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DIRECT ADAPTIVE FUZZY BACKSTEPPING CONTROL FOR A CLASS OF NONLINEAR SYSTEMS

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Abstract. *In this paper, a direct adaptive fuzzy backstepping control approach for a class of unknown nonlinear systems is developed. By a special design scheme, the controller singularity problems are avoided perfectly in this approach. Furthermore, the closed-loop signals are guaranteed to be semiglobally uniformly ultimately bounded and the outputs of the system are proved to converge to a small neighborhood of the desired trajectory. The control performances of the closed-loop systems can be shaped as desired by suitably choosing the design parameters. Simulation results obtained demonstrate the effectiveness of the proposed approach*
Keywords: Fuzzy adaptive control, Nonlinear systems, Stability, Backstepping

1. **Introduction.** Since L. A. Zadeh introduced the fuzzy set theory in 1965, it has received much attention from various fields and also demonstrated good performance in various applications. One of those successful fuzzy applications is to model the unknown nonlinear systems by a set of fuzzy rules. One important property of fuzzy modeling approaches is that they are universal approximates. In other words, fuzzy systems can be used to model virtually any nonlinear systems within a required accuracy provided that enough rules are given. Based on the universal approximation theorem and by incorporating fuzzy logic systems into adaptive control schemes, the stable direct and indirect fuzzy adaptive controllers are first proposed by Wang [1,2]. Afterwards, various adaptive fuzzy control approaches for nonlinear systems have been developed [3,4,10,11]. Generally, the direct and indirect adaptive fuzzy control approaches can give good performance. However, the results mentioned above were addressed for a class of nonlinear systems described by input-output models, and require the unknown nonlinear functions in systems to satisfy the "matched" conditions. However, in practice, a large class of physical systems may be subject to some unknown nonlinear functions which do not satisfy the matching conditions. In this case, the adaptive fuzzy control approaches mentioned above fail.

In recent adaptive and robust control literature, the backstepping design provides a systematic framework for the design of tracking and regulation strategies [5], suitable for a large class of state feedback linearizable nonlinear systems. Integrator backstepping is used to systematically design controllers for systems with known nonlinearities with mismatched conditions. The approach can be extended to handle systems with unknown parameters via adaptive backstepping. Apart from the systematic approach used, another