Study of Fuzzy-PID Control in MATLAB for Two-phase Hybrid Stepping Motor

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Abstract: two-phase hybrid stepping motor is widely used for driving part in industry controlling, the research for control algorithm applied in stepping motor becomes more and more important. The mathematic model of the two-phase hybrid stepping motor and the structure of Fuzzy-PID controller are detailed, and the simulation model of Fuzzy-PID controller in MATLAB/simulink is also founded. Finally, the simulation is done separately for a conventional PID controller and the Fuzzy-PID controller, and the result shows that the setting time and the maximum overshoot value is greatly reduced for the fuzzy-PID controller, and the performance of fuzzy-PID controller is better than conventional PID algorithm.

Keywords: two-phase hybrid stepping motor; model; simulation; MATLAB/simulink

Introduction

Two-phase hybrid stepping motor is a brushless DC electric motor that divides a full rotation into a number of equal steps [1] [2]. The motor's position can then be commanded to move and hold at one of these steps without any feedback sensor, as long as the motor is carefully sized to the application. The Two-phase hybrid stepping motor is widely used in controlling appliances with its characters of low cost, high precision, high torque output and low vibration and noisy [3-4]. So the research for control algorithm applied in stepping motor is very important.

In this paper, in the first section, the model of the two-phase Hybrid Stepping Motor is selected. In the second section, the structure of Fuzzy-PID controller is designed. In the last section, the experiment is done and some conclusions are derived from the experiment data.

The model of the two-phase Hybrid Stepping Motor [5]

The open-loop transfer function $G(s)$ of two-phase Hybrid Stepping Motor is as follows:

$$G(s) = \frac{A(s)}{B1(s) + B2(s)}$$

Where, $A(s) = \left(K_{Pv} + \frac{K_{Iv}}{s} + K_{Dv}s\right)(K_{pi}s + K_{Ii})k_e N K_H$, $B1(s) = JLs^4 + (JR + \beta L + JK_{pi}K_H)s^3$,

$B2(s) = \beta K_{Ii}K_H s + (JK_{Ii}K_H + \beta R + \beta K_{pi}K_H)s^2$.

In order to reduce the complexity of system transfer function and reach to actual parameter for system performance, the subdivided driving is adopted for the stepping motor. The parameters of the stepping motor selected in simulation are as follows: $L = 4.0mH$, $R = 1.2\Omega$, $J = 260\ kg \cdot m^2$,

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$B = 0\,N\cdot m\cdot s/rad$, $k_e = 0.2\,N\cdot m/A$, $N = 180$, $K_H = 15$, $K_{Ii} = 500$, $K_{pi} = 5$, $K_{Pv} = 500$, $K_{Iv} = 0$, $K_{Dv} = 100$, $\beta = 1$.

The structure of Fuzzy-PID controller

The conventional proportional–integral–derivative (PID) controllers have been well developed and are extensively used for industrial automation and process control today because of its simplicity of operation, ease of design and high robustness[6~7]. As for nonlinear systems, higher order and time-delayed linear systems, and particularly complex and vague systems that have no precise mathematical models, fuzzy control, which is not depended on mathematical models, is one of promising control method in current applications[8~10]. Considering the difficulty to obtain the mathematical models for electro-optical tracking system, and get high tracking precision, the control strategy, put fuzzy control and PID control together, is adopted.

The structure of Fuzzy-PID controller is shown in figure 1, the parallel combination between PID controller and Fuzzy controller is adopted in this system. The difference between the input r and the output v is the $e(k)$, and both the value $e(k)$ and its derivative $e'(k)$ is send to the fuzzy controller. The PID parameter k_p, k_i and k_d is calculated out according to offline rules in fuzzy controller, at the same time, the k_p is also refined by P controller which is the immune PID controller, so the parameter k_p, k_i and k_d can be continuous updated according to error $e(k)$ and its derivative $e'(k)$.

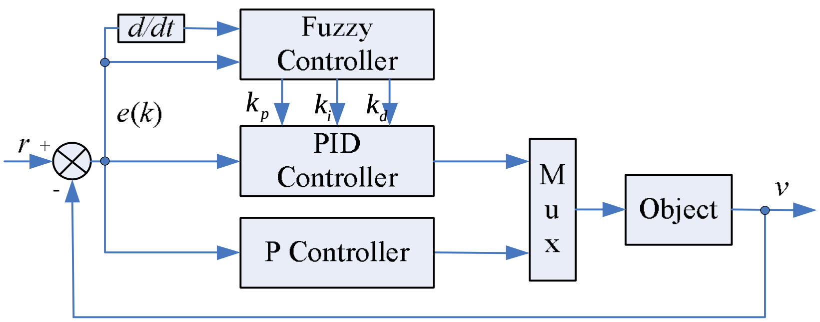

Fig. 1 the structure of Fuzzy-PID controller

The simulation of MATLAB/simulink for the Fuzzy-PID control

The simulation model of the Fuzzy-PID control. According to above description, the selected open-loop transfer function of two-phase Hybrid Stepping Motor is

