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MBD of grey prediction fuzzy-PID irrigation control technology

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ABSTRACT

For the water and fertilizer ratio adjustment, irrigation control precision and problems and development cycle in the agricultural water–fertilizer irrigation, the control model of the combination of proportion-integral-derivative (PID) control, fuzzy control and grey prediction control were designed, and the controller design was carried out based on the model design method. It can achieve the engineering code to the embedded hardware requirements of the whole process of automation, efficiency of water and fertilizer irrigation controller, rapid development and application. PID control was based on fuzzy rules and query fuzzy matrix table to obtain parameter self-turning, then it could adjust PID parameters in real time, furthermore, joined multi-factors grey forecasting multi-variable grey model (1, *n*), so as to effectively predict the water requirement of the crop and achieve the precise irrigation of the system. The running results the system reduces the overshoot by 14.68% compared with the conventional PID control, and the adjustment time of the system is reduced by 86.62%. Compared with the fuzzy PID control, the overshoot is slightly increased by 1.9%, but the adjustment time is reduced by 177.71%. Meanwhile, in the water and fertilizer concentration control system, the controller is developed quickly, the code quality is high, the system response speed is good, the real time is good and stable, and the effect of water and fertilizer is greatly improved.

Keywords: Water fertilizer irrigation; Model-based design; Fuzzy PID control; Grey prediction control

1. Introduction

Nowadays, water security is the basis of food security. To achieve the efficient use of agricultural water resources, protection of water security and food security is a fundamental way [1]. In recent years, China's crop water-saving irrigation for the promotion of a variety of suitable conditions for the equipment, water-saving irrigation automation equipment has made great progress, and water-saving irrigation technology has been widely applied in agriculture. However, the water-saving irrigation systems need an automatic control system for high-precision irrigation and fertilization according to different crops [2], the research process to improve the control accuracy of the research progress is relatively slow, and the controller development process is more complex. Development cycle is long, and all the links are more prone to error [3], but the control process is very easy.

Precise irrigation not only can control the irrigation for normal growth required water and fertilizer but also can obtain the maximum benefit with the least amount of water and fertilizer. However, the irrigation object is a large inertia, nonlinear and pure delay system, it cannot establish a precise and unified mathematical model, so, the traditional control method has been a serious challenge [4–6]. Fuzzy control does not need to establish the mathematical model of the controlled object, robust and effective to improve its nonlinear and time-varying problems [7–9], but the lack of large delay phenomenon.

According to the controller development in the traditional water–fertilizer irrigation, the algorithm control was used by manual programming development, and complex algorithm required a high programming ability, and the process was more complex, long development cycle. But

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model-based design (MBD) can generate engineering files through the underlying driver tool-tag support package (TSP) chained links, links Simulink, STM cubemx and Keil, and completes the rapid embedding of the model algorithm to realize the water–fertilizer irrigation controller was developed rapidly [10,11]. At the same time, MBD method was more researched in the field of automatic code generation [12], while the research on the pre-test validation phase and the entire development process optimization was less.

In this study, combined with the control effect of proportion-integral-derivative (PID) controller, fuzzy control to improve its nonlinear control effect, grey predictive control to solve the phenomenon of large delay were researched, which is a good way to overcome the control accuracy. The MBD method can solve the above problems such as the physical modelling of the controlled object, the validation of the code and the generation of the underlying driver code. The simulation results show that the controller can control the water and fertilizer effect in the water–fertilizer irrigation control machine.

2. Materials and methods

2.1. Working principle of precision water and fertilizer control

The precision water–fertilizer irrigation control machine is mainly composed of controller, flowmeter, pressure gauge, solenoid valve, pump, filter and sensor and control software, crop water and fertilizer demand database software and so on. Access to the collection of soil crops and water temperature and ground temperature information, the water and fertilizer mixture for the closed-loop control, continuous control of water and fertilizer frequency to achieve intelligent automatic water and fertilizer irrigation control, with automatic and manual control mode.

Its working principle: the crop water shortage state was collected by soil moisture sensor in the field, the controller receives the signal, sends instructions, opens the inlet pump, opens the solenoid valve, let the water into the pipeline and water flow meter to detect water, to a certain value sends feedback to the controller, then the controller to make a decision to determine the start of the corresponding nutrient solution by the fertilizer pump, open the solenoid valve into the pipeline, according to the expert system matching crop nutrient solution concentration, water and fertilizer mixed outlet into the scene network for precise irrigation.

The controller that mainly uses the RAM as the control core, has adopted the fuzzy PID control, controls the precision of water and fertilizer ratio adjustment and the fuzzy algorithm integrates with the expert experience to automatically adjust the PID parameters. It can get the main performance index, overshoot σ = 9.82% , the adjustment time ts = 20.1 s, the current time lag phenomenon, the real-time fertilization will have a significant impact, it needs to further reduce the adjustment time, closed-loop control schematic shown in Fig. 1.

