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Nonlinear control of Direct Current Servo Motor

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Abstract
This paper gives a speed control design for a DC servo system based on a newly developed fuzzy system, which is very powerful and has brought about many incredible achievements in the field of fuzzy logic control. The basic advantage of fuzzy control over classical control methods is that it is possible to synthesize the controller without knowing the exact characteristics of the object in advance. In fact, to make full use of the advantages of each type of fuzzy controller and classical controller, in the process of control often use systems that combine two types of traditional and fuzzy controllers to create a controller, which is the new fuzzy controller.

Keywords: DC Servo Motors, Fuzzy Controller, Fuzzy PID

1. Introduction

Servo motors have lightweight, low-inertia armatures that respond quickly to excitation-voltage changes. The DC motor speed can be adjusted to a great extent to provide easy control and high performance. Several conventional and numeric controller types are intended to control the DC motor speed at executing various tasks: PID Controller, Fuzzy Logic Controller (FLC) [1]; or the combination between them: PID-Particle Swarm Optimization, PID-Neural Networks, PID-Genetic Algorithm. One of the problems that might cause unsuccessful attempts to design a proper controller would be the time-varying nature of parameters [2-6], unknown the plants' parameters, and variables that might be changed while working with the speed systems. One of the best-suggested solutions to solve this problem would be the use of the new Fuzzy PID Controller call a hybrid fuzzy PID controller [7-11]. The hybrid fuzzy PID controller is not sensitive to change and yet would have an adequate response to the system variations. The new Fuzzy PID Controller is a computationally efficient analytic scheme suitable for a real-time closed-loop digital control implementation [12-21]. Numerous computer simulations are included to demonstrate the effectiveness of the controller not only in linear but also in nonlinear systems. The hybrid fuzzy PID Controller can achieve a better response than classical methods in terms of shorter settling time, less overshoot and more stability. Thus, the hybrid fuzzy PID controller is adopted in this paper, which is very flexible to control the speed of the DC servo motor.

2 The Hybrid Fuzzy PID controller

The control structure of two loops to stabilize the speed of the DC motor is built in this section. The simulation structure of the DC motor speed stability control system with hybrid fuzzy algorithm is presented as shown in Fig 1.

In the hybrid fuzzy PID simulation structure, the PI controller has a range of operation when the ET error and DET deviation have small absolute values, while the fuzzy controller has a range of operation when the ET error and DET deviation are small. has a large absolute value. Through the switch with two inputs will decide when to allow which controller to work. Thus, in addition to the primary function of the fuzzy controller, which is to synthesize the control signal for the speed loop of the DC motor, it also performs the second function of outputting the comparison signal to the switching switch, helping to the switch can open and close flexibly to coordinate between the two dimming controllers and the PI controllers during the working process.

