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Controller design for 2-D stochastic nonlinear Roesser model: A probability-dependent gain-scheduling approach☆

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Abstract

This note is concerned with the static output feedback control problem for two-dimensional (2-D) uncertain stochastic nonlinear systems. The systems under consideration are subjected to time delays, multiplicative noises and randomly occurring missing measurements. A random variable sequence following the Bernoulli distribution with time-varying probability is employed to character the missing measurements which are assumed to occur in a random way. A new gain-scheduling method based on the time-varying probability parameter is proposed to accomplish the design task. By constructing a suitable Lyapunov functional, sufficient conditions to guarantee the systems to be mean-square asymptotically stable are established. The addressed 2-D controller design problem can be reduced to a convex optimization problem by some mathematical techniques. In the last section, a numerical example and the comparative analysis are provided to illustrate the efficiency of our proposed design approach.

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1. Introduction

In the past few decades, 2-D systems have been receiving considerable attention due to their pervasive application in many engineer fields, such as the analysis of satellite weather photos, multidimensional digital filtering, multivariable network realizability, and electron heating systems [13,32]. From a physical perspective, 2-D system is a class of system that depends on two variables. For example, an image is a generalization of a temporal signal where it is defined over two spatial dimensions instead of a single temporal dimension [24]. It can essentially be governed by the Roesser model with space coordinates i and j taking the place of time t. There are a great deal of results focusing on the modeling of 2-D systems, for instance, the state-space models of 2-D systems have been investigated in [13,21]. As is well known, Roesser model is one of the most important model of 2-D linear systems, which has been widely used due to its practicality. Meanwhile, the design of controllers and filters, stability analysis and stabilization for 2-D systems have been extensively studied by researchers, and a large number of results have been reported, see e.g. [3,14,15,20].

In the process of modeling, vast amount of reasons can lead to parameter uncertainties which would perturb the elements of system matrices, for example, the variations of the operating point. With these factors, it becomes almost impossible to set up an exact mathematical model for a real-time plant. For another, for the purpose of high control precision, the parameter uncertainty should be added to the model to capture the essential characteristics of the real process under consideration. Therefore, over the past few decades, a large number of attention have been paid to linear or nonlinear uncertain systems, see e.g. [30] and references therein. There has been some initial research attention on 2-D systems with parameter uncertainty, for example, a state estimator has been designed in the presence of data missing, sensor saturation, parameter uncertainties as well as stochastic perturbations in [17]. Meanwhile, time-delay is a common phenomenon which extensively exists in control systems. Encouragingly, some significant progresses on the design problem of controller and filter for one-dimensional (1-D) systems with time-delay have been made in previous researches, see e.g. [16,23,30,31,35]. For 2-D systems, time-delay has also gained more and more attention, and some significant results have been achieved. The stability analysis problem for 2-D systems has been investigated in [2], and the result has been applied to a time-delay system.

The literatures of the past decade have been a renewed interest in the research of gain-scheduling method, owing to its practicability and effectiveness in the aspect of actual engineering, see e.g. [18,33]. For the design problem of controller, to realize the system performance and improve the robustness of a system with time-varying parameters, gain-scheduling method is especially important, and the past few decades have witnessed significant progress on this issue for continuous-time and discrete-time systems. In [28], for linear systems with time-varying parametric uncertainties, a new algorithm for gain-scheduled controller synthesis has been provided. However, the gain-scheduling method has not yet been well studied for 2-D stochastic nonlinear systems, and current literatures in this regard are very limited, for example, the previous literature on this topic has studied a $\mathcal{H}_\infty$ gain-scheduled controller for 2-D linear parameter-varying systems, see [25] for more details.

As is well known, missing measurement is a kind of the incomplete information phenomenon, there are many reasons account for this phenomenon, such as intermittent mechanical failures and probabilistic packets loss, see e.g. [9,11,12,19,26]. Missing measurements cannot completely reflect the actual states and activities of objectives, and will inevitably bring huge difficulties to research work. Therefore, it is very vital to exploit corresponding control method to cope with such kind of negative effect. Consequently, researchers are increasingly focusing on systems with missing measurements in recent years, and many results in 1-D systems have appeared on