metering device; meanwhile, the sensor detects the seeding situation and transmit feedback signals to the CPU. The wheat seeder by fuzzy PID control, it not only keeps the advantages of PID control system, such as simple operation, good robustness and high precision; but also the advantages of fuzzy control, such as good flexibility and adaptability (Li *et al*., 2012; Duan and Yang, 2006). Through the man-machine interface display and adjust the parameters of operation condition of seeding.

WORKING PRINCIPLE OF THE CONTROL SYSTEM

The study purpose is to use fuzzy PID control in the precision seeding system of wheat, in order to improve the seeding accuracy and quality. Fig. 1 shows a schematic diagram of system control in the fuzzy PID control of wheat precision seeding machine.

The automatic control of wheat precision seeding system is based on AT89C52 microcontroller (CPU). The

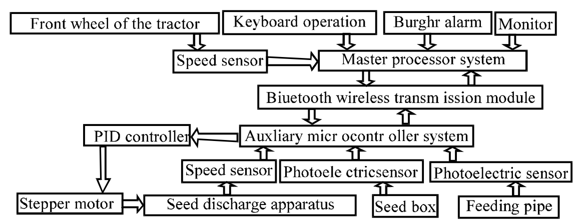

Fig. 1: Schem

CPU could control the stepping motor and the stepping motor drives the axle of seed metering device. In order to ensure the uniformity of seeding, the speed of seeding and the revolving speed of stepping motor should maintain a certain corresponding relationship; therefore, system must preset the revolving speed of stepping motor in MCU (Zhuang, 1996). Normal sowing, microcontroller CPU receive information from different channels, timely analysis and processing, such as: Tractor speed, sowing shaft speed, less seed in seed box, seed conveying pipe blockage, etc. sends out the control command to the corresponding member of the seeding machine (Ding, 2002). Information transmission between the main and auxiliary microcontroller is using Bluetooth wireless mode (Wang *et al*., 2002). Fuzzy PID control technology is applied to the computer analysis and processing, can further determine whether need to adjust the speed of the stepping motor, to ensure it's cooperation with tractor speed, according to the actual needs of seeding to drive the shaft rotation.

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Table 1: Parameters for three phase hybrid stepping motor

85series three -phase stepping motor	Teeth No. Z_r	Inductance L (mH)	Inertia moment J ($kg*cm^2$)	Viscous damping D coefficients	Phase current
	40	3	1.1	0.08	5.8

HARDWARE OF CONTROL SYSTEM SELECTION

Choice of step motor: According to the different types of stepper motor performance, parameters and so on careful analysis, comparison and judgment, can be learned, hybrid stepping motor has the advantages of both reluctance stepping motor and permanent magnetic stepping motor ,such as smooth operation, a good internal damping and no low-frequency resonance (Crnosija *et al.*, 2000). It is an optimal terminal actuator. The system uses a three-phase hybrid stepping motor and its parameter index is shown in the Table 1.

The main device selection of control system: Because the output of the encoder is the continuous pulse, MCU need frequent judging and handling, so the MCU being demanded to have better stability. Here, STC12C5A60S2 MCU is being selected, The hardware circuits of the main microcontroller system were installed at the tractor, auxiliary microcontroller system were installed at the seeding machine, the transmission of various information were transmitted by HC-06 Bluetooth module in full duplex mode, this transfer is wireless serial communication, can receive and transmit data at the same time. The man-machine dialogue interface is used to setting the control system parameter and display alarm, etc.

DESIGN OF THE CONTROL SYSTEM SOFTWARE

Selection of the stepper motor control mode: Through the experiments, we can find that seed metering device had weaker consistency at different speed of the stepping motor which was bound to affect the uniformity of sowing. Therefore, the control system requires an appropriate algorithm to achieve online self-tuning of controller when parameters of control object changed which can analyse, integrate and process the measured data quickly and accurately, in order to achieve intelligent real-time control of the stepping motor (Senjyu *et al.*, 1995).

In the industrial process control, adjusting parameters of PID controller properly may achieve the satisfied system performance. PID algorithms can be implemented by computers and the control law for discrete PID is given as follows:

$$U(n) = k_P e(n) + k_I \sum_{j=0}^{n} e(j) + k_D \frac{e(n) - e(n-1)}{T}$$

U(n)-Output of the controller in the n th sampling time.

e (n)-Input of the controller in the n th sampling time(deviation signal).

k_P, k_I, k_D-Proportional coefficient, integral coefficient and differential coefficient.

