

Robust Switching Control Systems with Input Delay

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Abstract: This paper uses the concept of multiple models and the concept of switching controllers. The analog part of the system is described by a finite set of continuous-time models with input delays. The continuous-time models include unmodeled dynamics in the form of affine matrix family. By using suitable transformation, the models with input delay are converted into delay free models. Then, by using the LMI tool, the class of robust LQ controllers with the prescribed degree of stability is proposed and for every controller the upper bound for the performance index is given. The switching logic is based on the selection of minimal upper bound from the collection of upper bounds. Finally, it is shown by means of performance dominant conditions, that the resulting closed-loop is stable.

Keywords: Multiple models, Input delay, LMI inequalities, Switching rule, Stability

1. Introduction

Hybrid systems describe the interaction between software, modeled by finite-state systems such as finite-state machines, and the physical world described by differential equations. The several key verification and control synthesis results for hybrid systems, guided by the concept of bisimulation, are outlined in the reference [1]. From the classical control theory point of view the hybrid systems can be considered as a switching control between analog feedback loops [2]. There are numerous applications of switching systems. For example, the reference [3] presents a vision based cart-inverted pendulum system under a hybrid feedback configuration. In [4] was considered unicycle and constrained pendulum as examples for switched control systems. The reference [5] presents impedance control of a robot manipulator using hybrid control.

Time-delay occurs in many dynamical systems such as biological systems, process industry, and long transmission lines in pneumatic systems, hydraulic systems, and electrical networks. It is frequently a source of the generation of oscillation, instability and poor performance. The effect of delay on the stability properties of dynamical systems is considered in [6]. Design of feedback control law for time-delay systems, based on dynamic programming, is presented in [7].

In this paper we use predictor like techniques for systems with input delay. Such techniques are considered in [8] and [9]. By using a suitable transformation the original problem can be described in the form of delay free system.

A specific class of problems (robust switching control in the presence of input saturation and switching stochastic nonlinear systems) is considered in [11] and [12].

In this paper we describe input delay systems using the multiple-model concept. The model includes unmodeled dynamics in the form of affine matrix family. By using the LMI (linear matrix inequalities) tool [13] the robust hybrid LQ controller with the prescribed degree of stability is proposed. It is formally proved that such a switching closed-loop system is stable.

2. System Description by Multiple Models

We assume that the process model is a member of admissible process models

$$F = \bigcup_{p \in P} F_p, \quad (1)$$

where P is matrix index set which represents the range of parametric uncertainty so that for each fixed $p \in P$ the subfamily F_p accounts for unmodeled dynamics. Usually P is the compact subset of finite-dimensional normed vector space. The process with input delay will be described in the following form

$$\dot{x}(t) = A_p(q)x(t) + \sum_{i=0}^r B_{pi}u(t-h_i), \quad (2)$$

$$h_0 = 0,$$

$$A_p(q) = A_{p0} + \sum_{i=1}^l q_{pi} A_{pi}, \quad q_p \in Q_1 \subset R^l$$

$$B_{pi} = [0 \cdots 0 \ B_{pil}^{(i)} \ 0 \cdots 0]$$

