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ROBUST ADAPTIVE FUZZY CONTROL FOR NONLINEAR SYSTEM WITH DYNAMIC UNCERTAINTIES BASED ON BACKSTEPPING

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Abstract. *In this paper, a robust adaptive fuzzy backstepping control is developed for a class of strict-feedback canonical nonlinear systems. The systems may possess unknown functions, the nonlinear dynamic uncertainties and unmodeled dynamics. The fuzzy logic systems are used to approximate the unknown nonlinear functions and nonlinear damping terms are used to counteract the nonlinear dynamic uncertainties and unmodeled dynamics. It is proved that the derived fuzzy adaptive controller can guarantee the semi-global uniform ultimate bound property for all the signals and the output converge to a small neighbordhood of the origin. Simulation studies are included to illustrate the effectiveness of the proposed approach.*
Keywords: Nonlinear systems, Fuzzy control, Adaptive robust control, Backstepping technique

1. **Introduction.** Fuzzy control methodologies have emerged in recent years as promising ways to approach nonlinear control problems. Fuzzy control, in particular, has had an impact in the control community because of the simple approach it provides to use heuristic control knowledge for nonlinear control problem. In very complicated situations, where the plant parameters are subject to perturbations or when the dynamics of the systems are too complex for a mathematical model to describe, adaptive schemes have to be used online to gather data and adjust the control parameters automatically. Based on the universal approximation theorem and by incorporating fuzzy logic systems into adaptive control schemes, a stable fuzzy adaptive controller was first developed to control unknown nonlinear systems [1]. Afterwards, various adaptive fuzzy control approaches have been developed for the nonlinear systems [2-5,21-22]. Generally, these adaptive fuzzy control approaches can have nice performance. However, these approaches have been applied only to a relatively simple class of nonlinear systems. The key requirement is that the unknown nonlinearities appear on the same equation as the control input in a state space representation. Such restrictions on the location of the uncertain nonlinear functions are usually referred to as the matching conditions. If physical systems do not satisfy the matching conditions, the adaptive fuzzy control approaches mentioned above can not be applied.

In recent years, with the development of adaptive and robust backstepping designs in nonlinear systems [6-8], many fuzzy adaptive control schemes have been reported that combined the backstepping technique with adaptive fuzzy logic systems [12-20]. Among them, the results proposed by references [12-14,18-20] are for a class of SISO unknown nonlinear systems, and those in references [15-17] are for a class of MIMO unknown nonlinear