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PURE MAGNETIC CONTROL FOR ATTITUDE SLEW MANEUVERS

Abstract

The paper proposes a novel control technique for exact attitude acquisition by using magnetic actuators only. The proposed command law allows one to stir a rigid spacecraft towards an arbitrary final attitude by means of a sequence of two steps, possibly iterated in a back-stepping-like control structure.

The use of magnetic actuators provides several advantages over other attitude control effectors, provided only renewable electric energy is used (which means no fuel is required for actuation) and no mechanical component featuring moving parts is present. These characteristics make their operational lifetime virtually unlimited. On the other hand, electrical power required is high, magnetic sensors do not work while magnetorquers are active and, more importantly in the framework of the present study, magnetic control is inherently underactuated, provided that control torque components are available only in the plane normal to the direction of the Earth magnetic field.

Many studies were devoted in the past for tackling this issue, many of which exploit the time-varying nature of the geomagnetic field in the orbital frame. This study aims at providing a dynamic implementation of a kinematic planning technique for underactuated spacecraft derived for defining arbitrary slews by means of a sequence of admissible rotations, where an admissible rotation takes place around an axis perpendicular to the torqueless direction. The kinematic planning technique is based on the principle that a sequence of two admissible rotations allows for the acquisition of an arbitrary attitude. If more than two rotation are possible, the overall angular path can be reduced.

The dynamic implementation of the kinematic planning technique is based on driving the Euler axis on the plane of admissible rotation first, while performing a second step around the admissible Euler axis, thus completing the acquisition of the desired attitude. When the torqueless direction is prescribed in the orbit frame, magnetic control becomes the natural application of the resulting control law. Asymptotic stability of closed-loop dynamics is proven in an ideal scenario, without perturbation torques. Numerical simulation of several maneuvers for a relevant applicative example in the framework of small-scale spacecraft flying in Low-Earth-Orbits proves the robustness of the control law in the presence of external perturbations and uncertainties on spacecraft inertia tensor.