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Application of direct adaptive fuzzy sliding mode control into a class of non-affine discrete nonlinear systems

Key words: Nonlinear system, Discrete system, Dynamic fuzzy logical system, Direct adaptive, Sliding mode control

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Motivation

- Most of fuzzy sliding mode control (FSMC) and sliding mode fuzzy logic control (SMFC) designs for discrete nonlinear systems were sporadically reported.
- SMC has one obvious drawback, i.e., the chattering phenomenon, which would significantly impede its practical application. In particular, the chattering becomes more serious for discrete systems (Castillo-Toledo *et al*., 2008).
- Another problem in engineering practice is the unknown precise model dynamics. Fortunately, the combination of SMC and FLS is a proper approach to dealing with discrete nonlinear systems, especially for those systems with unknown dynamics.

Main idea

- For a class of non-affine discrete nonlinear systems with unknown dynamics and uncertainties, a dynamic fuzzy logic system (DFLS), for which the parameters are self-tuned by the adaptive laws, is first constructed to approximate the unknown dynamics.
- An adaptive FSMC design is specifically presented. The SMC controller is designed based on the DFLS.

Method

1. A dynamic fuzzy logical system (DFLS) is used to implement an equivalent control, in which the parameters are self-tuned online.
2. Establish the appropriate adaptive mechanism for both the parameters of the DFLS and its recursive computation. Both the parameters adaptive law and the recursive operation of the DFLS are determined by the sliding mode.
3. The stability of the tracking error and the reaching condition of the sliding mode are then validated using the Lyapunov stability theory.

Major results

1. Given discrete nonlinear system and reference trajectory, the designed sliding modes are reachable and the system tracking errors are globally asymptotically stable under the proposed adaptive FSMC controllers, which are based on the DFLS. (Theorem 1)
2. Application design is implemented to to a robotic arm with two degrees of freedom.

Major results

- The application simulation results show the performance of our method. The control signal is chattering-free.

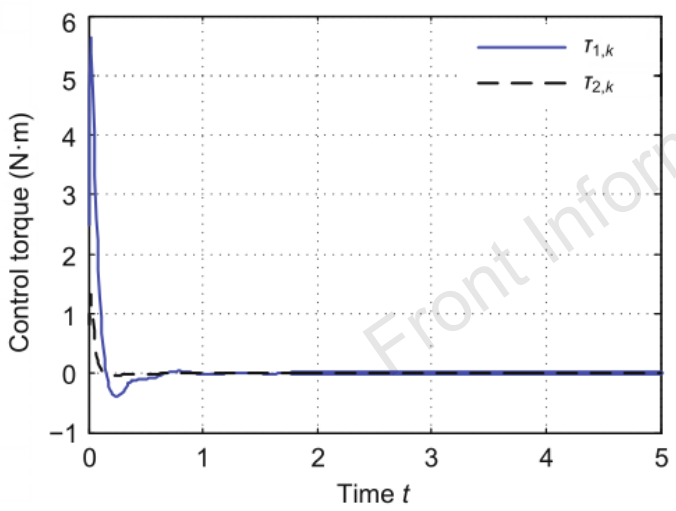

Fig. 13 Control torque curves: $\tau_{1,k}$ and $\tau_{2,k}$ (DFLS sampling time 0.001 s)

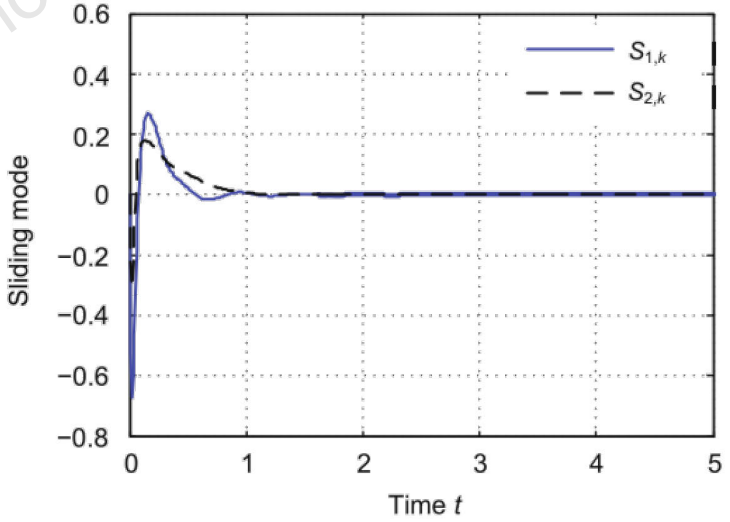

Fig. 12 Sliding mode curves: $S_{1,k}$ and $S_{2,k}$ (sampling time 0.01 s)

Conclusions

- An adaptive FSMC design method for a class of non-affine discrete nonlinear systems has been proposed, in which the SMC was designed based on the DFLS. As a result it has strongly adaptiveness and robustness to the unmodeled dynamics.
- The appropriate adaptive mechanism guarantees the stability of the closed-loop system. Due to the use of the DFLS, the chattering of the SMC has been greatly weakened.
- A numerical example was given, that validated the proposed method. We also implemented our design to a robotic arm with two degrees of freedom. Simulation results demonstrated the good performance.