$$G(s) = \frac{2700000(5 + s)(s + 100)}{s^4 + 19799s^3 + 650000s^2 + 7500s}$$

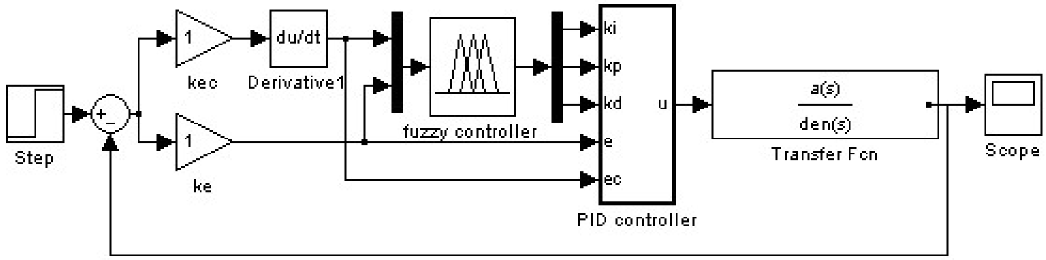

Fig.2 the fuzzy-pid simulation model in MATLAB

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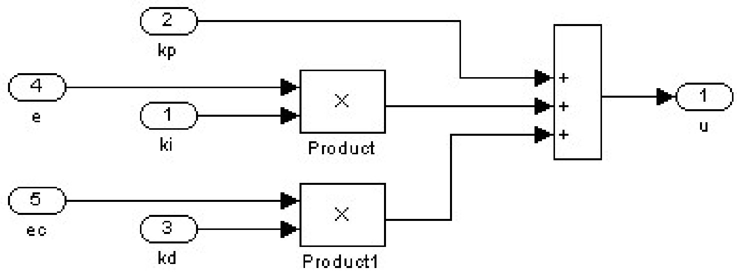

Fig. 3 the internal structure for PID controller

And the fuzzy-PID simulation model in MATLAB is shown in figure 2, and the internal structure for PID controller is illustrated in figure 3, the input parameters for the PID controller are e, ec, k_p, k_i and k_d, the output u is the output for the controller.

Experiment and result analysis. Based on above model, the simulation is done. In simulation, the input signal is the step-function signal with the amplitude of 1, and the sampling time is 1ms. At the time of 450 sampling period, a disturbance with its amplitude of 1 is applied to controller.

To analysis the performance of different algorithm, the PID control and Fuzzy-PID control is separately applied to the simulation. The step response curve of PID controller and its tracking error are shown in figure 4; the maximum overshoot of system is more than 17% and setting time more than 0.32s. While the step response curve and its tracking error are shown in figure 5; the maximum overshoot of system is less than 7% and setting time less than 0.16s.

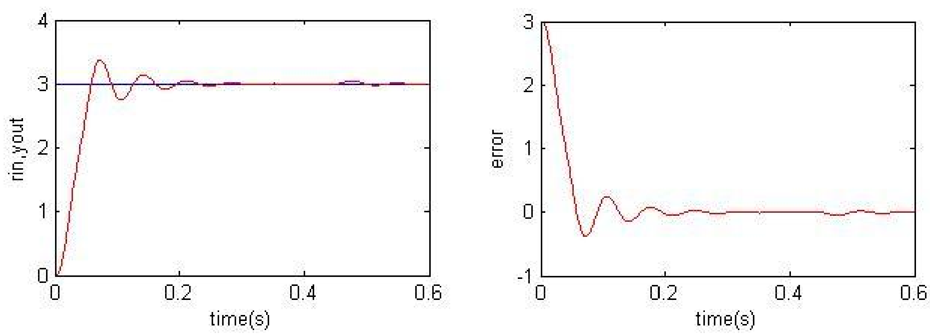

Fig. 4 the step response curve of PID controller and it's tracking error

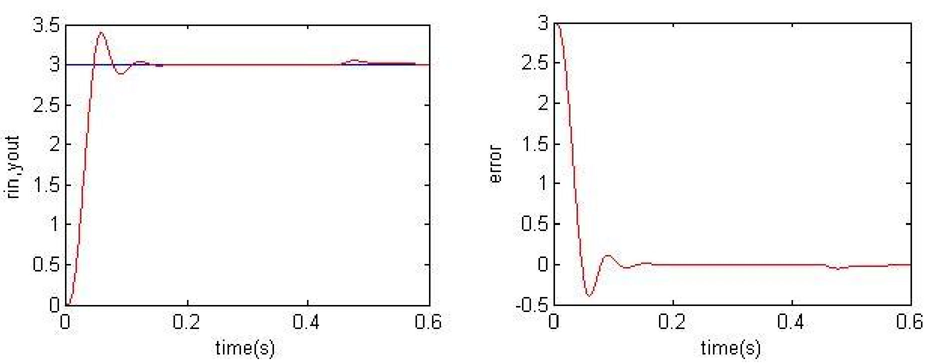

Fig. 5 the step response curve of fuzzy-PID controller and it's tracking error

So, we can infer that, the setting time and the maximum overshoot value is greatly reduced for the fuzzy-PID controller, so the performance of fuzzy-PID controller is better than conventional PID algorithm.

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Conclusions

Based on the selected model for two-phase hybrid stepping motor, the simulation in MATLAB/simulink is done, and the data is analyzed, for the conventional PID controller, the maximum overshoot of system is more than 17% and setting time more than 0.32s, and for the fuzzy-PID controller, the maximum overshoot of system is less than 7% and setting time less than 0.16s. So the performance of fuzzy-PID controller is better than conventional PID algorithm.

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