Conventional PID controller is quite convenient but cannot adjust parameter online, thus cannot control complex system well. When PID control theory is combined with fuzzy control theory which is applied to stepping motor control system, it can make full use of their own advantages and improve control performance of stepping motor system.

Principle of self-tuning fuzzy PID controller: The stepping motor control system is a closed-loop system with feedback,which is used for providing the controller with measured values. The pulse number measured by photoelectric encoder acts as the actual measured value c (t) of the controller.

According to characteristic of the general fuzzy controller and input characteristics of motor control system, the design of self-tuming fuzzy PID controller chooses two-dimensional fuzzy controller. Stepping motor's velocity error (e) and error rate of change (ec) are regarded as the input variable of fuzzy PID controller the number of output pulses of stepping motor are regarded as output variable.Meanwhile, k_P, k_I and k_D are regarded as output variable of the fuzzy controller. The self-correcting fuzzy PID controller corrects the PID parameters on-line according to fuzzy theory. The controller structure is shown as Fig. 2.

The role of fuzzy controller is to regulate three parameters of PID control: kP, kI and kD. Parameters should be divided into two parts:initialization and correction:

$$K_P = K_{P0} + \Delta K_P$$

$$K_I = K_{I0} + \Delta K_I$$

$$K_D = K_{D0} + \Delta K_D$$

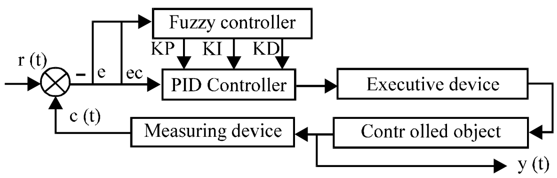

Fig. 2: Fuzzy PID controller structure

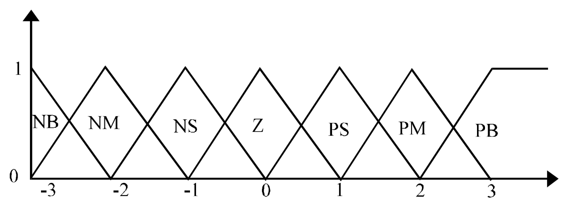

Fig. 3: Membership function for error (e) and change in error (ec)

Table 2: ΔK_P Table rules table

e^{ec}	NB	NM	NS	Z	PS	PM	PB
NB	PB	PB	PB	PB	PM	PS	Z
NM	PB	PB	PB	PB	PM	Z	Z
NS	PM	PM	PM	PM	PS	Z	NS
Z	PM	PM	PS	Z	NS	NS	NS
PS	PS	PS	NS	NM	NM	NM	NM
PM	Z	Z	NM	NB	NB	NB	NB
PB	Z	Z	NM	NB	NB	NB	NB

Table 3: ΔK_I Table rules table

e^{ec}	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NM	NM	NS	Z	Z
NM	NB	NB	NB	NS	NS	Z	Z
NS	NM	NM	NS	NS	Z	PS	PS
Z	PM	PM	PS	Z	PS	PM	PM
PS	PS	PS	Z	PS	PS	PM	PB
PM	Z	Z	PS	PS	PM	PB	PB
PB	Z	Z	PS	PM	PM	PB	PB

Table 4 ΔK_DTable rules table

e^{ec}	NB	NM	NS	Z	PS	PM	PB
NB	PS	NS	NB	NB	NB	NM	NB
NM	PS	NS	NB	NM	NM	NS	Z
NS	Z	NS	NM	NM	NS	PS	PS
Z	Z	NS	NS	NS	NS	NS	Z
PS	Z	Z	Z	Z	Z	Z	Z
PM	PM	NS	PS	PS	PS	PS	NB
PB	PB	PM	PM	PM	PM	PM	NB

ΔK_P, ΔK_I, ΔK_D-Three correction coefficient calculated by the fuzzy PID controller at kth sampling time. K_{P0}, K_{I0}, K_{D0}-Three initial value.