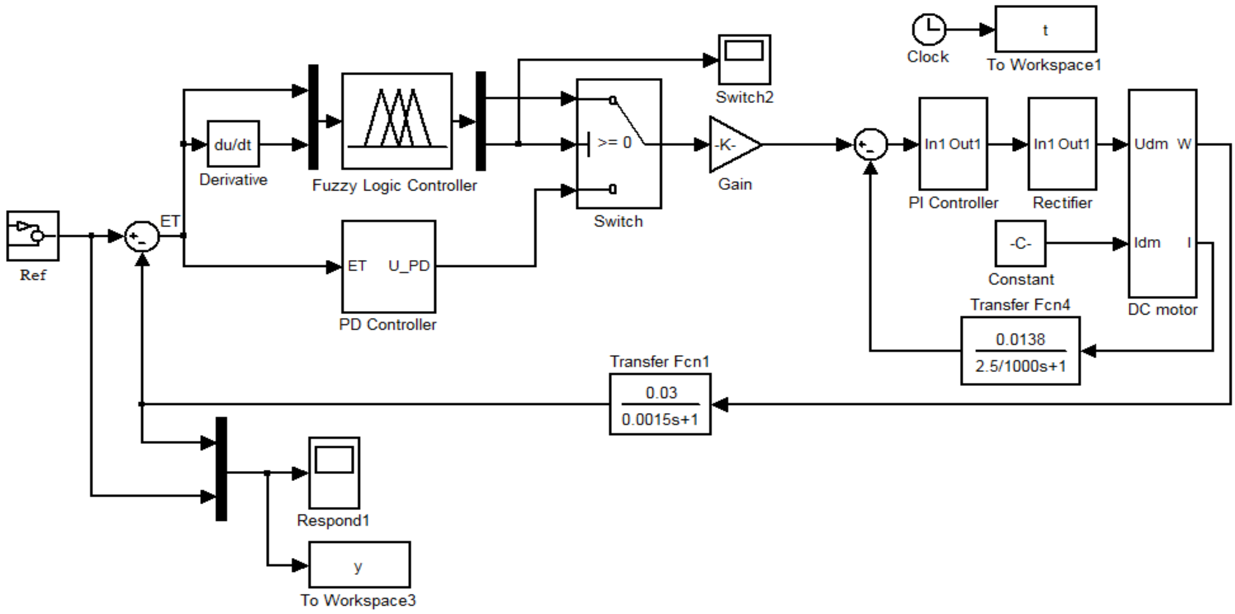

Fig 1: Structural diagram of hybrid fuzzy PID system for DC servo motor

The Hybrid Fuzzy PID Controller algorithm for speed loop is presented in this paper which of input/output language variables as follows:

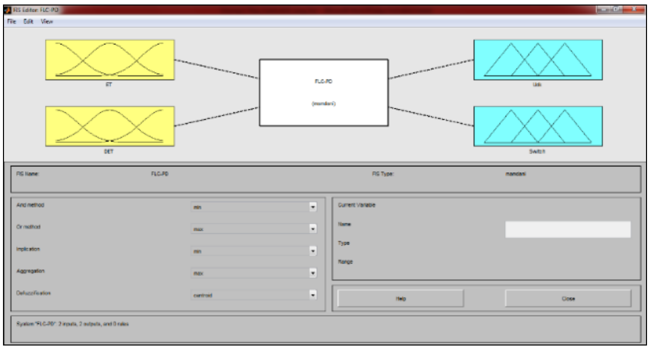

Fig 2: The input and output language variables

The first input language variable: error ET = [-5 5] (V).

+ ET ≤ -4: Big Negative (AL);
+ ET ≈ -2.5: Small Negative (AN);
+ ET ≈ 0: Zero (K);
+ ET ≈ 2.5: Small Positive (DN);
+ ET ≥ 4: Big Positive (DL).

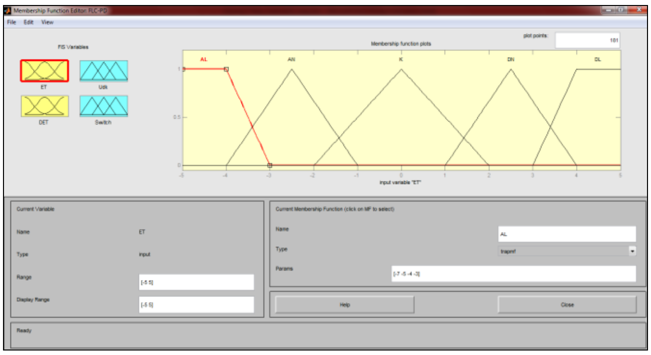

Fig 3: Function for the input language variable ET

The second input language variable: derivative error DET = [-100 100] (V/s).

+ ET ≤ -80: Big Negative (AL);
+ ET ≈ -50: Small Negative (AN);
+ ET ≈ 0: Zero (K);
+ ET ≈ 50: Small Positive (DN);
+ ET ≥ 80: Big Positive (DL).

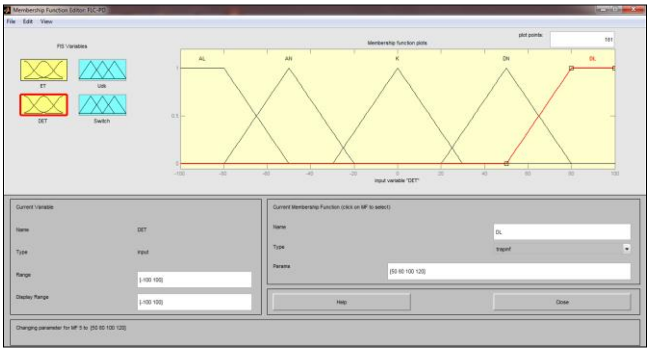

Fig 4: Function for the input language variable DET

The first output language variable: Two-state switching signal

+ ET ≈ -1: Negative (A);
+ ET ≈1: Positive (D).

