Chapter 20

Robust Iterative Learning Control for Linear Discrete-Time Switched Systems

Ouerfelli Houssem Eddine
University ElManar, Tunisia

Dridi Jamel
University ElManar, Tunisia

Ben Attia Selma
University ElManar, Tunisia

Salhi Salah
University ElManar, Tunisia

ABSTRACT

This chapter aims to study the problem of stability analysis, and robust exponential stabilization for a class of switched linear systems with polytopic uncertainties is reviewed. A sufficient condition based on the average dwell time that guarantees the exponential stability of uncertain switched linear systems is given. First, the iterative learning control is presented to build a formulation ensuring the exponential stability of the given system. The integrated design of this ILC scheme is transformed into a robust control problem of an uncertain 2D Roesser system. The results are obtained through original connection with the notion of stability along the pass for 2D repetitive systems. An overview of the stabilization methods of switched discrete systems found in the literature is outlined. All the given formulations are presented in terms of LMIs. A numerical simulation example is established, showing the effectiveness of the proposed method.

DOI: 10.4018/978-1-4666-7248-2.ch020
1. INTRODUCTION

The stability analysis of switched linear systems is one of the active over the past research due to their wide applications in many areas such as the automotive industry, aircraft and air-traffic control, switched power converters (Branicky, 1998; Liu et al., 2010). A switched system is a hybrid dynamical system, which consists of a family of continuous-time or discrete-time subsystems and a rule that orchestrates the switching between them (Koutsoukos & Antsiklis., 2002; Attia et al., 2012; Attia et al., 2010). For the stability analysis of switched systems there are two issues to be addressed: stability under arbitrary switching (Attia et al., 2009a; Attia et al., 2009b; Attia & Bernussou, 2009c; Xiang & Huang., 2013) and stability under constraint switching, such as dwell time, average dwell time constraints (i.e. minimum time between switching) (Du et al., 2006; Elci et al., 2002; Mitra et al., 2008; Lian et al., 2011; Zhang et al., 2009). Although the dwell-time and average dwell time mainly characterize the time-controlled switching signals, the slow switching idea can be generalized to hybrid systems or state-controlled switching signals. In (Mitra et al., 2008) the authors studied the stability analysis problem for a given hybrid automaton (called structured hybrid automaton) via abstracting it into a `similar’ switched system. The similarity is in the sense of preserving the average dwell time property. Actually, the authors developed abstraction schemes to guarantee that the derived switched system has no greater average dwell time than the original hybrid automaton. Under the assumption that all the subsystems are stable, the stability of the abstracted switched systems then implies the original hybrid automaton’s stability. However, the stabilization problem of discrete switched systems with classic control law has been studied in (Attia & J. Bernussou., 2009c; Xiang & Huang., 2013; Shi et al., 2005; Liu et al., 2010; Attia et al., 2012; Fang et al., 2003), by using the common Lyapunov function approach, multiple Lyapunov function approach, piecewise Lyapunov function and switched Lyapunov function (Mehrzi et al., 2007; Attia et al., 2009b; Du et al., 2006). Many results on the issues of stability and control synthesis for the 2D switched systems have been obtained in (Benzaouia et al., 2009; Attia et al., 2012), most of them are based on the dwell time approach. Specifying the minimum dwell time that ensures the exponential stability of the switched systems is an especially attracting problem in this paper. We first introduce necessary notation and review several existing results using the dwell time approach. Given a positive constant $\tau_a$, let $S[\tau_a]$ denote the set of all switching signals with time interval between consecutive switching’s being no smaller than $\tau_a$. The constant $\tau_a$ is called the “dwell time” (Morse et al., 1996). When all subsystem matrices $A_i$ are Hurwitz stable, it has been shown in (Morse et al., 1996) that we can choose $\tau_a$ sufficiently large so that the switched system is exponentially stable for any switched sequence $\sigma(t) \in S[\tau_a]$. In (Zhat et al., 2001) a dwell time scheme is analyzed for local asymptotic stability of nonlinear switched systems with the activation time being used as a dwell time. The stability issues of such switched systems include several interesting phenomena. For example, even when all the subsystems are exponentially stable, the switched systems may have divergent trajectories for certain switching signals (Decarlo et al., 2000; Liberzon et al., 1999). Another remarkable fact is that one may carefully switch between unstable subsystems to make the switched system exponentially stable. As these examples suggest, the stability of switched systems depends not only on the dynamics of each subsystem but also on the properties of switching signals. On the other hand, from the practical viewpoint, it is important to investigate switched systems which contain uncertain parameters, there are few results concerning the stability of switched linear systems with uncertainties, recently (Attia et al., 2009b; Shi...
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