Doctoral proposal

Thesis: Robust Fault-tolerant control of collaborative mobile robots
Thesis: Control colaborativo tolerante a fallas robusto de robots móbiles

Supervisors: Dr. Francisco Ronay LÓPEZ ESTRADA & Prof. M. CHADLI (Univ Paris-Saclay, France)
Research line: Mechatronic systems
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1 Introduction

Consensus control is fundamental in the study of collaborative control, and its objective is to design distributed controllers to make a group of agents converges to a common state. Its applications range from cooperative control of autonomous vehicles to formation control of air and ground vehicles, among others. An application example was seen in the recent Olympic Games in Tokyo, where 1,800 drones worked collaboratively to form the earth's surface. However, as with any other automated system, any individual agent who becomes part of a collaborative group could be affected by faults. This work is dedicated to studying some techniques to improve the controller performance even in the presence of faults. When a fault affects an agent of the collaborative robots, the consensus is compromised. In this case, the common task could not be achieved, for example, in the formation control of drones, a faulty element could cause all the formation a failed drone can cause the entire formation to be lost, even crashes that ultimately end in an accident.

Few works have been proposed to answer these questions in the literature. For example, in Deng and Yang (2019) a distributed adaptive FTC approach to cooperative output regulation for linear multiagent systems was proposed based on the matrix theory and the linear algebraic technique. An actuator fault estimation observer was proposed in Farrera et al. (2020) by considering a proportional-integral observer and simultaneous faults. Another adaptive FTC consensus protocol was proposed in (Ke et al., 2020), where a set of distributed adaptive laws were designed to accommodate for compensating the effects of fault and uncertainty. A robust FTC consensus method was proposed in Li et al. (2020) by considering a H_∞ norm to deal with external disturbances and the faults. The previous contribution can be classified as node faults because it only changes the individual dynamics of a particular agent. Distributed controllers can be consulted in Chadli et al. (2017); Jin et al. (2021). However, faults can also appear by the interconnections, which affect the network topology or communication condition Ma and Yang (2015). For example, consider a collaborative drone formation in a leader-follower configuration. In this case, an actuator (e.g., loss of performance on the rotors) or sensor fault (e.g., bias or electromagnetic interference) can affect the formation. However, a local FTC can deal with these faults, avoiding performance loss. In addition, it is also clear that the synchronization depends on the information shared through the wireless robotic communication network Chen and Hung (2019), which can also be interrupted due to environmental conditions or malicious attacks (DoS attacks). Both faults are frequent and have undesirable effects on the consensus protocols. However, typical FTC methods only guarantee local stability and are not applicable when the communication network is affected. Few works on collaborative FTC are reported to deal with this problem. In Ma and Yang (2015) an active FTC approach was proposed to track the leader reference despite actuator faults and network disconnections. In Zhao and Yang (2020) an adaptive impulsive FTC method to deal with the deception attacks and actuator bias faults was proposed.

However, despite the contributions reported, the problem is not entirely solved for collaborative robotics working in harsh environments where the systems are subject to disturbances, noise, and uncertainties. This works will be dedicated to study fault-tolerant control consensus protocols for collaborative robots subject to actuator, sensor and interconnection faults. Mixed H_∞/H_- or H_∞/H_2 techniques will be explored in order to guarantee the robustness of the algorithms against noise, disturbances and uncertainties. These combined techniques have proven to be effective on FTC control for a single agent López-Estrada et al. (2015), and this thesis will explore their application to collaborative robots. Finally, the main idea is to test these consensus protocols on mobile robots in the automatic control laboratory, sharing information through a wireless network and an Optitrack movement capture system.

2 Financing

The main goal of this work is to develop theoretical algorithms. Therefore, it is not necessary extra financing for the strengthening of the project. The scholarship will be cover the National Council of Science and Technology (CONACYT) of Mexico. The travel expenses to Paris (Flight ticket + Train) will be covered under the cotutelle agreement with the University Paris-Sacley.

