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ATTITUDE MANEUVER CONTROL OF A SPACECRAFT BY ONE VARIABLE-SPEED CONTROL MOMENT GYROS

Abstract

A variable-speed control moment gyro (VSCMG) comprises of a spinning wheel, the speed of which is allowed to vary continuously, mounted on one controlled gimbal. With only one VSCMG, the spacecraft becomes an underactuated nonholonomic system since only two control torques can be provided while the degrees-of-freedom of the spacecraft is three.

The problem of controlling an underactuated spacecraft has attracted increasing interests in recent years, which will benefit the development of low cost and weight small satellites and onboard satellites encountering actuator failures. Several papers have recently approached the attitude control issue of a spacecraft using one VSCMG, namely, spacecraft angular velocity stabilization and line-of-sight control. In these works, however, only the kinetic equations and/or partial kinematic equations are considered. Stabilization of the complete equations (kinetics and kinematics) is much more difcult but still desireable for objectives such as attitude maneuver.

The attitude control problem of a rigid spacecraft using only one VSCMG is investigated in this paper. First, nonlinear controllability theory is used to analyze the small-time local controllability (STLC) of the spacecraft-VSCMG system on every angular momentum level set and the corresponding conditions, guaranteeing STLC of the system at an equilibrium, are presented. Furthermore, these locally controllable equilibrium points can be asymptotically stabilized by both time-invariant piecewise continuous feedback laws and time-periodic continuous feedback laws. Specially, maneuvering control of a spacecraft by one VSCMG is considered under the restriction that the total angular momentum of the spacecraft-VSCMG system is zero, which not only ensures that the feasible equilibrium attitude can be any orientation but also renders STLC for these attitudes. The generalized dynamic inversion control method is utilized to derive a control law to reorient the spacecraft. Then, the inherent singularities of this control law, i.e., initial singularities and steady-state singularites, are carefully attended. Constant inputs are adopted to escape from the initial singularities while restrictions on control gains are imposed to avoid steady-state singularites. The eventual attitude maneuver control law is actually piecewise continuous. Numerical simulation shows that the reorientation maneuver of a spacecraft with one VSCMG is precisely achieved by the proposed control algorithm. This paper is the first one, to the best of the authors' knowledge, providing a maneuvering control strategy for a spacecraft with only one VSCMG.