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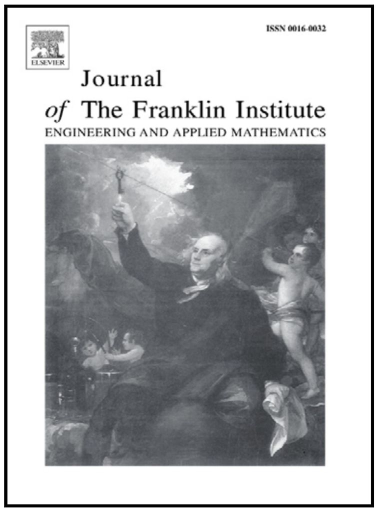

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PII: S0016-0032(15)00221-5
DOI: http://dx.doi.org/10.1016/j.jfranklin.2015.05.031
Reference: FI2354

To appear in: *Journal of the Franklin Institute*

Received date: 30 October 2014
Revised date: 5 March 2015
Accepted date: 14 May 2015

Cite this article as: Gang Chen, Yong-Duan Song, Robust Fault-Tolerant Cooperative Control of Multi-agent Systems: A Constructive Design Method, *Journal of the Franklin Institute,* http://dx.doi.org/10.1016/j.jfranklin.2015.05.031

Robust Fault-Tolerant Cooperative Control of Multi-agent Systems: A Constructive Design Method

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Abstract

This paper investigates the distributed cooperative controller design problem for multi-agent systems in the presence of actuator faults. Both the partial loss of actuator effectiveness and the actuator bias faults are considered. A constructive design method is presented to achieve the synchronization and/or tracking control of multi-agent systems. The control protocol for each agent consists of three modules: the actuator fault detection module, the nominal control module, and the auxiliary control module. The auxiliary control module is activated as soon as the actuator faults are detected. The control protocols are locally distributed in the sense that the control modules designed for each agent only require the information of itself and its neighbors. The loss of symmetry in the digraph Laplacian matrix is also considered. The analysis is suitable for the multi-agent systems with a general directed communication graph. The proposed fault-tolerant control schemes are applied in the formation control of multi-robot systems. Numerical simulation results are presented to show the effectiveness of the proposed control methods.

I. Introduction

Distributed cooperative control of multi-agent systems has received significant attention from the control community due to its potential applications in many areas, such as distributed control of networked systems, formation control of unmanned aerial/ground vehicles, and cooperative control of distributed generator systems. Distributed cooperative control aims at designing appropriate controllers by using the information of each agent and its neighbors such that all the networked agents achieve the coordination requirements. Fruitful results have already appeared in the literature, for example, consensus [1]-[4], formation control [5], [6], synchronization [7], [8], and target tracking control [9]-[11].

The development of advanced control technologies and the explosion in computation and communication capacities enable the applications of cooperative control systems. Compared to a single agent that performs certain task, greater efficiency and capability can be achieved by a group of agents operating in a coordinated fashion. On the other hand, advances in computer, communication, and control technologies have increased the complexity of engineering systems. Sometimes, a fault in the systems may deteriorate the systems performance or even cause catastrophic accidents. Thus, the reliability is one key objective for the design of engineering systems. It is required that the systems operate safely even in the presence of faults. In general, the faults in the systems are difficult to foresee. Thus, fault tolerance control is viewed as one of the most promising control technologies that are capable of maintaining stable and acceptable performance of the systems in the presence of unexpected faults. The fault tolerance control approaches can be classified into two classes: the passive approach and the active approach. The passive approaches use unchangeable controllers throughout the healthy and faulty cases [12], [13]. In contrast to the passive fault-tolerant control approach, the active approaches compensate for the faults either by selecting a pre-computed control strategy or by synthesizing a new control scheme on-line as soon as a diagnostic algorithm has detected the presence of a fault [14]-[19]. Although the fault tolerance control of centralized systems has been extensively investigated, it is only in recent years that the fault-tolerant cooperative control of distributed systems with actuator faults receives some researchers' attention. The work in [20] investigated the problem of fault tolerant control in cooperative interception. The work in [21] studied the mean-square consensus problem for a class of multi-agent systems subject to noise perturbations and actuator failures, where the stability analysis requires that the actuator failures are globally synchronous. In [22], the authors provided a fault-tolerant strategy for a class of multi-agent systems such that the states of all agents reach a common target point in spite of agent faults. The work in [23] presented a novel cooperative fault-tolerant fuzzy control scheme for multi-agent systems with the actuator bias faults. In [24], the authors proposed a decentralized fault-tolerant synchronization strategy for a group of networked satellites with actuator faults. The work in [25] provided the performance analysis of a team of unmanned vehicles subject to actuator faults.

In this paper, we provide a constructive method to design the robust fault-tolerant control scheme for multi-agent systems subject to actuator faults. An actuator fault detection algorithm is first presented. Then, a robust fault-tolerant protocol is proposed to achieve the synchronization and/or tracking control of multi-agent systems. The works in [20], [21], [22], [25] investigated the passive fault-tolerant control methods. We discuss the active fault-tolerant control methods. The control protocol

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