ROBUST H_∞ FIR SAMPLED-DATA FILTERING

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Abstract: This paper investigates the problem of robust H_∞ filter with FIR(Finite Impulse Response) structure for linear continuous time-varying systems with sampled-data measurements. It is assumed that the system is subject to real time-varying uncertainty which is represented by the state-space model having parameter uncertainty. The robust H_∞ FIR filter is proposed for the continuous-time linear parameter uncertain systems. It is also derived from the equivalence relationship between the robust linear H_∞ FIR filter and the robust linear H_∞ filter with sampled-data measurements.

Keywords: H_∞ FIR filter, continuous-time linear filtering, robustness, uncertainty, time-varying system, sampled-measurements.

1 Introduction

Very often in filtering problem for continuous-time systems, one is required to produce a continuous-time estimate of an analog signal based on sampled-data measurements. In this situation, the filtering performance measure should be defined directly in terms of the continuous-time signals, i.e. in the continuous-time context. We refer to this filtering approach as *sampled-data filtering*. As compared with the traditional discrete-time filter designs, the sampled-data filtering approach has the advantage of taking the inter-sampled behaviour into consideration. Another important feature of sampled-data filtering is that we deal directly with a continuous-time model of the signal generating mechanism which is highly desirable, in particular when the model is subject to parameter uncertainty as is often the case. A state space approach for sampled-data filtering in an H_∞ formulation has been recently proposed in [10]. To date, however, to-date the design of robust filters for uncertain continuous time- varying systems using sampled-data measurements has been fully investigated.

The problem of H_∞ filtering for both continuous-time and discrete-time systems has been extensively studied in the past few years [9]. Several techniques have been proposed to solve this problem, including polynomial equation approach [4], a Riccati equation approach [7,8,12] and an interpolation theory approach [2]. However, the conventional H_∞ filters proposed so far are mainly limited to time-invariant systems. Therefore they can not be applied to general time-varying systems on the infinite horizon since one of two Riccati differential equations required to solve the problem can not be computed on the infinite horizon [5].

In this paper we consider an H_∞ FIR filtering problem for a class of continuous time-varying uncertain systems under sampled-data measurements on the infinite horizon. The class of uncertain systems is described by a linear state space model with real time-varying norm-bounded parameter uncertainty in the state and output matrices. Here attention is focused on the design of linear filters for time-varying systems which guarantee a prescribed performance, irrespective of the uncertainty. The performance measure use is defined directly in the continuous-time context and is of an H_∞ type.

The basic idea of the current paper is to formulate the robust H_∞ filtering problem on the continuous-time moving horizon $[t-T, t]$ and to adopt the FIR (Finite Impulse Response) filter structure. The estimator of the current paper is rather a one-step-ahead predictor than a filter. This filtering problem is referred to as *robust H_∞ FIR sampled-data filtering* in the sense that it is an H_∞ sampled-data filter with the FIR structure for uncertain systems. We show that the robust H_∞ FIR sampled-data filtering problem can be solved in terms of two Riccati equation.

One of the main contributions of the current paper is that the H_∞ FIR sampled-data filter always has a solution if the standard H_∞ sampled-data filter exists on the finite horizon. Therefore, it is noted that the sampled-data filter proposed works on the time-varying systems with sampled-data measurements.

This paper is organized as follows: In Section 2, the robust H_∞ FIR sampled-data filtering problem is formulated under the continuous time-varying state-space model with parameter uncertainty. The preliminaries for solving robust H_∞ FIR sampled-data filtering problem is recalled in Section 3, and the robust H_∞ FIR sampled-data filter is proposed under the model uncertainty in Section 4. Conclusions are summarized in Section 5.

2 PROBLEM FORMULATION

Let us consider the following class of uncertain sampled-data time-varying systems:

$$\dot{x}(t) = [A(t) + \Delta A(t)]x(t) + B(t)w(t) \quad (1)$$

$$z(t) = L(t)x(t) \quad (2)$$

$$y(i) = [C(i) + \Delta C(i)]x(i) + D(i)v(i), \quad (3)$$

where $x(t) \in \Re^n$ is the state, x_0 is unknown initial state, $w(t) \in \Re^q$ is the process noise, $y(i) \in \Re^m$ is the sampled measurement, $v(i) \in \Re^r$ is the measurement noise, $z(t) \in \Re^p$ is a linear combination of state variables to be estimated over a moving horizon $[t-T, t]$, i is an integer, $A(t)$, $B(t)$, $C(i)$, $D(i)$ and $L(t)$ are known real time-varying bounded matrices of appropriate dimensions with $A(t)$, $B(t)$ and $L(t)$ being piecewise continuous, and $\Delta A(t)$ and $\Delta C(i)$ are real-valued matrix functions which represent real time-varying parameter uncertainties in A and C, respectively. These uncertainties are assumed to be of the form

$$\Delta A(t) = H(t)F(t)E(t) \quad (4)$$