3 Collaboration

The work will be carried out in collaboration with the University of Paris-Saclay (Prof M. Chadli). A cotutelle agreement will be signed for student mobility. Indeed, co-supervision of the thesis is expected. As a result of this collaboration agreement, the thesis will be developed under the double degree modality with which the graduate will obtain the title of Doctor of Engineering Sciences from TecNM and the University Paris-Saclay.

4 About the candidate

We are looking for a student with background solving and analytical skills. The candidate must be detailed oriented, knowledgeable on control (preferential FTC, FDI, discrete controllers), work comfortably under pressure, and deliver tight deadlines. Top candidates will have the ability to reason abstractly and quantitatively while constructing viable arguments and critiquing others' reasoning. It is also important to note that the candidate must stay in Paris, France, for one or two years to have both the TecNM and the University of Paris Sacley academic degree.

5 How to apply?

- Send CV to frlopez@ittg.edu.mx and mchadli20@gmail.com

- Review the call 2022 to see the administrative requirements https://bit.ly/calldci22
- Dead-line: 16 May 2022.

6 About the supervisors

Francisco-Ronay López-Estrada received his Ph.D. degree in automatic control from the University of Lorraine, France, in 2014. He has been with National Technological Institute of Mexico, IT Tuxtla Gutiérrez, as a lecturer since 2008. He is part of the Editorial Board of the Mathematical and Computational Applications and Int. J. of Applied Mathematics and Computer Science journals. He is the author/co-author of more than 40 research papers published in ISI-Journals and several international conferences. He has led several funded research projects, and the funding for these projects comprises a mixture of sole investigator funding and collaborative grants. Furthermore, he collaborates with European universities as the University of Lorraine, University of Paris Sacley, University of Stavanger, Polytechnique University of Catalonia, among others. His research interests are fault diagnosis and fault-tolerant control based on convex LPV and Takagi-Sugeno models and their applications. Also, the extension of these techniques for the safety and management of UAV and water distribution systems. https://www.grupoturix.com/ronay

Mohammed Chadli (Senior Member, IEEE) received the M.Sc.Eng. (DEA) degree from the Engineering School, INSA-Lyon, Villeurbanne, France, in 1999, the Ph.D. degree from the University of Lorraine (UL-CRAN), Nancy, France, in 2002, and the habilitation from the University of Picardie Jules Verne (UPJV), Amiens, France, in 2011, all in electrical engineering.,He was a Lecturer and an Assistant Professor with the Institut National Polytechnique de Lorraine-UL, Nancy, France, from 2000 to 2004. Since 2004, he was an Associate Professor with the UPJV and is currently a Full Professor with the University Paris-Saclay, Saint-Aubin, France, Univ Evry, vry-Courcouronnes, France, IBISC Lab., Evry-Courcouronnes, France. He was a Visiting Professor with the Technical University of Ostrava, Ostrava, Czech Republic, Universitetet i Agder, Kristiansand, Norway, Shanghai Maritime University, Shanghai, China, from 2014 to 2017, and Nanjing University of Aeronautics and Astronautics, Nanjing, China, from 2018 to 2019. On the application side, he is mainly interested in automotive control and renewable energy. He has authored or coauthored books and book chapters (Wiley, Springer, Hermes), and numerous articles published in international journals and conferences. His research interests include fuzzy/LPV and switched systems, singular systems, robust control, fault detection and isolation (FDI), fault tolerant control (FTC) via LMI, SOS, and Lyapunov methods.,Dr. Chadli is also an Editor/Associate Editor/Editorial Board Member of several international journals, including the IEEE Transactions on Fuzzy Systems, the IEEE Transactions on Industrial Electronics, the IET Control Theory and Applications, the Franklin Institute Journal, Asian Journal of Control, Cogent Engineering, and was a Guest Editor for special issues in international journals. https://ieeexplore.ieee.org/author/37271150000

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