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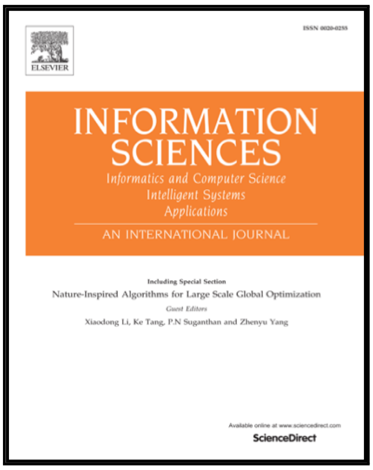

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Self-Triggered and Event-Triggered Set-Valued Observers

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Abstract

This paper addresses the problem of reducing the required network load and computational power for the implementation of Set-Valued Observers (SVOs) in Networked Control System (NCS). Event- and self-triggered strategies for NCS, modeled as discrete-time Linear Parameter-Varying (LPV) systems, are studied by showing how the triggering condition can be selected. The methodology provided can be applied to determine when it is required to perform a full ("classical") computation of the SVOs, while providing low-complexity state overbounds for the remaining time, at the expenses of temporarily reducing the estimation accuracy. As part of the procedure, an algorithm is provided to compute a suitable centrally symmetric polytope that allows to find hyper-parallelepiped and ellipsoidal overbounds to the exact set-valued state estimates calculated by the SVOs. By construction, the proposed triggering techniques do not influence the convergence of the SVOs, as at some subsequent time instants, set-valued estimates are computed using the *conventional* SVOs. Results are provided for the triggering frequency of the self-triggered strategy and two interesting cases: distributed systems when the dynamics of all nodes are equal up to a reordering of the matrix; and when the probability distribution of the parameters influencing the dynamics is known. The performance of the proposed algorithm is demonstrated in simulation by using a time-sensitive example.

Index Terms

State estimation; Fault detection; Self-triggered; Networked Control Systems.

I. Introduction

In the context of distributed systems and Networked Control Systems (NCSs), the performance bottleneck is often located in the communication network, either due to low bandwidth, competition for access to a shared medium of communication, or because the network is much slower than the remaining components of the control loop. In distributed systems, different nodes are typically running an algorithm to achieve a certain goal and are often designed to use information from their communicating neighbors. In networked control systems, sensors might be spatially spread over a region of interest and, therefore, measurements have to be sent to a controller/observer over the network. In any of such cases, the network resources are valuable and the communication issues must be considered as they can prevent the stability as given in [38] and [45]. For further details on this topic, the reader is referred to the detailed survey in [37], [16], [44] and [13]; and the book [6].

In the control community, two main strategies have emerged to reduce the communication overhead, namely: event triggering, where the sensor decides, based on the current measurements, if it should transmit to the controller/observer the measured quantities; self triggering, where the controller/observer decides, based on the current estimate of the state, when the sensor should perform the next measurement. An event-triggered solution results in a more informed choice, since the sensor has access to the actual measurement, but prevents the sensor from being shut down between updates. For a recent discussion on event- and self-triggered control and estimation, the reader is referred to [15].

The problem of state estimation for general discrete-time Linear Parameter-Varying (LPV) systems relates to that of determining the set of possible future state values for a given set of inputs, initial state, measurements, and (deterministic) bounds on the noise and disturbances affecting the system. LPV models allow for considering NCSs with parametric uncertainty that may arise from incomplete knowledge of the physical parameters of the processes to be controlled. In the context of distributed observer-based control strategies, uncertainty may also arise due to node heterogeneity or the inability to determine at the observer side which nodes are communicating or taking actions upon the plant. Two interesting instances of the state estimation problem can be found in the following contexts:

- asynchronous distributed algorithms - determining the state of each of the nodes given partial measurements and knowledge of the whole system dynamics;

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