2.2. Grey prediction control theory

There are many factors that can affect water required for crops, such as climate factors, soil moisture and so on, some of these factors can be clearly known, some are unknown, it is in line with the grey system hair category. According to this situation, the grey prediction with multi-factor multi-variable grey model (MGM) (1, n) can have a forecast effectively, such as water requirement. In addition, the grey prediction model is a set of partial differential equations [6–9].

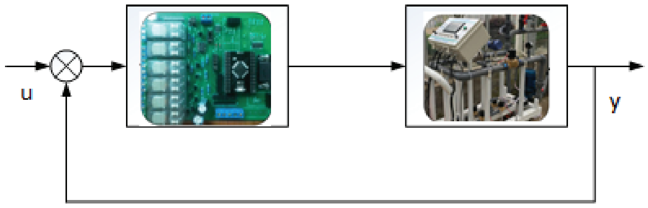

Fig. 1. Schematic diagram of water–fertilizer precision control.

The following equations show the algorithm for multi-factor grey prediction model, where n indicates n sequences data and m indicates m historical data in each sequence. To calculate accumulation for χ_i^0, get $x_i^0 = \{x_i^0(1), x_i^0(2), \cdots, x_i^0(m)\}$. Set there are n inputs in the system and each input has N time data $\{X_i^{(0)}(k)\}$. Do an accumulation for it $\{X_i^{(1)}(k)\}$.

The equation is:

$$X_i^{(1)}(k) = \sum_{j=1}^{k} X_i^{(0)}(k) \tag{1}$$

where $i = 1, 2, ..., n$; $k = 1, 2, ..., N$

Ordinary differential equations of MGM (1, n) model:

$$\begin{cases} \frac{\mathrm{d}X_1^{(1)}}{\mathrm{d}t} = a_{11}X_1^{(1)} + a_{12}X_2^{(1)} + \cdots + a_{1n}X_n^{(1)} + b_1 \\ \frac{\mathrm{d}X_2^{(1)}}{\mathrm{d}t} = a_{21}X_1^{(1)} + a_{22}X_2^{(1)} + \cdots + a_{2n}X_n^{(1)} + b_2 \\ \vdots \\ \frac{\mathrm{d}X_n^{(1)}}{\mathrm{d}t} = a_{n1}X_1^{(1)} + a_{n2}X_2^{(1)} + \cdots + a_{nn}X_n^{(1)} + b_n \end{cases} \tag{2}$$

Define:

$$\begin{aligned} X^{(0)}(k) &= [X_1^{(0)}(k), X_2^{(0)}(k), \cdots, X_n^{(0)}(k)]^T \\ X^{(1)}(k) &= [X_1^{(1)}(k), X_2^{(1)}(k), \cdots, X_n^{(1)}(k)]^T \end{aligned} \tag{3}$$

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}, B = \begin{bmatrix} b_1 \\ b_2 \\ \vdots \\ b_n \end{bmatrix} \tag{4}$$

where A and B are identification parameter. And rewrite Eq. (2) to matrix:

$$\frac{\mathrm{d}X^{(1)}}{\mathrm{d}t} = AX^{(1)} + B \tag{5}$$

where $X^{(1)} = (X_1^{(1)}, X_2^{(1)}, \cdots, X_n^{(1)})$

Then obtain the prediction by computing MGM (1, *n*) model:

$$\hat{X}_i^{(1)}(k) = e^{\hat{A}(k-1)}(X_i^{(1)}(1) + \hat{A}^{-1}\hat{B}) - \hat{A}^{-1}\hat{B} \tag{6}$$

Reduction writing:

$$\begin{cases} \hat{X}_i^{(0)}(1) = \hat{X}_i^{(1)}(1) \\ \hat{X}_i^{(0)}(k) = \hat{X}_i^{(1)}(k) - \hat{X}_i^{(1)}(k-1) \end{cases} \tag{7}$$

where $i = 1, 2, ..., n; k = 2, 3, ..., N$

2.3. MBD method

2.3.1. Model-based design

MBD is to design and solve complex control system, signal processing and communication system-related issues of mathematical and visual methods, the technology is gradually extended to a variety of embedded control, the demand, control algorithms, embedded hardware and software and other factors, which were integrated into a graphical executable design protocol for early simulation verification and process automation [13]. The entire development process is shown in Fig. 2.

