Distributed Fault Detection Using Relative Information in Linear Multi-Agent Networks

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Abstract

This paper addresses the problem of fault detection in the context of a collection of agents performing a shared task and exchanging relative information over a communication network. We resort to techniques in the literature to construct a meaningful observable system and overcome the issue that the system of systems is not observable. A solution involving Set-Valued Observers (SVOs) is proposed to estimate the state in a distributed fashion and a proof of convergence of the estimates is given under mild assumptions. The performance of the proposed algorithm is assessed through simulations.

I. Introduction

The problem of detecting faults in a group of dynamical systems cooperating over a network is considered in this paper. The motivation for this work is to provide tools to facilitate the distributed fault detection task in a system with sub-systems with a shared objective and only sharing relative information. The importance of this problem is reported in [1] and later in [2], where the detection is crucial as a single malfunctioning node can severely impact the overall network performance. Applications span the areas of mobile robots, cooperating unmanned vehicles tasks such as surveillance and reconnaissance, distributed state estimation, among others (see [3] and the references therein).

In [3], one of the main results is showing that the overall system of the dynamical system is unobservable when only considering relative information of the states of the individual systems. A transformation is introduced that allows to perform fault detection and isolation by considering the observable subspace of the overall system. The algorithm requires a centralized detection scheme and in this paper, we aim at giving an alternative approach based on Set-Valued Observers (SVOs) which enables a distributed detection for the observable subspace.

In [4], the use of SVOs for distributed fault detection were firstly introduced for the specific case of consensus. The overall system is constructed using a Linear Parameter-Varying (LPV) system where the communications are modeled as a parameter influencing the system dynamics matrix. A main characteristic of the system was that although it is not observable in every time instant, after a sufficiently long time interval to allow communications between every pair of nodes in the network, the system is observable as long as the underlying network topology is strongly connected. The main difference to the work presented in this paper is what are the available measurements. Whereas in [4], each node has access to its own state and one of the neighbor states to which it communicates, in this paper, it is assumed that nodes have access only to relative information. The distributed detection can also be improved by resorting to exchanging state estimates whenever the systems communicate or take measurements by using a similar algorithm to the one presented in [5].

The Set-Valued Observers (SVOs) framework, whose concept was introduced in [6] and [7] (further information can be found in [8] and [9] and the references therein) is used as a way to represent and propagate the set-valued state estimates. The approach allows us to easily consider any kind of linear dynamics for the agents, and also to incorporate disturbances and model uncertainties.

The main contributions of this paper are as follows:

- the use of SVOs to compute the set-valued state estimates for the observable subsystem in a distributed fashion;
- it is shown how the nodes can estimate only their neighbors or the whole system;
- we show two options for addressing the case where the system is unobservable but detectable with its corresponding features.

References

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