Attitude control and stability analysis of satellites in earth and moon orbit

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ABSTRACT

This project presents a way of controlling the attitude of a pico-satellite, actuated by means of magnetic torquers, using a technique called explicit model predictive control. This is an optimal control algorithm, designed to reduce the energy needed to control the satellite.

The work was done using the mathematical model of the Norwegian student satellite nCube. This is a pico-satellite based on the cubesat design, developed by Professor Bob Twiggs at Stanford University, limiting the size and weight of the satellite to a box measuring 10cm×10cm×10cm of less than 1 kg. Due to the small size, the space available to solar arrays are limited, this in turn reduces the available power, requiring high energy efficiency of the control system.

In order to reduce the power requirements, the satellite will use a combination of active and passive control. The passive control method consists of a gravity boom stabilizing the satellite along the positive or negative nadir vector. The active control performed by 3 magnetic torquers, along the three body axes, to provide full 3-axis control. The magnetic torquers are copper coils which produce a variable magnetic moment, which interacts with the Earth's magnetic field generating a torque vector.

In this work a new way of controlling the magnetic torquers based on the theory of optimal control, is proposed. This controller is analyzed for stability and performance, and compared to a nonlinear controller using feedback from euler parameters and angular velocities.

The control method proposed, is based on the theory of explicit model predictive control, eMPC. This theory originates in traditional model predictive control, but instead of computing the control actions online at every sample, the state-space is divided into regions and a optimal linear controller is computed off-line for each region. This reduces the online computational effort, while retaining the optimal qualities of the control law. This is especially useful in a spacecraft, where power and computational resources are scarce.

The mathematical model of the satellite was simulated, using a model of the magnetic and gravitational field, with both the nonlinear controller and the eMPC controller. The results showed that while the nonlinear controller managed to regulate the satellite along the nadir vector in 2-3 orbits, the eMPC controller achieved almost the same accuracy after about 5 orbits. The main advantage of the eMPC controller is that it is energy efficient, and reduces the energy consumption with up to 50% when compared to the nonlinear controller.

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