Fig. 2 shows the MBD development flow in the form of two-dimensional coordinates, the abscissa is from the model simulation to the final product process and the vertical coordinate is the algorithm design matching the initial demand. First, simulation link is the initial realization of the graphical needs, and transform the algorithm into the algorithm, build in the Simulink platform, it also can model in the state flow in series with the same platform. Furthermore, the system-level closed-loop simulation not only involves the design of things, the controller model also has a controlled object model, early to establish a closed loop, the system behaviour early verification. Second, the real-time test link is a functional type of rapid prototyping, detection algorithm is consistent with the real-time simulation results, the algorithm model generated code downloaded to the IPC or controller by real-time comparison. The most important of the part is hardware in the ring simulation, which is a large system different from the functional rapid prototyping, this system must be connected to the various components, the controlled object through the sensor and other equipment as an interface, the control system microcontroller unit (MCU) and the controlled object hardware in the ring platform to connect by real-time simulation, fast iterative design method. Finally, the product link is the model directly to the code, the design to achieve a fast iteration, to achieve model and code consistency, the model is reflected to the real system. In the ongoing test, the code is verified and tested under the PC, MCU, non-real-time and real-time environment to ensure the reliability and real-time engineering. So, model based on design and development can greatly improve the embedded development efficiency.

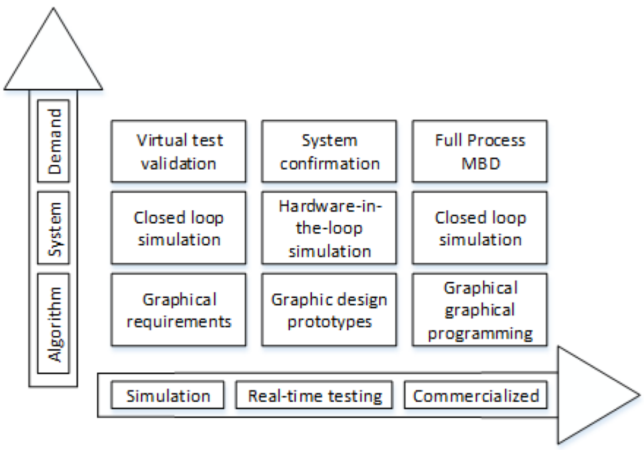

Fig. 2. MBD complete development flow chart.

2.3.2. Bottom driver support package

To further improve the efficiency of development, for STMicroelectronics ARM chip STM32F407, the driver code TSP is provided, it is suitable embedded engineers in the Simulink environment configuration and can automatically generate code. This package TSP enables embedded development of water–fertilizer irrigation control-based entirely on the model development process and supports automation from code to hardware implementation processes. ST officially provides TSP for STM32-MAT/TARGET, and the compiler (STM32 embedded target) already supports the MATLAB R2014a version. It mainly provides two components, Simulink toolbox provided by the peripheral driver library Peripheral Simulink Library (PSL) and Toolchain, the structure is shown in Fig. 3.

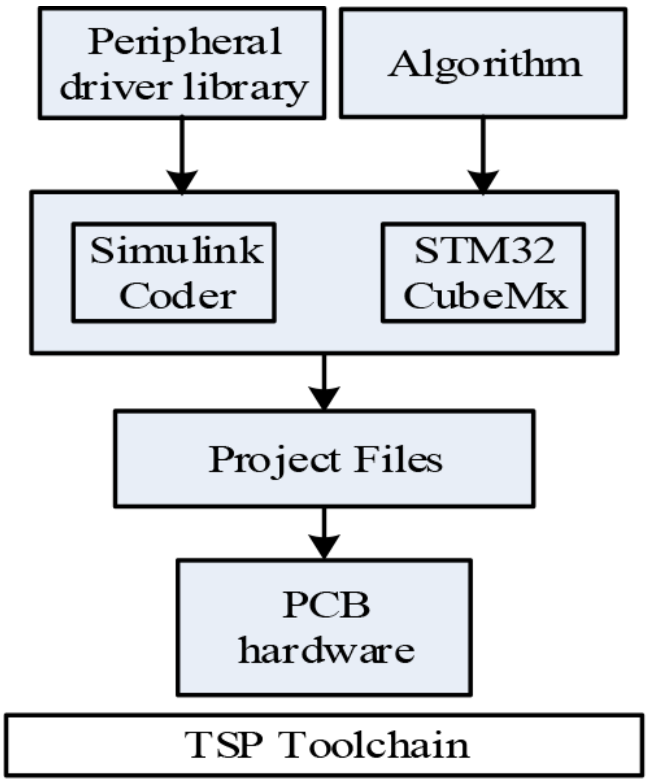

Fig. 3. TSP structure diagram.

PSL for embedded engineers to provide peripheral driver module, fully support Simulink environment, to achieve rapid algorithm construction. PSL provides analog-to-digital converter (ADC), controller area network (CAN), digital -to- analog converter (DAC), general purpose input/output (GPIO) and other peripheral modules and MCU CONFIG chip configuration module. Toolchain link, through it and Simulink and keil MDK5 and other tools link, the custom algorithm model and TSP generated by the combination of driver code, generate engineering documents compiled, directly downloaded to the real machine for verification.

