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# STABLE INDIRECT ADAPTIVE TYPE-2 FUZZY SLIDING MODE CONTROL USING LYAPUNOV APPROACH

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Abstract. *In this paper, a stable adaptive type-2 fuzzy tracking control equipped with sliding mode and Lyapunov synthesis approaches is proposed to attenuate the effects from unmodeled dynamics, external disturbance and approximation errors for nonlinear SISO systems. By employing adaptive fuzzy-neural control theory incorporated with Lyapunov stability criterion, the adaptive laws will be derived for approximating the uncertain nonlinear dynamical system. In comparison with conventional sliding model control and adaptive type-1 fuzzy control, the advocated approach not only guarantees closed-loop stability but also tracking performance of the overall system can be achieved without prior knowledge on the upper bound of the lumped uncertainty. Furthermore, chattering effect of the control input will be substantially reduced by the proposed technique. To validate the capability of the proposed approach, two examples, the inverted pendulum system and the vehicle active suspension system of a quarter-car, are given. Simulation results show that the interval type-2 fuzzy logic system can handle unpredicted internal disturbance and data uncertainties very well, but the conventional sliding mode controller and the adaptive type-1 fuzzy controller must expend more control effort in order to deal with noisy training data.*
**Keywords:** Interval type-2 fuzzy set, Upper and lower membership functions, Indirect adaptive control, Sliding mode control, Lyapunov approach, SISO

1. **Introduction.** Most of the conventional control system design problems are usually solved based on the system mathematical models. But many physical systems are complex in practice so that their accurate mathematical models are not available or difficult to formulate. Various fuzzy models have been developed in the last few years [4], because the fuzzy control can provide a good solution for these difficulties by incorporating linguistic information from human experts. In the meantime, neural networks [5-7] are also applied to solve many control problems. Based on the universal approximation, to obtain better control performance, both the fuzzy logic systems and the neural networks have been used to construct various fuzzy-neural controllers.

Research in adaptive control started in the early 1950's in connection with the design of autopilots for high-performance aircraft which operates at a wild range of speeds and altitudes and thus experience large parameter variations. Adaptive control [1-3] is proposed as a way of automatically adjusting the controller parameters in the face of changing aircraft dynamics. Recently, there has been a surge of interest in the adaptive control of nonlinear systems. Some adaptive control schemes for nonlinear systems based on feedback linearization have proposed in [8,9]. More recently, an important adaptive fuzzy-neural control system has been derived to incorporate with the expert information systematically and the stability guaranteed by theoretical analysis [10-18,24-26,32].