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CONVEX OPTIMIZATION OF SPACECRAFT REST-TO-REST ATTITUDE REORIENTATION MANEUVERS WITH KEEP-OUT CONSTRAINTS

Abstract

This paper proposes a novel formulation for the convex optimization of rest-to-rest reorientation maneuvers of a spacecraft in presence of attitude constraints.

Attitude control is an essential aspect of spacecraft operations. Reorienting maneuvers are especially critical in many spacecraft missions, including Earth observation, remote sensing, and communications. Depending on the specific application, these maneuvers must be optimized to minimize the time or propellant required to change the spacecraft orientation from one attitude to another. Also, during the maneuver, sensing instruments, such as star trackers or cameras, must not point toward high-brightness celestial objects, like the Sun or the Moon, to avoid damaging such delicate devices.

The problem of steering a spacecraft toward a target attitude in the presence of keep-out zones has been addressed by several authors in the literature. Traditional solutions are based on geometric approaches, where the whole maneuver is split into a sequence of elementary rotations with intermediate attitudes respecting the keep-out constraints. Lyapunov control functions have been also used to guarantee asymptotic convergence to the desired attitude, with penalty and barrier-function terms that prevent the solution from falling inside the keep-out zones. More recently, computational guidance methods emerged as a way to optimize performance and ensure meeting all system requirements.

This paper follows the latter approach, proposing a convex optimization-based approach to the constrained reorientation problem. Leveraging a combination of lossless relaxations and successive linearization techniques, the original (non-convex) optimal control problem is recast into a convex (hence computationally efficient) form. As an original contribution, a novel problem formulation is devised, by relying on a semidefinite description of the convex hull of rotation matrices, so as to minimize the number of non-convex constraints to be handled.

This novel formulation is tested on a few relevant study cases. Numerical results are first presented to assess the performance of the proposed control approach in open-loop simulations for both minimum-time and minimum-fuel problems. A closed-loop computational steering algorithm is then devised via a model predictive control framework. The robustness of the proposed approach is then investigated by means of Monte Carlo analysis in the presence of external disturbances and system uncertainties.