2.3.3. Irrigation-controlled object model

The pump is a key component of the water and fertilizer irrigation control system, and the motor is an important component of the pump. It is mainly supplied to the system water and fertilizer power, and its electrical and mechanical parts are linked by the central rotor of the electric energy and mechanical energy. The induced electromotive force of the rotor also affects the electrical and mechanical equations of the motor. From the law of induced electromotive force, we can see that the rotor of the electrical part of the motor will produce a reverse induced electromotive force and the external voltage to prevent the rotor from running. Therefore, if the rotor is to be rotated, it is necessary to overcome the induced electromotive force. Taking into account the rapid development of the controller, and the use of MBD, the simscape toolbox is used for multi-domain physical system modelling and simulation, more intuitive, convenient and fast in this paper [14].

The simscape model completed the design of the DC motor model, and configures the physical parameters of each block with the assumed values as shown in Fig. 4.

where resistance is R (Ohm), inductance is L (H), rotational inertia is J (kg m^2), torque coefficient is K (V/(rad/s)), damping coefficient is b (N m/(rad/s)).

In order to improve the response of the simulation system, sensors are needed to be added to simulate the various physical parameters of the measurement. Further, the simscape module needs to be associated with the Simulink module because the simscape signal represents a unit of physical quantities, whereas the Simulink signal is a dimensionless number, so the signal needs to be converted, using the Simulink-PS Converter and the PS- Simulink Converter module as shown in Fig. 5.

The five physical parameters were taken after the value of the simulation and linearization process, the DC motor simulation curve is shown in Fig. 6, it can be seen that the use of physical modelling model corresponding to the DC motor corresponding to generate control voltage signal in the accused (0–12 V) within the adjustable range of the object, indicating that the pump can be adjusted for the purpose of adjusting the flow rate.

2.4. Grey prediction fuzzy PID control and design principle

2.4.1. Fuzzy PID control system

The system is comprised of adjustable parameter PID systems and fuzzy control systems. The former system is to control systems and the latter is to correct the three parameters of PID control automatically. Normally, the digital PID controller can be expressed as the following function [15–18]:

$$u(k)=\frac{1}{\delta}\left(e(k)+\frac{T}{T_i}\sum_{i=1}^{k}e(i)+\frac{T_d}{T}\mathrm{ec}(k)\right) \tag{8}$$

where $u(k)$ is the control effective, $e(k)$ is the error and ec(k) is the rate of error change. All of them can be set as inputs of fuzzy systems. T is the sampling period of controller, δ is the proportional band, T_i is the integral time and T_d is the differential time.

2.4.2. Principle for fuzzy PID control design

The data are collected by sensors accurately in the systems, the parameters are unrecognized by the fuzzy controller directly. The analogy data need A/D conversion, and the result should transfer into fuzzy language according to certain rules. In the 2D fuzzy control, (due to the confuse meaning, cannot transfer the original sentences completely) according to latter deviation and deviation change rate to define [19–21]. In other words, the deviation which is

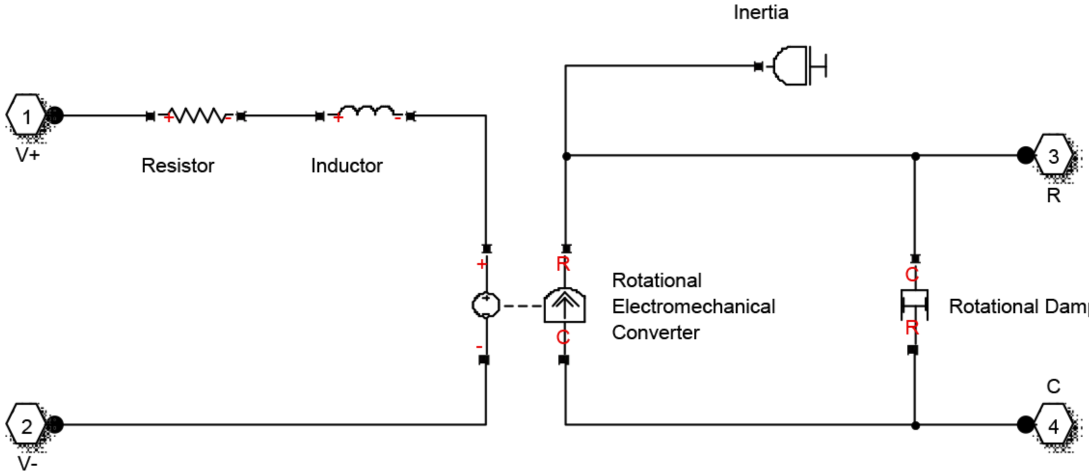

Fig. 4. DC motor simscape model.

