ASTRODYNAMICS SYMPOSIUM (C1)
Attitude Control, Sensors and Actuators (7)

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ATTITUDE COORDINATION FOR SWARMS OF PICO- AND NANO-SATELLITES

Abstract

This contribution addresses control method for attitude coordination of swarms of pico- and nano-satellites. We propose a distributed, low-cost yet effective control method that maintains stability and optimality of the swarm's attitude. Meanwhile, the control method incorporates delays caused by inter-satellite communications within the swarm. In this paper we assume a leader-following configuration for the swarm, namely a leader receives attitude commands from the ground station. The other spacecrafts establish their own relative attitude profile with respect to the leader. The inter-satellite communication is assumed to be based on IP networks.

Pico- and nano-satellites normally possess no propulsion systems while using magnets or small reaction wheels for attitude stabilization and manoeuvre. On the other hand, some do have GPS receivers for localization and simple sensors for attitude determination. For missions where attitude coordination is desired, e.g. for earth observation, the control problem is non-trivial because:

1. As there is no orbital control , establishment of the attitude profile as well as the attitude coordination must rely on GPS measurement;
2. Dynamics of small, low cost actuators for the attitude control need to be considered;
3. Inter-satellite communication suffer from delays and packet drops;
4. On-board resources are strictly limited for pico- and nano-satellites.

In this paper, we propose to use a receding horizon control for multi-satellite attitude coordination. This is a constrained optimal control problem where the actuator dynamics must be included. Considerations in terms of optimality such as energy consumption and control performance are naturally incorporated in the cost function design. The control algorithm is distributed in the sense that each satellite only needs attitude and position information of itself and its neighbouring spacecraft. We take the pico-satellite UWE (University of Würzburg's Experimental Satellite) as example. After exploring it's attitude and orbital determination systems, attitude control algorithm is implemented for each spacecraft and the entire swarm system is simulated with a circular low-earth orbit. Simulation studies show feasibility of the proposed attitude coordination method. We also investigate limitations of the proposed method with respect to communication rate and control bandwidth, as well as control performance influenced by the sensor systems.