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DETUMBLING AND ATTITUDE CONTROL OF CUBESATS VIA MULTI-MODEL BASED EMBEDDED OPTIMIZATION

Abstract

This paper presents a novel Multi-Model (MM)-based embedded optimization algorithm to de-tumble and control CubeSats. The control problem is particularly challenging because of the high non-linearity of the attitude dynamics, magnitude uncertainty of initial angular velocity after the deployment, limited actuators authority and computation power available onboard. Today, mostly B-dot controllers are employed to address the control problem because tumbling satellite might have as high as 30 degrees/sec initial angular rate and B-dot controllers are able to minimize the rate error regardless of the attitude of the satellites. Similarly, the de-tumbling problem is formulated such that the angular rates can be minimized. Additionally, the algorithm also has the ability to explicitly handle the input constraints in the system. This feature has the potential to take into account the magnitude of the Earth's magnetic field and avoid saturation of reaction wheels, which must be closely monitored to avoid failure of the mission. Furthermore, the algorithm is real-time implementable because the control problem is formulated as convex optimization problem such that deterministic convergence properties and finite time solution are guaranteed. The proposed MM-based algorithm has three distinctive features when compared to other real-time implementable convex optimization based algorithms. First, the nonlinear spacecraft attitude dynamic model is completely covered with the proposed novel multi-model strategy and those models are taken into account over the prediction horizon within the Model Predictive Control (MPC) framework, which allows the controller to include and preview the future dynamic models behavior to represent the nonlinearity in advance. Second, as small satellites mostly use Earth's magnetic field and reaction wheels for de-tumbling and pointing purposes, the algorithm is not only able to formulate the limits of the actuators but also the variations of it. This feature is particularly useful when the magnetic field of Earth varies from the Equator to the poles, varying thus the torque capability of the magnetic actuators. Third, embedded optimization (MPC) reduces the horizon of the convex optimizations, which reduces the run time of the algorithm towards real-time implementation. The algorithm is tested and compared with currently used controllers on the High-Fidelity-Engineering-Model (HFEM) provided by industrial partner. Later, Monte-Carlo simulations are run to evaluate the performance for different initial conditions, and for magnitude uncertainties of the magnetic field. Simulation results show that the proposed algorithm

is promising because It can respect the input constraints, represents the nonlinear model while still being real-time implementable.