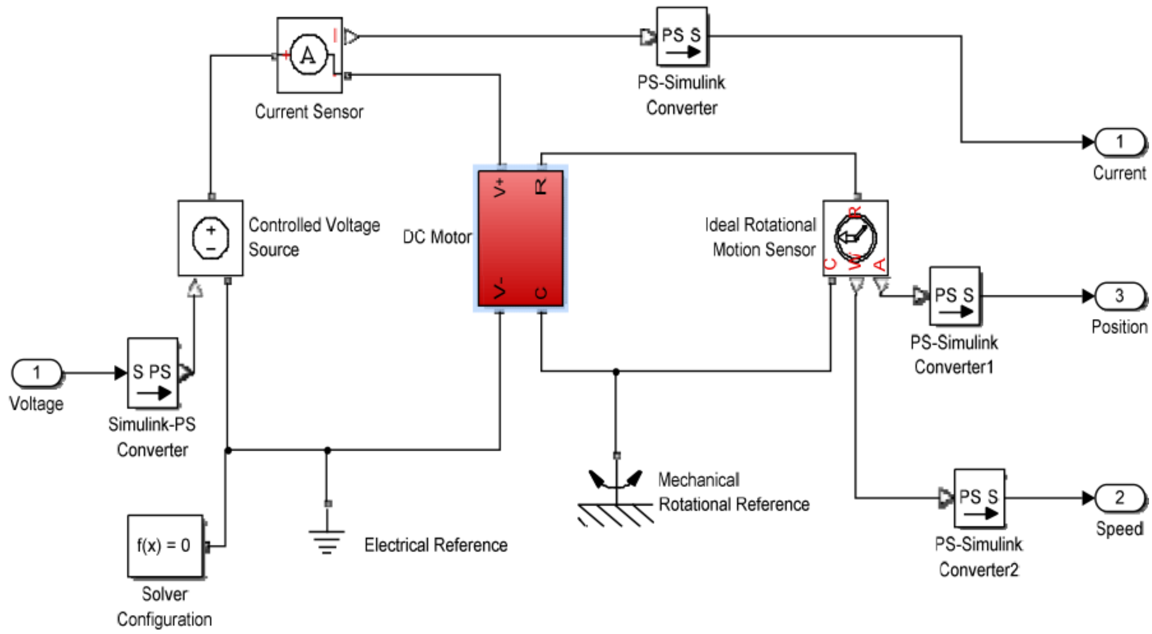

Fig. 5. Simulation model of DC motor simscape.

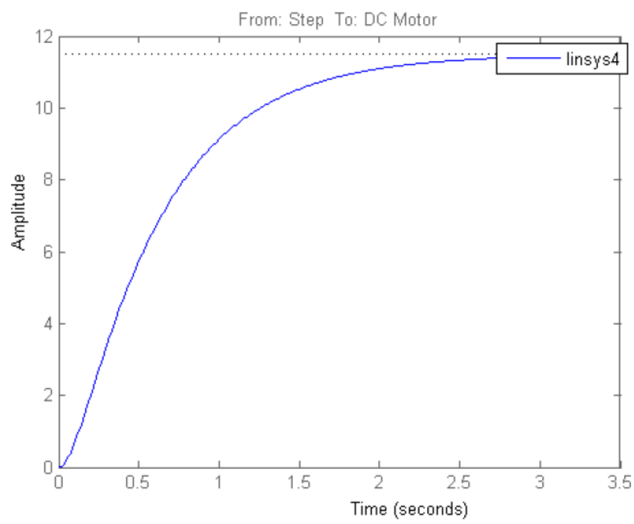

Fig. 6. Motor simulation curve.

mapped into fuzzy group of input domain called deviation E. by the same operation, do the map for the deviation change rate. Then get the language variable EC [22]. At last transfer the deviation and deviation change rate into fuzzy collective domain $X = \{-n, -n-1, \ldots, 0, \ldots, n-1, n\}$, by scale transformation according to the range of real situation.

$$E = \left\langle k_e \cdot \left(e - \frac{e_H + e_L}{2} \right) \right\rangle \tag{9}$$

$$EC = \left\langle k_{ec} \cdot \left(ec - \frac{ec_H + ec_L}{2} \right) \right\rangle \tag{10}$$

where < … > mean rounding operations.

The output of fuzzy controller needs be converted into variable u, the conversion formula is shown as below:

$$u = k_u \cdot U + \frac{u_H + u_L}{2} \tag{11}$$

According to precision requirement, it is divided the quantization of deviation and deviation rate into seven grades, for instance, {–3, –2, –1, 0, 1, 2, 3}. The input of fuzzy system includes fertilizer and water flow rate error e and error change rate ec, and the output includes three correcting parameters ΔK_p, ΔK_i, ΔK_d of PID controller [7–9,23]. Moreover, define the all fuzzy domain of e, ec and u are {large negative, medium negative, small negative, zero, small positive, medium positive, large positive}, which is expressed as {NB, NM, NS, ZO, PS, PM, PB}. The discourse domain range of e, ec and u are defined as {–3, 3}, the membership function uses the curve of triangle membership function [24]. According to the rules of PID control parameters, we can obtain the fuzzy rules of outputs, shows as Tables 1–3.

