ASTRODYNAMICS SYMPOSIUM (C1)
Guidance, Navigation and Control (3) (5)

Author: Mr. Leonel Palacios
University of Glasgow, United Kingdom

Dr. Matteo Ceriotti
University of Glasgow, United Kingdom
Prof. Gianmarco Radice
University of Glasgow, United Kingdom

AUTONOMOUS DISTRIBUTED LQR/APF CONTROL ALGORITHMS FOR CUBESAT SWARMS MANOEUVRING IN ECCENTRIC ORBITS

Abstract

Spacecraft formation has shown to be a promising approach to enhance mission capabilities and this paradigm has shown evidence of technological and economic benefits as well as enhancing mission reliability by increasing the number of spacecraft in orbit. Besides, the size reduction tendency in spacecraft – as in the case of CubeSats – could be an enabling component for future SF missions with a large number of elements. Nevertheless, formation flying presents several control challenges which escalate as the numbers of elements in the formation is increased. The objective of this research is to develop reliable, decentralised control algorithms to regulate the station-keeping, reconfiguration and collision avoidance capabilities of a formation of CubeSats. Having a large numbers of elements with agent-based autonomy in a formation requires complex, coordinated and collective response manoeuvres and therefore the formation is modelled as a swarm of spacecraft following biological rules of repulsion for short distances, attraction for long distances and position maintenance. To this end, the combination of linear quadratic regulators (LQR) and artificial potential fields (APF) to obtain the necessary control requirements is proposed. LQR will provide station-keeping and reconfiguration capabilities driving the CubeSats towards the desired positions, while optimizing fuel consumption and the APF will ensure collision free manoeuvres between the elements of the swarm during reconfiguration or threat avoidance. Additionally, this work also analyses the necessary Lyapunov stability conditions to guarantee the swarm convergence towards favourable regions by studying and exploiting the dynamics embedded in the mathematical models. Numerical tools developed in MATLAB are validated through simulations in STK. Previous work looked at the advantages of using LQR and APF applied to spacecraft in formation however these results are limited to formations with a reduced number of elements or to proximity and rendezvous manoeuvres. Moreover, these studies only consider formations following circular orbits which are not suitable for many types of missions. Therefore, spacecraft swarms following elliptical orbits around the Earth will be considered by using the Tschauner and Hempel (TH) model for relative dynamics.