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A robust fault-tolerant control strategy for networked control systems

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ABSTRACT

Networked control systems (NCS) are one type of distributed control systems where serial communication networks is used to exchange system information and control signals between various physical components of the systems that may be physically distributed. The existence of real-time network in the feedback control loop makes analysis and design of an NCS complex, and conventional control theories such as synchronized control and non-delayed sensing and actuation must be reevaluated prior to application to networked control systems. NCS is a kind of feedback control systems where the control loops are closed through real-time control network. The performance of the closed-loop system is not only determined by the characteristics of the control system, but also determined by the scheduling manner imposed by network. In this paper, adjustable deadbands are explored as a solution to reduce network traffic in networked control systems and we presented a new modeling method for networked control systems with random time delays and communication constraints based on quasi-T–S fuzzy models. The integrity design for the kind of networked control systems is analyzed based on robust fault-tolerant control theory and information scheduling. Parametric expression of controller is given based on feasible solution of linear matrix inequality (LMI). After detailed theoretical analysis, this paper also provides the simulation results, which further validate the proposed scheme.

1. Introduction

A major trend in modern industrial and commercial systems is to integrate computing, communication, and control into different levels of machine/factory operations and information processes (Halevi and Ray, 1988; Nilsson, 1998). The traditional solution for exchanging information and control signals is point-to-point communication, which is a wire connects the central control computer with each sensor or actuator point and has been successfully implemented for decades. The point-to-point wiring is complex and expensive and the whole system is difficult to maintain and diagnose due to large number of connectors and cables. With the development of network technology, there is a trend in factory, home and automotive equipment toward distributed networking (Zhang, 2001; Fengli, 2002). This trend can be inferred from many proposed or emerging network standards, such as controller area network (CAN, ANSI/ISO 11898, ANSI/ISO 11519-2) for automotive and industrial automation, BACnet (ANSI/ASHRAE 135) for building automation, and ProfibBus (EN 50170) and WorldFIP (EN 50170) feildbus for process control.

In manufacturing plants, HVAC systems, vehicles, aircraft and spacecraft, serial communication networks are employed to exchange information and control signals between spatially distributed system components, such as supervisory computers, controllers, and intelligent I/O devices (e.g., smart sensors and actuators). Each of the system components connected to the network directly is denoted as a node. When a control loop is close via a serial communication channel (wireline or wireless), it is labeled as a networked control system.

Feedback control systems wherein the control loops are closed through a real-time network are called networked control systems (NCS) (Halevi and Ray, 1988; Nilsson, 1998; Walsh et al., 1999; Zhang, 2001; Fengli, 2002). The defining feature of an NCS is that information (reference input, plant output, control input, etc.) is exchanged using a network among control system components (sensors, controller, actuators, etc.). Fig. 1 illustrates a typical setup and the information flows of an NCS. Compared with conventional point-to-point interconnected control systems, the primary advantages of an NCS are modular and flexible system design (e.g., distributed processing and interoperability), simple and fast implementation (e.g., reduced system wiring and powerful configuration tools), ease of system diagnosis and maintenance, and increased system agility. Consequently, there is a growing theoretical interest in the field of networked control systems (Nilsson, 1998; Walsh et al., 1999; Zheng et al., 2004).

The insertion of the communication network in the feedback control loop makes the analysis and design of an NCS complex. Conventional control theories with many ideal assumptions, such as synchronized control and non-delayed sensing and actuation, must be reevaluated before they can be applied to NCS. Many scholars have worked on the analysis, design, modeling and control

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