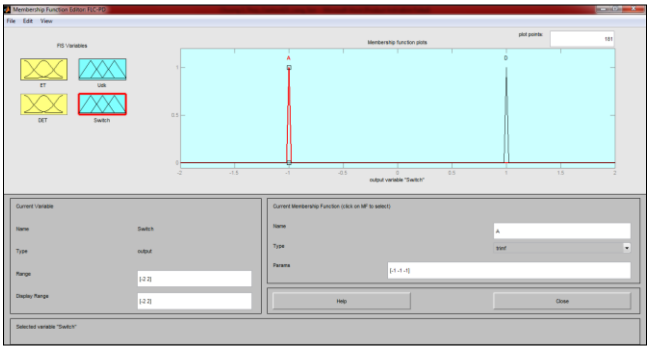

Fig 5: Function for the output language variables switch between PI controller and fuzzy controller

The second output language variable: Control signal Uđk = [0 10] (V).

+ ET ≈ 0: Zero (K);

+ ET ≈ 3: Small (N);
+ ET ≈ 5: Medium (V);
+ ET ≈ 7: Large (L);
+ ET ≈ 10: Very Large (RL).

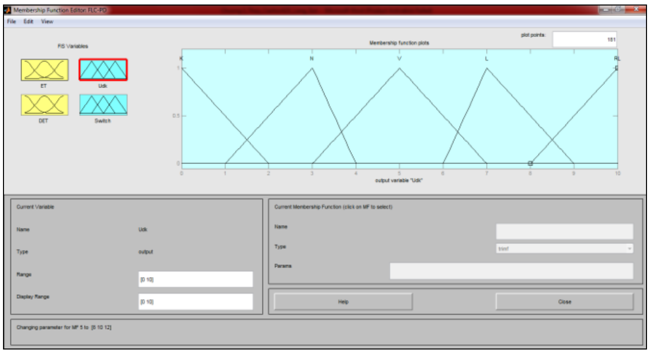

Fig 6: Function for the output language variable Switch switches

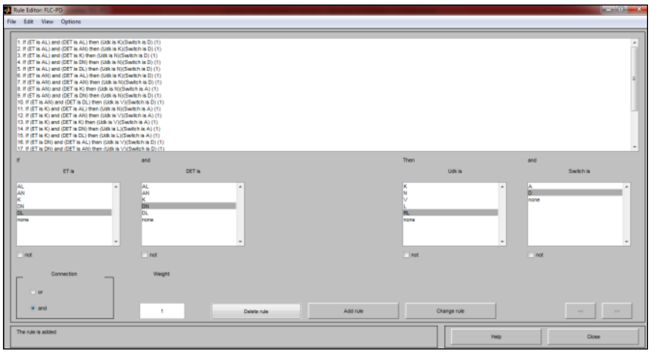

Fig 7: Setting the control law

The construction of a control rule table for fuzzy controllers in the hybrid fuzzy controller structure is based on control thinking between the relationship between the input error ET and the deviation derivative DET, while taking into account the function of the fuzzy controller. The second function of the fuzzy controller is to open and close the switch for the PI controller to work or the fuzzy controller to work.

Table 1: Control rule table for fuzzy controller

U_{dk} / Switch		ET				
		AL	**AN**	**K**	**DN**	**DL**
DET	**AL**	K/D	K/D	N/A	V/D	V/D
	AN	K/D	N/D	V/A	V/D	L/D
	K	N/D	N/A	V/A	L/A	L/D
	DN	N/D	N/D	L/A	L/D	RL/D
	DL	N/D	V/D	L/A	RL/D	RL/D

3. Conclusion

In this research presented the control structure of a DC servo motor when combining two classical and fuzzy regulators into motor speed control. To make understandable clarify the superiority of the proposed hybrid fuzzy PID controller which is the speed stability control problem with the influencing noise factor. The author has implemented a system simulation structure to compare the simulation results between the classical PID controller and the proposed hybrid fuzzy PID controller for the speed loop in stability control problem for DC motor. Simulation results will be mentioned in next study.

