Adaptive Receding Horizon H_∞ Controller Design for LPV Systems

°P. PooGyeon* and J. SeungCheol**
* Electrical and Computer Eng. Division, POSTECH Pohang, Kyungbuk, 790 Korea
(Tel : 82-54-279-2238; Fax : 82-54-279-2903; Email : ppg@postech.ac.kr)
** Electrical and Computer Eng. Division, POSTECH Pohang, Kyungbuk, 790 Korea
(Tel : 82-54-279-5588; Fax : 82-54-279-2903; Email : abraham@postech.ac.kr)

Abstract

This paper presents an adaptive receding horizon H_∞ controller for the linear parameter varying systems in the deterministic environment, which combines a parameter range estimator and a robust receding horizon H_∞ controller using the parameter bounds. Using parameter set inclusion and terminal inequality condition, the closed-loop system stability is guaranteed. It is shown that the stabilizing adaptive receding horizon H_∞ controller guarantees the H_∞ norm bound.
Key words: parameter range estimation, adaptive receding horizon control, H_∞ control, asymptotic stability

1 Introduction

Recently, some results are presented on receding horizon H_∞ control (RHHC) for time varying systems, which guarantee stability and H_∞ norm bound of the closed-loop system [1, 2]. Also those controllers yield good performance, while it is assumed that the values of the time-varying parameters are known for a finite future time. However, when large model uncertainties exist or unknown time-varying parameters exist, the performance of the robust receding horizon H_∞ control may be much degraded and the closed-loop stability may not be guaranteed. A solution is to combine a recursive parameter estimator and a robust receding horizon H_∞ controller.

In this paper, we shall suggest a new kind of adaptive receding horizon H_∞ controller that guarantees the closed-loop stability of a linear system with unknown parameters and unknown but bounded noises, by combining a recursive parameter estimator and a robust receding horizon controller. The recursive parameter estimator yields parameter bounds through parameter range estimation algorithm which is composed of time update and measurement update. Based on these parameter bounds, the robust receding horizon H_∞ controller is forced to regulate the closed-loop system over the parameter bounds and guarantee the H_∞ norm bound.

In outline, Section 2 states a basic model and problem. The model is deterministic, linear but time-varying with partially unknown parameters and bounded noises. Section 3 provides a parameter range update algorithm and Section 4 supplies a robust receding horizon H_∞ controller based on a robust finite-horizon H_∞ control about parameter uncertainties. In Section 5, it is shown that the proposed controller stabilizes the closed-loop system and guarantees the H_∞ norm bound. Section 6 provides an example.

2 Problem Statements

We shall consider a state-feedback control problem for a discrete-time linear system with uncertain time-varying parameters such as, for all $k \geq 0$,

$$x_{k+1} = \{A + \sum_{i=1}^{p} \theta_k(i)E(i)\}x_k + Bu_k + Dw_k, \quad (1)$$

where $x_k \in \mathcal{R}^n$, $u_k \in \mathcal{R}^m$ and $w_k \in \mathcal{R}^p$ are state, input and disturbance vectors, respectively, and all matrices are known except $\theta_k(i)$. Assume that we can perfectly measure the state of the given system and that the uncertain parameter vector $\theta_k \triangleq [\theta_k^T(1) \cdots \theta_k^T(p)]^T$ are driven by external noises as follows.

$$\theta_{k+1} = F_k\theta_k + v_k, \quad (2)$$
$$y_k = H_k\theta_k + w_k, \quad (3)$$

where F_k and H_k are given, $y_k \in \mathcal{R}^l$ are measurements that can be used to estimate θ_k, and all components of noise vectors w_k and v_k are bounded by

$$-q_k(i) \leq v_k(i) \leq q_k(i), \quad -r_k(j) \leq w_k(j) \leq r_k(j) \quad (4)$$

for $i = 1, \cdots, p$ and $j = 1, \cdots, l$.

The problem is to find a state-feedback controller that asymptotically stabilizes the closed-loop system and guarantees the H_∞ norm boundedness of the system.

3 Recursive Parameter Range Estimation

Let us assume that the initial bounds on entries of θ_k are given. All the inequalities for vectors are applied for