Nonlinear Generalized Predictive Control for Spacecraft Formation Flying under Parametric Uncertainties

By
Divya Rao Ashok Kumar
PhD Student
Spacecraft Robotics and Control Laboratory
Carleton University

This research addresses the relative motion control problem for spacecraft formation flying missions in near-Earth orbit. The increasing use of small satellites (< 500 kg), with the potential benefits of lower cost and complexity, has a huge impact on the future of formation flying missions. Functions and payloads can now be distributed among multiple spacecraft placed in a predetermined coordinated formation to perform the larger mission objective. SFF has enabled many interesting applications with distributed space systems for stellar optical interferometers, synthetic aperture radar, and many more technological demonstration missions. However, the major challenges are associated with the design and development of a higher-accuracy autonomous relative motion control systems.

In order to develop computationally efficient guidance, navigation, and control systems, this thesis presents design and development of analytical nonlinear relative motion control for SFF, with precision tracking capabilities and minimal tracking error to avoid collisions and manage orbital perturbations with minimal ground support. The relative motion control law proposed to be developed is based on the Nonlinear Generalized Predictive Control (NGPC) theory. The NGPC law has never been studied and implemented for SFF or relative motion tracking control problem. The NGPC is augmented with two adaptation methods towards controller gains and unknown spacecraft mass and disturbances estimation of a spacecraft. Thus, an Adaptive Nonlinear Generalized Predictive Controller (ANGPC) is proposed for the onboard compatible, autonomous relative motion control of the participating satellites of SFF.

Divya Rao Ashok Kumar

PhD Student

Divya Rao Ashok Kumar is a PhD student in the Department of Mechanical and Aerospace Engineering at Carleton University. She is pursuing her doctoral studies under the supervision of Dr. Steve Ulrich at the Spacecraft Robotics and Control Laboratory, with the research focused on onboard implementable autonomous control systems for spacecraft formation flying m issions. S he received her M.Tech (Master of Technology) in Instrumentation Control Systems from Manipal University. She started her career in the space industry with a year-long internship during her master's degree at the Indian Space Research Organisation (ISRO), India on the attitude control design using control moment gyros. Furthermore, she served as Assistant Professor and Principal Design Engineer at the Crucible of Research and Innovation, PES Institute of Technology, India. She was the head of attitude determination and control systems for PISAT, which was launched in 2016. She gained extensive experience in the design and development of nanosatellites while being part of the development of PISAT-1,2,3 for about seven years. She also served as Principal Investigator for a funded project from the Naval Research Board, DRDO, India in the domain of low-cost MEMS-based sensors data fusion and estimation. Divya's work resulted in 4 journal articles and 15 conference papers at reputed international conferences. She was also awarded the "Young Engineers Award" by the Institution of Engineers India chapter in the aerospace discipline for the year 2017 and IAF Emerging Space Leaders (ESL) for the year 2019 at the International Astronautical Congress (IAC), Washington DC.