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A novel controller design and evaluation for networked control systems with time-variant delays

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Abstract

A new delayed state-variable model for networked control systems is presented, upon which a linear quadratic regulator (LQR) is designed. A method of delays-estimation online is also given. A fuzzy logic with LQR controller is addressed for the difficulty on implementation of LQR in networked control systems (NCSs) with time-variant delays. Simulation results prove that the novel controller can make the system stable and robustly preserve the performance in terms of time-variant delays.

Keywords: Networked control systems; Fuzzy logic; LQR; Online estimation

1. Introduction

As a system becomes more and more intelligent and flexible, the system requires more sensors, actuators, and controllers, which are often referred to as field devices. In most cases, these field devices require some type of electrical connection because they are distributed over a certain area. Conventionally, these devices are connected with point-to-point connections and the number of cable is proportional to the square of the number of devices. In contrast, more recently, there has been a strong push for these field devices to be

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connected by network, this kind of feedback control systems wherein the control loops are closed through a real-time network can be called networked control systems (NCSs).

The change of communication architecture from point-to-point to network, however, introduces different forms of time delay uncertainty between these devices. Delays are widely known to degrade the performance of a control system, so there has been a lot of research on NCSs to reduce the performance degradation caused by delays. In Ref. [1], the author studied the effect of delays on the system modeling, and then a new optimal controller was designed to control the plant, however, the controller only considered the constant delay. In Ref. [2], the author utilized clock synchronization technology to evaluate the delays online, and then a LQR optimal controller based on the obtained delays was adopted to stabilize the plant, but the implementation of the controller caused some performance degradation. In Ref. [3], a fuzzy logic controller was used to control the NCSs, which regretfully didnot use the communication information in design of controller.

Since networked control systems is an integrated research area, which is not only concerned about control, but also relevant to communication, we must combine the knowledge of control and communication together to improve the system performance, at the same time, the system design must consider that the delays in NCSs may be time-variant. Following this direction, in this paper, we address a novel scheme that integrates control technology with communication technology for a class of NCSs with time-variant delays.

2. Problem formulation

Consider a NCS, in which sensor is time-driven with a constant sampling period h, and both actuator and controller are event-driven, which is shown in Fig. 1. We use s and a to represent the sensor–controller and controller–actuator delays, respectively, and all sample values of plant states are transmitted in one package. In Fig. 1, the continuous-time, state–space model of the linear time-invariant plant dynamics, $G(s)$, can be described by the following standard form:

$$\dot{x}(t) = Ax(t) + Bu(t), \quad y(t) = Cx(t), \tag{1}$$

where plant states $x \in R^N$, inputs $u \in R^M$, outputs $y \in R^R$ and the constant matrices A, B, C are of compatible dimensions.

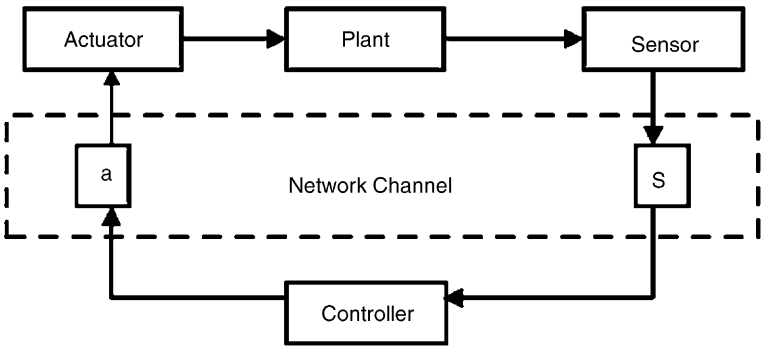

Fig. 1. The block diagram of a networked control system.