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Author: Mr. Ahmed Mahfouz
University of Luxembourg, Luxembourg

Ms. Nourhan Abdelrahman
Skolkovo Institute of Science and Technology, Russian Federation
Mr. Salman Ali Thepdawala
Skolkovo Institute of Science and Technology, Russian Federation
Dr. Dmitry Pritykin
Moscow Institute of Physics and Technology (MIPT), Russian Federation

MULTI-AGENT ATTITUDE TASK ALLOCATION AND CONTROL IN A SWARM OF MAGNETICALLY CONTROLLED CUBESATS

Abstract

The study has been conducted as a part of the Skoltech University project to deploy a swarm of 3U CubeSats in LEO. Mission objective is collective gamma-ray bursts detection, which requires the satellites' coordinated attitude control. Prior to this work, we designed the attitude determination and control subsystem with magnetic actuation. We consider four identical CubeSats deployed into the ISS orbit as a multi-agent system, which exhibits swarm behaviour by optimal attitude task allocation on receipt of a command from the mission control center.

Prior research shows that PD-based magnetic three-axis attitude control is very sensitive to the choice of the controller gains. Moreover, the magnetic controller gains are dependent on the required attitude. Gain tuning usually relies on periodicity of the required trajectories in simplified models and employs different techniques to optimize the degree of stability for the required motion. The first part of this study shows how to obtain the controller gains as functions defined on SO(3) (i.e. for all possible required attitudes with respect to the orbital frame). This is done in two steps. The first step is linearization of the spacecraft rotational dynamics in the vicinity of the required attitude regime and subsequent numerical optimization (carried out in terms of Floquet theory). The obtained gains are used as inputs for a genetic algorithm that optimizes the gains with respect to the complete nonlinear dynamics of the spacecraft based on a high-fidelity environmental model. The procedure allows obtaining optimal gains for all possible required attitudes, however, depending on the spacecraft inertia tensor and estimated environmental effects there can be zones of unfeasible attitudes, to which the controller cannot converge.

The second part of this study shows the collective attitude control scenario. The task of the swarm is to ensure maximum sky coverage around the principal direction uplinked to the spacecraft by the mission control center. This is measured by the minimum angular distance between the principal direction and any point in the sky that does not fall into the field of view of any of the spacecraft's instruments. Thus the swarm spacecraft act as four agents to solve a multi-objective optimization problem maximizing the coverage and negotiating to allocate their individual attitudes so as to maximize the resulting degrees of stability given the attitude feasibility constraint. The implemented optimization algorithm employs a negotiation-based approach and can be scaled to a greater number of spacecraft.