3. Results

When the flow rate of fertilizer and water is changed by the decision of irrigation system, the characteristics of controlled object parameters changed in a sensitive range. Therefore, the system uses the control method combined with PID control, fuzzy control and grey prediction control. On the one hand, integral effect of PID control can decrease steady state error and improve accuracy. In addition, fuzzy control can improve the adaptability of system by adjusting the PID parameters in real-time. On the other hand, the grey prediction control can solve the pure time delay of controlled object to increase control effect of object. The structure diagram of water-saving irrigation system is shown in Fig. 7.

Table 1
Fuzzy control rules of ΔK_p

e	ec						
	NB	NM	NS	ZO	PS	PM	PB
NB	PB	PM	ZO	PM	NM	NB	NS
NM	PB	PB	PM	PS	PS	ZO	ZO
NS	PB	PM	PS	ZO	ZO	NS	NS
ZO	PM	PS	PS	ZO	ZO	NS	NM
PS	PS	PS	ZO	NM	NS	NM	ZB
PM	PS	PS	PM	ZO	NS	NM	NB
PB	ZO	ZO	NS	NS	NM	NB	NB

Table 2
Fuzzy control rules of ΔK_i

e	ec						
	NB	NM	NS	ZO	PS	PM	PB
NB	NB	PB	NM	NM	NS	ZO	ZO
NM	NB	PB	NM	NS	NS	ZO	ZO
NS	NS	NB	NS	NS	ZO	PS	PS
ZO	NM	NB	NS	ZO	ZO	PS	PM
PS	NM	NS	ZO	ZO	PS	PM	PM
PM	ZO	ZO	ZO	PS	PM	PB	PB
PB	ZO	ZO	PS	PS	PM	PB	PB

Table 3
Fuzzy control rules of ΔK_d

e	ec						
	NB	NM	NS	ZO	PS	PM	PB
NB	PS	PS	NS	NB	NM	NB	PS
NM	PS	NS	NS	NM	NM	NS	ZO
NS	ZO	NS	NM	ZO	NS	NS	ZO
ZO	ZO	NS	NS	NS	ZO	NS	ZO
PS	ZO	ZO	NS	ZO	NM	ZO	ZO
PM	NB	NS	ZO	ZO	PM	PS	PB
PB	PB	PM	ZO	PM	PS	PB	PB

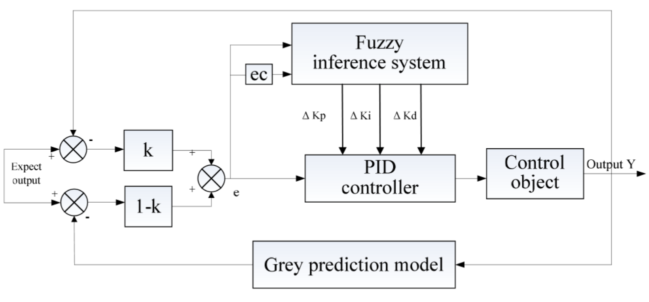

Fig. 7. Structure of grey prediction fuzzy-PID control for irrigation.

In fact, due to many factors such as around situation and control affection, there is an offset between output value and expected value. Then do the fuzzy logic inference, get the three PID tuned parameters under the present condition. Proceed to the next step, calculate the output value of PID controller for the controlled objects as a further operation. Moreover, set information collected from object as system feedback. The grey prediction model can get the value of next time, in other words, the feedback value which had not happened and value is the input value for system at present. This kind of control is called pre control.

Grey prediction fuzzy PID in Simulink model is shown in Fig. 8.

3.1. Analysis for experiment result

3.1.1. Simulation debugging experiment

Do a simulation test to verify effective of grey fuzzy-PID control algorithm. Model the system by fuzzy logic toolbox in the Simulink, set step signal as input for the system. Then do normal PID control, fuzzy-PID control and grey prediction fuzzy-PID control simulations, respectively, and the simulation result is shown in Fig. 9. Meanwhile Table 4 shows the performance of these three kinds of systems according to the experiment results.

From the above table, it is clear to get the system based on grey theory and fuzzy control method to have the best performance, for example, smooth curve, less overshoot and better stability. In the meantime, this system has both less rise time and settling time than the first two systems. In addition, system can reach steady state rapidly, this means grey prediction fuzzy-PID control has a good control performance and robustness.

3.1.2. Water and fertilizer concentration irrigation test

Open the project in keil MDK, compile and generate executable files, download to the entity control machine, that is the traditional PID control, fuzzy PID control and grey prediction fuzzy PID control are loaded into the irrigation system, and the data are sent to the PC through the serial port, and the experimental results are verified.

In the experiment, in order to be able to better respond to the system under different algorithms, while the amount of calculation is not too large for the traditional PID control, fuzzy PID control fertilizer flow sampling period of 0.5 s, and grey prediction fuzzy PID control of the fertilizer flow sampling period of 0.2 s. Table 5 for each data to take a data after the experimental data table, because the flow sensor range of 0.6–6 m^3/h, 0.6 m^3/h following data reliability is not high. The experimental data were fitted with the spline curve in MATLAB, and the experimental response curve is shown in Fig. 10.

