Trajectory Optimization for Magnetorquer-Based Underactuated Control of Small Satellites

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Abstract

Given the ever-decreasing size and ever-increasing scope of small satellites, novel methods of precise satellite attitude determination are now attractive and technically viable. Interactions between on-board magnetorquers and the Earth's magnetic field have been used for decades on satellites to work in concert with momentum wheel and control moment gyroscopes to precisely alter the attitude of Earth-orbiting bodies. With extremely small satellites, however, mechanical actuation devices become exorbitantly expensive to operate, both in mission cost and in power required.

This paper presents a magnetorquer-only control method that utilizes trajectory optimization techniques to circumvent the under-actuated nature of satellite magnetic field interactions. Given a known orbital trajectory and desired attitude states, the model utilizes simplified dynamics and a trajectory optimization package with iLQR and augmented Lagrangian techniques to arrive at a nominal input profile for the satellites magnetorquers. The computational complexity of this process is discussed in regards to the possible implementation on-board small satellite microprocessors.

The input profile is then wrapped in a time varying LQR control system and simulated in a complex environment to estimate the validity of the given input. The final simulation is carried out in an environment that includes an IGRF magnetic field, nrlmsise-00 atmosphere model, and solar radiation, whereas the input profile was developed in an environment that simply included a dipole estimation of the Earth's magnetic field. The profile calculated by the trajectory optimization package coupled with the time varying LQR control system was shown to adequately control the small satellite for appropriately small attitudes and rotation rates.

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2 Additional Information

This abstract is intended for the Advanced Technologies Session Topic. Please consider this abstract for the Pre-Conference Workshop and Poster Sessions. Thank you.