Stabilization of Piecewise-Linear Systems with Unknown Switching Information

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Abstract: Stabilization of piecewise-linear systems with unknown switching information is presented. The current subsystem is identified from the output, and the identified subsystem is used for the observer-based control. The stability of the overall system is proven and the performance is evaluated via a simulation.

Keywords: piecewise-linear system, hybrid dynamic system, subsystem identification, dwell-time switching

1. Introduction

Recently much effort has been spent on the control and analysis for piecewise-linear systems, which can be considered to be a special kind of hybrid dynamic systems and switching systems [1, 2, 3, 4]. However, the stabilization of piecewise-linear systems whose information about the current subsystem and switching time is not known has been seldom investigated. In this paper, the current subsystem is identified using the system output, and the identified subsystem is utilized to synthesize the observer-based stabilizing controller. Using the dwell-time switching concept [5, 6], the stability is assured which imposes some limitation on the minimum switching interval. The input and output matrices B and C are set to be identical for all subsystems for the sake of simplicity. Systems with different input and output matrices can be easily handled in the similar manner.

2. Subsystem Identification

Consider a piecewise-linear (PL) system

$$\dot{x} = A_j x, \quad y = Cx, \quad j = 1, 2, \ldots, r, \tag{1}$$

where $x(t) \in \mathbb{R}^n$ is the state, $y(t) \in \mathbb{R}^m$ the output. We assume that each subsystem (C, A_j), $j = 1, 2, \ldots, r$ is observable. The PL system can be in any of r linear operation modes depending on the characteristics of the system. In subsystem identification, we wish to identify the current subsystem index at each $t = kT$, $k = 1, 2, \ldots$, where T denotes the identification interval. Now suppose that the i-th subsystem is activated at $(k-1)T \le t \le kT$. Then there exists a sequence of time $(k-1)T = t_0^k < t_1^k < \ldots < t_{p-1}^k < t_p^k = kT$ such that

$$rank\left(\begin{bmatrix} C \\ C\Phi_i(t_{p-2}^k, t_{p-1}^k) \\ \vdots \\ C\Phi_i(t_0^k, t_{p-1}^k) \end{bmatrix}\right) = n \text{ (full column rank)}, \tag{2}$$

where $\Phi_i(\cdot,\cdot)$ is the state transition matrix of the i-th subsystem. Therefore we can obtain the following equation:

$$\begin{aligned} \mathrm{Y}^k &\triangleq \begin{bmatrix} y(t_{p-1}^k) \\ y(t_{p-2}^k) \\ \vdots \\ y(t_0^k) \end{bmatrix} \\ &= \begin{bmatrix} C \\ C\Phi_i(t_{p-2}^k, t_{p-1}^k) \\ \vdots \\ C\Phi_i(t_0^k, t_{p-1}^k) \end{bmatrix} x(t_{p-1}^k) \triangleq H_i^k x(t_{p-1}^k). \end{aligned} \tag{3}$$