It can be seen from Fig. 10 that the adaptive grey prediction fuzzy PID control is basically stable at 8.5 s, while the fuzzy PID and the traditional PID are basically stable at 12.5 s and 14.5 s, respectively. The experimental results show that the grey predictive fuzzy PID controller can so that the system quickly stabilized, the appropriate overshoot to improve the speed of DC pump motor tracking characteristics; when

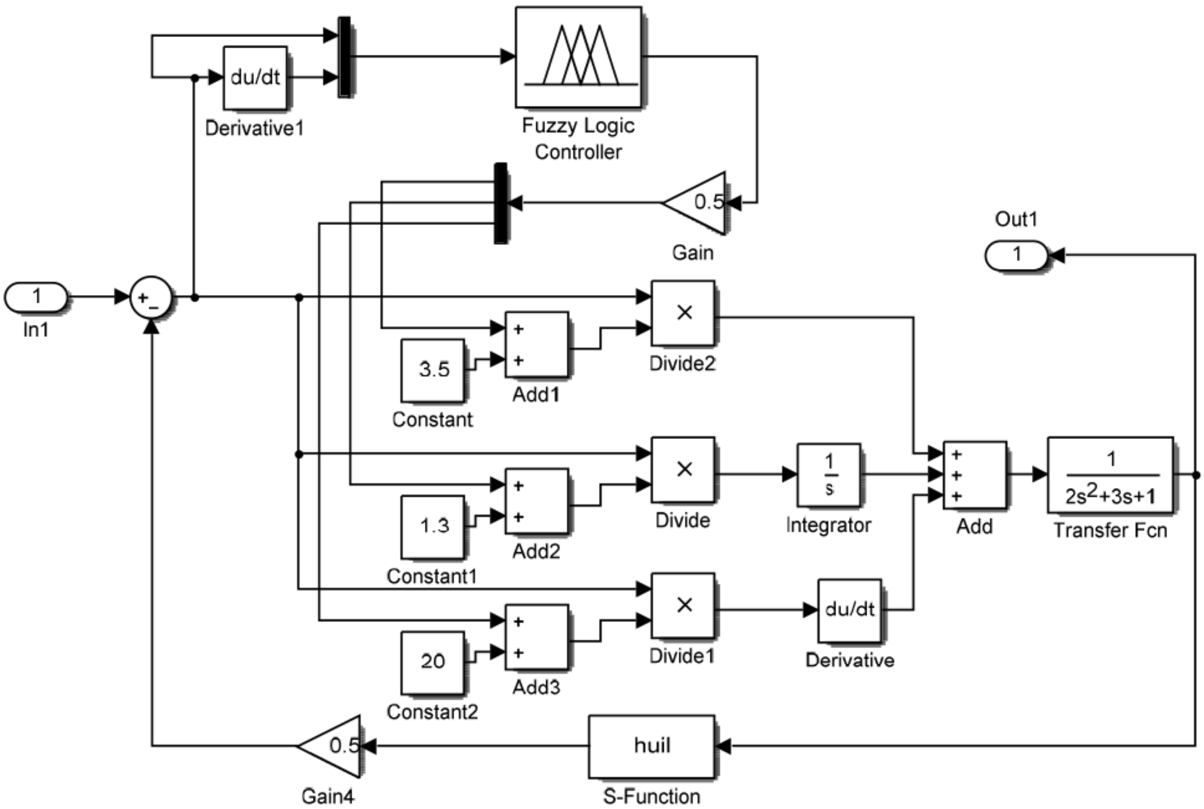

Fig. 8. Diagram of Simulink simulation.

Table 4
System performance

	Delay t_d (s)	Rise time t_r (s)	Peak time t_p (s)	Overshoot σ%	Settling time (s)	Steady state error e_{ss}
PID	3.493	5.302	12.5	25.59	33.5	0.0004
Fuzzy PID (F-PID)	2.0142	3.698	10.4	9.82	20.1	0
Grey fuzzy PID (GMF-PID)	1.2787	0.424	1.8	10.91	4.48	0.0002

GMF: grey prediction model of fuzzy-PID.

the expected flow of fertilizer and the actual does not match, can automatically adjust the fertilizer flow, so that the proportion of water and fertilizer has always been maintained in the appropriate range Inside, in order to achieve precision irrigation.

