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Dynamic Output Feedback Control of Discrete-Time Nonlinear Quadratic Systems with Stochastic Parametric Uncertainty and Missing Measurements

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Abstract. Finite-time dynamic output feedback control for a class of discrete-time nonlinear quadratic systems with stochastic parametric uncertainty, exogenous disturbance and missing measurements, modeled by a Bernoulli distributed stochastic variable, is considered and sufficient conditions for FTSB under a dynamic output feedback controller are provided. As a consequence, a sufficient condition for FTSS is derived. A numerical example demonstrates the effectiveness of the method.

AMS subject classifications: 93D15

Key words: Discrete-time nonlinear quadratic system, missing measurement, output feedback control, finite-time stochastic boundedness.

1. Introduction

In recent years, the Lyapunov asymptotic stability of dynamical systems on infinite time intervals has been energetically studied. Nevertheless, in practical applications, it is more important to establish the system trajectories over fixed finite time intervals [12, 16]. For example, this problem is connected to saturation elements in closed-loop systems and to controlling the trajectories of space vehicles during prescribed time intervals. The concept of finite-time stability (FTS) was introduced by Kamenkov [10] in 1953. Since then, substantial efforts have been spent on FTS analysis [8, 9, 21]. Later on the finite-time boundedness (FTB) of dynamical systems with exogenous disturbances has been considered [4, 5] and, recently, FTS and FTB of deterministic systems have been extended to stochastic ones. In addition, the problems of finite-time stochastic boundedness (FTSB) and finite-time stochastic stabilisation (FTSS) for Markovian jump systems with partially unknown transition probabilities are discussed in [22, 23].

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During the past years, the control problems for nonlinear systems have attracted a wide attention because of numerous practical applications. In particular, quadratic systems are often encountered in chemical reactors, electrical power systems [15], robotics [11] and biology [13]. More specifically, the domain of attraction (DA) problems are discussed in [3,7], finite-time stability and stabilisation problems arising in the design of optimal control strategies is considered in [20], a guaranteed cost control in [1,2], the sufficient conditions for finite-time boundedness and stabilisation of continuous-time quadratic systems are derived in [6].

Another group of actively studied non-linear systems includes systems with missing measurements [14,18]. Missing measurement phenomena can be modeled by binary switching sequences. A binary switching sequence is specified by a conditional probability distribution and enters into the system observation. It can be considered as a Bernoulli distributed white sequence taking values 0 and 1 — cf. Refs. [17,19]. Nevertheless, it is often very difficult, if not impossible, to accurately determine certain system parameters. Therefore, for discrete-time nonlinear quadratic systems with stochastic parametric uncertainty, it is very important to consider the stochastic stabilisation. However, to the best of author's knowledge, so far the FTSB and FTSS problems for such kind systems have not been studied. We also note that the most works on control problems deal only with state feedback control strategies, although in many engineering systems the state is not always accessible and the output feedback control is of practical significance. In this work, we consider a dynamic output feedback controller for discrete-time nonlinear quadratic systems with stochastic parametric uncertainties and missing measurements. In particular, we establish sufficient conditions to guarantee the FTSB and FTSS for closed-loop systems.

The paper is organised as follows. In Section 2, the target plant is described by a class of discrete-time nonlinear quadratic systems with stochastic parametric uncertainty and exogenous disturbance. Then the measurement-missing phenomena are proposed and a dynamic output feedback controller is developed. In Section 3, a sufficient condition of FTSB for the closed-loop system is presented. It yields a sufficient condition of FTSS for closed-loop system without exogenous disturbance. An example in Section 4 demonstrates the efficiency of the result obtained.

2. Preliminaries and Problem Formulation

We consider the discrete-time nonlinear quadratic system with stochastic parametric uncertainty and exogenous disturbance

$$\begin{aligned} x(k+1) &= (A+\alpha(k)\Delta A)x(k) + F(x(k)) + Bu(k) + B_w w(k), \\ y(k) &= Cx(k) + D_w w(k), \\ w(k+1) &= Gw(k), \end{aligned} \tag{2.1}$$

where $x(k) \in R^n$ is the state vector, $u(k) \in R^m$ the control input, $w(k) \in R^p$ the exogenous disturbance, $y(k) \in R^r$ the output, $A \in R^{n\times n}$, $B \in R^{n\times m}$, $B_w \in R^{n\times p}$, $C \in R^{r\times n}$, $D_w \in R^{r\times p}$, $G \in R^{p\times p}$ are constant matrices and