

Robust Control of Hybrid Systems with Analog Uncertainty

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Abstract: *In this paper design of robust hybrid controller for nonlinear systems is considered. The feedback is nonlinear function. Switching sequence is determined by minimization of suitable defined priority function. Model uncertainty belongs to the compact set. Finally, the stability of closed-loop systems is proved. It is shown that state variables is bounded. Such kind of stability is not a Lyapunov stability and closely related to the notion of stability used in adaptive control.*

Keywords: *Nonlinear systems, model uncertainty, hybrid controller, stability*

1. INTRODUCTION

Hybrid dynamical systems (HDS) have attracted considerable attention in the last a few years. These systems involve the interaction of discrete and continuous dynamics. Continuous variables take the values from the set of real numbers and the discrete variables take the values from a finite set of symbols. The HDS systems have the behaviour of an analog dynamic system before certain abrupt structural or operating condition changes. Well known example of hybrid system is the dynamic system described by a set of ordinary differential equations with discontinuous right-hand sides (systems with relays, switches, and hysteresis). Such kind of system described in the frame of theory in [1]. Another example is the sliding mode control [2]. The next typical example of a hybrid system is control of continuous-time process by digital controller. These systems known under the name sampled-data systems [3]; [4].

The important part of hybrid systems is event driven dynamics which can be described using different framework used for discrete event systems (DES) such as timed automata, max-plus algebra or Petri nets [5]. For HDS whose components are dominantly discrete events main tool for analysis and design are: representation theory, supervisory control, computer simulation and verification. From the classical control theory point of view HDS may be considered as a switching control between analog feedback loops [6]. That is discontinuous feedback control. For the nonholonomic systems, that can be possible approach for control because in that case no smooth feedback control law exists for stabilization or tracking. The second approach for such system is

approximate inversion [7]. It is, also, possible to interpret HDS as a special form of adaptation. Such control system are capable of adapting to large modeling errors and structural changes [8]. Generally, HDS can achieve better performance than non-switching robust controllers because they can reconfigure and reorganize their structures. For that necessary correct coordination of discrete and analog control variables.

It is possible to mention a few approaches for design of hybrid controllers. The first one is dwelling-time switching strategies [6]. For stabilization it is necessary to have enough long dwell time but that will cause loss of performance. The second approach is the state space partition [9] which first divide the whole state space into a finite set regions and then design HS in the discrete domain can be reduced to finite automata. But, complexity problem is extremely difficult.

In [8] design methodology for hybrid state feedback which maps hybrid states to hybrid control variables is developed based on system performance. In [10] control of a class of uncertain systems is considered. The uncertainties satisfy the matching condition within a given bounding set. Proposed robust controller is modification of piecewise linear LQ controller (PLC). These modifications include the concept of low-and-high gain (LHG) and concept of allowed oversaturation. Resulting hybrid closed-loop system is exponentially stable. Paper [11] considers the design of switching controllers for linear systems. The controllers are LQ controllers with prescribed degree of stability and switching sequence is determined by minimization of suitable defined priority function. In the form of theorem is proved: equilibrium point of the hybrid systems no worse than the best non-switching strategy and prescribed degree of stability has an explicit upper bound.

In this paper we will consider system with analog uncertainty. The term of analog uncertainty belongs to compact set. Switching sequence for desired feedback is determined by minimization of nominal performance and switching penalty term. The last term imposes cautiousness in switching discrete states. Namely, the switching will be decided only if the worst-case performance for the system is better than the best performance of the system.

In the paper in the form of theorem robust stability of the closed-loop hybrid system is established.