3.1.3. Verification for precise irrigation machine

The core of system control strategy is the intelligent controller in the water–fertilizer irrigation machine, but also making as the need of actual irrigation water. This equipment has water–fertilizer detection function, also has the function of irrigation control and environment control. Precise irrigation machine is composed of ARM controller of grey prediction fuzzy-PID, touch screen, wireless transmission module, drive control module, pressure gauge, solenoid valve, pump, filter, sensors, control software, database, etc. Wireless transmission module including 433 MHZ wireless transmission, 4G wireless transmission, WIFI, SMS alarm and the drive control module can be divided into liquid fertilizer ratio, environmental control and irrigation control drive. The operation irrigation control platform contains man–machine interface equipment, mobile phone APP and PC system. The equipment applied in Ningbo Agricultural Science and Technology demonstration garden glass greenhouse for "Yong Tian 5" melon at autumn 96 d plant, its equipment application is shown in Fig. 11. The irrigation machine to which was applied the technology of this paper has the ability of precise control and automatic set PID control parameters by the experience of experts. System will reach a steady state after 5 s and show obvious fertilization effect in real-time.

4. Conclusion

This paper has a deep discuss of control decision and control model. In addition, this intelligent irrigation control technology is based on grey theory and this system has a better adaptability, control performance and robustness by

Table 5
Experimental acquisition data sheet

x	y1	y2	x3	y3	x3	y3
0	0	0	0	0	8.4	2.00
1	0	0	0.4	0	8.8	1.97
2	0	0	0.8	0	9.2	1.98
3	0	0	1.2	0	9.6	2.02
4	0.03	0.3	1.6	0	10	1.99
5	0.10	1.28	2	0	10.4	1.98
6	0.6	2.10	2.4	0.01	10.8	2.00
7	1.57	2.27	2.8	0.02	11.2	1.97
8	2.10	2.03	3.2	0.04	11.6	1.98
9	2.37	1.79	3.6	0.08	12	2.02
10	2.32	1.92	4	0.3	12.4	1.99
11	2.18	1.92	4.4	0.89	12.8	1.96
12	2.21	1.98	4.8	1.63	13.2	2.00
13	2.05	1.98	5.2	2.13	13.6	2.01
14	1.97	1.98	5.6	2.21	14	1.98
15	1.98	2.00	6	2.21		
16	2.02	2.00	6.4	2.18		
17	1.97	2.00	6.8	2.12		
18	1.98	1.96	7.2	1.95		
19	2.02	1.99	7.6	1.98		
20	1.99	1.99	8	2.00		

x (s)—PID and fuzzy PID acquisition time of the data.
y1 (m^3/h)—PID collected flow.
y2 (m^3/h)—PID collected flow.
x3 (s) —Flow collected by fuzzy PID.
y3 (m^3/h)—The time of the adaptive grey fuzzy PID acquisition data.

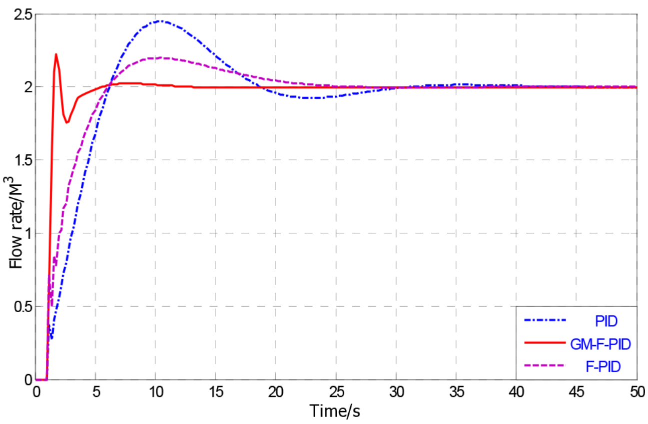

Fig. 9. MATLAB simulation result.

comparing with the PID control, fuzzy-PID control and grey prediction fuzzy-PID control. MBD method can accelerate the embedded development, and concentrate on the algorithm embedding research and verification in advance. And in the tool chain in the bottom of the role of supporting the package, easy to generate the underlying driver code to complete the project file to establish a substantial reduction in the development and maintenance of handwritten code burden,

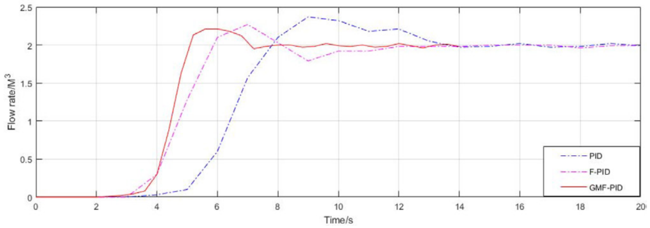

Fig. 10. System experiment response curve.

Fig. 11. Water–fertilizer irrigation control equipment and demonstration.

significantly shorten the development cycle and the amount of tasks.

The PID control can solve the issue about uncertain model of water-saving irrigation. The fuzzy PID control can solve the issue about large inertia and nonlinear of the system. One more, adding multi-factor grey prediction MGM (1, n) to overcome big time delay.

MBD and development method process are accelerated, and the model is established on the basis of demand. The algorithm is designed and pre-validated in advance. It is especially convenient for software/software integration test and system integration test. The manual input bug problem and reduce the late maintenance intensity, it is better to develop water-saving irrigation in agriculture.

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