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# L1 ADAPTIVE CONTROL OF SPACECRAFT FLYING IN VERY LOW EARTH ORBITS USING AERODYNAMIC TORQUES

**Abstract**

Aerodynamic torques normally become the dominating environmental torques to the attitude of satellites flying in very Low Earth orbits (below 400km). The number of Earth remote sensing satellites with sun-synchronized very Low Earth orbits has been increasing in the past years.

Theoretically, spacecraft with the ability to change their aerodynamic profile flying can use aerodynamic torques to control attitude. The challenges of designing the 3-axis aerodynamic attitude control are the uncertainties in the thermosphere (both wind and flow density), gas/surface interaction model and nonlinearity in the variable aerodynamic surface design. This paper presents the design of a novel L1 adaptive three-axis attitude control system, based on Cao-Hovakimyan L1 adaptive control algorithm, for spacecraft flying in very Low Earth orbits of using aerodynamic torques only.

The key benefits of using the L1 adaptive control method is that, parameter estimation and control can be decoupled. Therefore, the dynamics system can to have fast adaptation without sacrificing robustness. The fast adaption helps to compensate any rapidly varying uncertainties when the spacecraft travel through the polar region of the thermosphere. This is achieved by including a carefully designed low-pass filter into the controller and a state predictor into the feedback loop.

A case study is then presented of a planned University of Manchester CubeSat. The CubeSat is axisymmetric and has four independent steerable fins controlled by stepper motors to change the size and direction of the aerodynamic surface to the flow. The control system is simulated in a 6-DOF attitude propagator developed at the University of Manchester. The 6-DOF attitude propagator implements the aerodynamic effects including the Sentman gas-surface interaction model, horizontal wind model and rarefied gas particle density model to produce a high fidelity aerodynamic torque model in low Earth orbits. Simulation results show that in the closed-loop system, precise three-axis attitude control is achieved by using the L1 adaptive control architecture even without the knowledge of the bounds in the uncertainties and the fine dynamic model.