Set-theoretic methods in control. Applications to fault tolerant control and motion planning

Habilitation Thesis

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Summary

This manuscript presents the professional, academic and scientific results obtained in the last 7 years of my career (after obtaining my PhD) and the directions of interest in research I wish to follow in the medium term (based on the directions I identified in my research domain of interest).

In particular, I am interested in applying set-based methods to fault tolerant control and motion planning for autonomous systems. I consider that these methods are still insufficient due to a variety of factors (theoretical difficulty, numerical problems, etc.). Their widespread application will allow a rigorous analysis of the performance, stability and functionality of a system (e.g., nominal or faulty operation).

The first part of the manuscript reviews my professional and academic career to date (post-thesis). The main stages were the pursuit of a postdoctoral internship (NTNU, Norway) and employment in the Department of Automatic Systems and Systems Engineering UPB, Romania, where I currently hold the position of Associate Professor. Throughout this evolution, I have been involved in various research and teaching activities that have enabled me to develop my capacity of independent work.

The second part of the manuscript lists the main scientific results obtained after the completion of my thesis. In particular, I consider the following relevant working directions:

i) Extensive use of invariant sets (usually starting from zonotopic disturbances) to characterize the performance and functioning of a dynamic system; these approaches have been useful to me both for implementing a strategy for regulating tolerance to active defects (detection and isolation in a closed loop, parameterization of a reference generator, etc.) and to analyse the structure of the resulting problem (for example, for analysing the complexity of explicit MPC representation);
ii) Trajectory planning for nonlinear dynamic systems (in particular fixed wing and / or multi rotor UAVs); using the notions of platitude, through B-spline parameterizations I have managed to create reference trajectories that respect the system dynamics, constraints on entry and / or states;
iii) Relatively recently I became interested in the difference between discrete and continuous behaviour for a dynamic system; in this sense, I studied the problem of obstructing obstacles in order to propose a finite number of constraints (usually non-linear) that guarantee continuous obstacle avoidance.

A third part of the manuscript summarizes the problems I have identified over the last few years, as well as the approaches I wish to apply. A brief enumeration covers:

i) Explicit constructions for invariable (robust or robust controllable) regions to characterize the functionality of a dynamic system; to improve the existing results, I propose to exploit particular forms (zonotopic disturbances) and the intrinsic structure of the problem;
ii) Realization of a realistic fault tolerant control scheme: considering transitional behaviour; closed-loop detection and isolation behaviour; the question of observability in large-scale systems (e.g., the placement of sensors in water networks);
iii) Analysis of non-linear system trajectories through flatness and various parameterizations (e.g., NURBS); improved guarantees for functioning in the presence of faults, tracking errors, uncertainties in the model, etc.;
iv) For the evaluation of the previous points I plan to validate the results on complex systems (large, heterogeneous in terms of composition and / or geographic location, etc.); particularly, I am interested in the problem of detection in water networks, control of multi-agent drones and analysis of electrical transmission systems.