Design of fuzzy control rules: Fuzzy control rules is actually an experience for the process that people control. According to the actual situation of stepping motor, the universe of variables (e, ec, ΔK_P ΔK_I, ΔK_D) is divided into 7 grades:

$$e = \{-3, -2, -1, 0, 1, 2, 3\}$$
$$ec = \{-3, -2, -1, 0, 1, 2, 3\}$$
$$\Delta K_P = \{-0.3, -0.2, -0.1, 0, 0.1, 0.2, 0.3\}$$
$$\Delta K_I = \{-0.09, -0.06, -0.03, 0, 0.03, 0.06, 0.09\}$$
$$\Delta K_D = \{-0.3, -0.2, -0.1, 0, 0.1, 0.2, 0.3\}$$

Control rules of the fuzzy controller are usually expressed as a set of fuzzy conditional statements. When many elements are selected, the next control rule can be more detailed; however, the control rules become more complex. So, both flexibility and simplicity should be taken into consideration when we decide the number of elements. The design of fuzzy linguistic subset were selected as follows:

$$\{NB, NM, NS, Z, PS, PM, PB\}$$

The design select Triangle-shape grade of membership function for input variables and the output variable (Juang *et al*., 2008) and the membership function for e and ec is given as Fig. 3.

Fuzzy control rules: The linguistic control rules is in the form of "if A and B then C". Then, the fuzzy control table should be made according to the thought of parameter self-tuning. Fuzzy control rules tables for ΔK_P, ΔK_i and ΔK_D are given, respectively as Table 2-4.

Defuzzification for output: Fuzzy controller should transform fuzzy variable to precision variable at last. The design uses the method of maximum membership. This method is that the element with the largest membership grade should be selected from the output set. If there are two or more elements with the largest membership grade, the average value of these elements should be selected from them.

Mathematical model for the stepping motor: For verifying the control performance of fuzzy PID controller through simulink simulation platform,the transfer function of stepping motor must be established. The system used three-phase hybrid stepping motor, according to its mathematical model, can use different methods to represent the transfer function between the output and input variables. The motor rotor can be rotated for a standard step angle θ_1 theoretically but the actual angle θ_2 (the output) always oscillates around a new balance

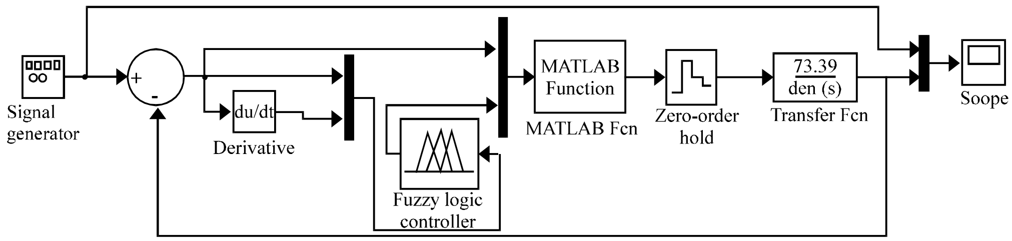

Fig. 4: Simulation block diagram of fuzzy PID controller

Table 5: Accuracy test of seeding

Required seeding quantity (Jin/mu)	Actual seeding quantity (Jin/mu)	Percentage of error (%)
4.0	4.2	5
5.0	5.2	4
6.0	5.8	3.3
7.0	6.9	1.4
8.0	7.9	1.3

point. According to vibration theory, the transfer function mathematical model of the stepping motor can be expressed as follows:

$$G(s)=\frac{\theta_2(s)}{\theta_1(s)}=\frac{Z_r^2L_1i_A^2/2J}{S^2+DS/J+Z_r^2L_1i_A^2/2J}$$

Simulation analysis: If we put parameters of three-phase stepping motor we have chosen into the transfer function of stepping motor, the specific transfer function will be obtained as follows:

$$G(s)=\frac{73.39}{S^2+0.0727S+73.39}$$

The system can implement the simulation of fuzzy PID controller, Fuzzy Logic Toolbox in simulink are used for the simulation, we can obtain Simulation block diagram of Fuzzy PID controller as Fig. 4.

Through the simulation diagrams, we know that fuzzy PID controller of stepping motor may effectively reduce the oscillation, furthermore, the fuzzy PID controller can correct steps and make the system return to normal quickly.

In order to further verify the control effect of the system, Here, we do mass accuracy test to the seeding machine prototype. The test results was shown in Table 5.

Table 5 shows, different sowing conditions, seeding percentage error is different, it presents the rules: Set per mu more sowing quantity, percentage error is lower; Mu sowing amount is smaller, the higher the percentage error.

CONCLUSION

Fuzzy PID control applied to seeding precision technology is discussed in this study which is a new thought for planting. A simple fuzzy controller is equivalent to a conventional PD controller,which may cause static errors. When PID control theory is combined with fuzzy control theory, it can improve control performance of stepping motor system and achieve synchronization with seeding. The self-correcting fuzzy PID controller corrects the PID parameters on-line according to fuzzy theory. This kind of controller has good robustness, high precision control ability and high reliability. In a word,the design is of high application value and popularization value.

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