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Exponential Stabilization of Nonlinear Switched Systems with Distributed Time-Delay: An Average Dwell Time Approach

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***Abstract*—In this paper, the exponential stabilization problem is discussed for nonlinear switched systems subject to the distributed time-delay. Attention is focused on the design of a state feedback controller such that, the closed-loop system is exponentially stable with a guaranteed weighted L_2 gain. By resorting to the average dwell time method and the piecewise Lyapunov functional approach, sufficient conditions are derived for the solvability of the addressed problem in terms of the feasibility of certain Hamilton-Jacobi inequalities (HJIs). The explicit expression of the desired controller is formulated via solving the presented set of HJIs. Furthermore, within the proposed framework, the exponential stabilization problems are investigated, respectively, for nonlinear switched systems with mixed time-delays and linear switched systems with the distributed time-delay. Finally, a simulation example is given to illustrate the effectiveness and applicability of the proposed algorithm.**

***Index Terms*—Nonlinear systems, switched systems, weighted L_2 gain, Hamilton-Jacobi inequality, distributed time-delay.**

I. Introduction

It is now recognized that almost all of the real-world systems are inherently nonlinear. As such, the analysis and synthesis problems for nonlinear systems have received considerable research interest during the past decades, see [32], [33], [38], [45] and the references therein. Many approaches have been exploited, among which the most wildly adopted one is the linearization method that results in approximations of original nonlinear systems around operating points [23]. The linearization approach has significantly promoted the theoretical study and practical application of nonlinear systems; however, it has the following limitations. First, as is well known, the dynamics of a nonlinear system is much richer than that of the corresponding linearized one. Second, certain essentially nonlinear phenomena, such as finite escape time, multiple isolated equilibria and subharmonic, to name but a few, can take place only in the presence of nonlinearity [23]. Consequently, alternative approaches have been developed in the literature to cope with the nonlinear systems, including T-S fuzzy model approximation [36], [38], [39], sliding mode control method [10], Hamilton-Jacobi equation/inequality approach [45] and so on. Up to now, the research on nonlinear systems has been a very active area within the systems science and control communities, which is still full of challenges.

On another research forefront, switched system has recently drawn much attention due to its ability in characterizing several categories of practical systems such as transportation systems, communication systems and so forth. Switched system is comprised of a number of subsystems which will be activated when the predetermined switching rules are violated [4]. Moreover, it has been demonstrated that, the scheme where multiple control laws switch according to the prespecified rules possesses certain advantages over the traditional strategies, especially when the systems under investigation are with complex dynamics. For instance, in [16], the performance of the closed-loop system has been significantly improved by adopting the proposed switching mechanism.

So far, there have been plenty of research fruits available regarding switched systems and several methodologies have been exploited, see e.g. [5], [8], [9], [11], [17], [39]. Most of these reported results, however, are focused on linear systems or nonlinear systems with relatively simple dynamics (e.g., linear systems with additive nonlinear perturbations), and the most frequently used method is the linear matrix inequality (LMI) approach [11], [41]. For general nonlinear systems, the corresponding results have been scattered due mainly to the

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