4. Acknowledgements

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5. References

1. Yesil E, Guzelkaya M, Eksin I. Fuzzy PID controllers: An overview. In The Third Triennial ETAI International Conference on Applied Automatic Systems, Skopje, Macedonia. ETAI Society of Macedonia, 2003, 105-112.
2. Bhushan B, Jha N, Devra S, Pillai SS. Performance analysis of PID and Fuzzy PD+ I controller on nonlinear systems. In 2014 IEEE International Advance Computing Conference (IACC). IEEE, 2014, 1195-1200.
3. Iqbal S, Ayyub M. Improved Performance of Fuzzy Logic Controller to Control Dynamical Systems: A Comparative Study. In 2018 International Conference on Computational and Characterization Techniques in Engineering & Sciences (CCTES). IEEE, 2018, 122-126.
4. Mondal S, Mitra A, Chowdhury D, Chattopadhyay M. A new approach of sensor less control methodology for achieving ideal characteristics of brushless DC motor using MATLAB/Simulink. In Proceedings of the 2015 Third International Conference on Computer, Communication, Control and Information Technology (C3IT). IEEE, 2015, 1-4.
5. Sun YL, Er MJ. Hybrid fuzzy control of linear and nonlinear systems. In Proceeding of the 2001 IEEE International Symposium on Intelligent Control (ISIC'01) (Cat. No. 01CH37206). IEEE, 2001, 303-307.
6. Bouras S, Kotronakis M, Suyama K, Tsividis Y. Mixed analog-digital fuzzy logic controller with continuous-amplitude fuzzy inferences and defuzzification. IEEE transactions on Fuzzy Systems. 1998; 6(2):205-215.
7. Zhou H, Ying H, Zhang C. Effects of increasing the footprints of uncertainty on analytical structure of the classes of interval type-2 mamdani and TS fuzzy controllers. IEEE Transactions on Fuzzy Systems. 2019; 27(9):1881-1890.
8. Lam HK, Leung FH. Fuzzy combination of fuzzy and switching state-feedback controllers for nonlinear systems subject to parameter uncertainties. IEEE Transactions on Systems, Man, and Cybernetics, Part B (Cybernetics). 2005; 35(2):269-281.
9. Kumbasar T. Robust stability analysis and systematic design of single-input interval type-2 fuzzy logic controllers. IEEE Transactions on Fuzzy Systems. 2015; 24(3):675-694.
10. Li HX, Zhang L, Cai KY, Chen G. An improved robust fuzzy-PID controller with optimal fuzzy reasoning. IEEE Transactions on Systems, Man, and Cybernetics, Part B (Cybernetics). 2005; 35(6):1283-1294.
11. Hu B, Mann GK, Gosine RG. New methodology for analytical and optimal design of fuzzy PID controllers. IEEE Transactions on fuzzy systems. 1999; 7(5):521-539.
12. Yi Y, Zheng WX, Sun C, Guo L. DOB fuzzy controller design for non-Gaussian stochastic distribution systems using two-step fuzzy identification. IEEE Transactions on Fuzzy Systems. 2015; 24(2):401-418.

13. Lee J. On methods for improving performance of PI-type fuzzy logic controllers. IEEE transactions on fuzzy systems. 1993; 1(4):298-301.
14. Kubica E, Madill D, Wang D. Designing stable MIMO fuzzy controllers. IEEE Transactions on Systems, Man, and Cybernetics, Part B (Cybernetics). 2005; 35(2):372-380.
15. Aliev RA, Pedrycz W. Fundamentals of a fuzzy-logic-based generalized theory of stability. IEEE Transactions on Systems, Man, and Cybernetics, Part B (Cybernetics). 2009; 39(4):971-988.
16. Liu J, Wang W, Golnaraghi F, Kubica E. A novel fuzzy framework for nonlinear system control. Fuzzy Sets and Systems. 2010; 161(21):2746-2759.
17. Aliasghary M, Eksin İ, Güzelkaya M, Kumbasar T. Design of an interval type-2 fuzzy logic controller based on conventional PI controller. In 2012 20th Mediterranean Conference on Control & Automation (MED). IEEE, 2012, 627-632.
18. Mudi RK, Pal NR. A robust self-tuning scheme for PI- and PD-type fuzzy controllers. IEEE Transactions on fuzzy systems. 1999; 7(1):2-16.
19. Zhang W, Fang Y, Ye R, Wang Z. Analysis and design of a double fuzzy PI controller of a voltage outer loop in a reversible three-phase PWM converter. Energies. 2020; 13(15):3778.
20. Zaidi E, Marouani K, Mabrek AE, Merabet E, Bentouhami L. Fuzzy logic control of multi-phase induction machine drives based on cascaded hybrid multi-level inverters. In 2018 International conference on electrical sciences and technologies in Maghreb (CISTEM). IEEE, 2018, 1-6.
21. Pramanick P, Bandyopadhyay S, Dey C. Fuzzy Supervisory Expert Tuner for PID Controller. In Proceedings of the Fourth International Conference on Microelectronics, Computing and Communication Systems. Springer, Singapore, 2021, 629-643.