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STABILIZATION OF UNDERACTUATED SPACECRAFT WITH TWO CMGS USING MODEL PREDICTIVE CONTROL

Abstract

The challenge of controlling of the attitude of an underactuated rigid spacecraft has always attracted significant interest in the recent years, and development in this area not only provide a degree of security against disastrous space mission failures, significantly increase reliability and simplify the design of attitude control systems. The stabilization of an underactuated spacecraft is complex, as such system of study does not have controllable linearization, is not feedback linearizable, and cannot be simply stabilized by continuous time-invariant feedback control laws, thus limiting control strategies. However, by using model predictive control (MPC), we can generate control laws that can be used to stabilize an underactuated spacecraft. The system of study is a small satellite equipped with two single-gimballed control moment gyroscopes (CMGs) that provide two control torques. This paper proposes the MPC-based strategy to stabilize the spacecraft's attitude with a pair of CMGs under the assumption of zero total system angular momentum. Unlike other methods, MPC allows for the direct incorporation of practically important constraints such as spacecraft pointing, angular velocity, gimbal angle and gimbal rate constraints. As a result, the singularity avoidance of the two CMGs can also be ensured by imposing a constraint on the gimbal angles of the two CMGs. This is one of the main attractive features of MPC. Unlike the majority of MPC applications to attitude control in the literature, which use an approximate discretized dynamics model, we utilize the exact continuous dynamics model in the MPC formulation. Our formulation includes the above-mentioned practical constraints. A rigorous proof of stability is presented. Numerical examples demonstrate the efficacy of the proposed approach.