Autonomous Collocation of Geostationary Satellites Using Control Barrier Functions

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As the Geostationary orbit region becomes increasingly crowded, two complementary technological shifts are reshaping stationkeeping strategies: the transition to all-electric propulsion (EP) platforms and the necessity for satellite collocation. This paper presents an autonomous orbit-control framework that addresses both challenges, progressing from a single-satellite closed-loop control law to a decentralized multi-satellite collocation scheme. A closed-loop stationkeeping control law based on nonsingular Milankovitch vectorial elements is introduced, with a rigorous proof of global asymptotic stability using Lyapunov's second method. To address EP operational constraints, a finite-set discrete burn-selection mechanism is developed and evaluated for single-satellite stationkeeping. The method predicts the continuous Milankovitch--Lyapunov reference trajectory, screens a 27-command on--off thrust set using low-cost approximate propagation, and accepts the selected burn only after accurate propagation checks consistency with the reference Lyapunov value. The framework is subsequently extended to a distributed system of collocated satellites using a decentralized control strategy. By integrating Control Lyapunov Functions (CLF) and Control Barrier Functions (CBF) via a Quadratic Program (QP), the proposed CLF-CBF-QP formulation modifies the nominal Lyapunov-based stationkeeping command when required by the pairwise safety constraints, while guaranteeing minimum separation distances within dense satellite clusters.

Closed-Loop Low-Thrust Transfers in the Sun-Mars Hill Problem

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Invariant manifolds provide low-energy access to planetary regions, and have been widely studied. However, closed-loop low-thrust transfer from libration-point orbits to planetary parking orbits has been less explored. This paper develops an orbital transfer methodology within the Hill restricted three-body problem, and applies it for travel from a Sun–Mars L1 Lyapunov orbit to a Mars-centered parking orbit with a prescribed altitude slightly offset from Deimos' orbit. The trajectory combines a ballistic coast along an unstable manifold with a capture spiral governed by a Lyapunov control law expressed in nonsingular Milankovitch elements. Particle swarm optimization selects the departure phase, coast duration, controller gains, and thrust deadband while minimizing propellant consumption. Variable, bounded-variable, and constant-magnitude electric-propulsion modes are compared under the Martian J2, solar radiation pressure, and solar third-body perturbations. All modes converge to continuous maximum-thrust operation, showing that thrust-direction steering, rather than throttling, governs performance.

Optimal Relative Terminal Angle Guidance for Accelerating Exo-atmospheric Pursuers

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An optimal linear–quadratic guidance law is developed for an accelerating exo-atmospheric pursuer, enabling the imposition of a predefined relative intercept angle between the pursuer's axial axis and the target's velocity vector. Planar motion in the absence of gravity is assumed, as well as known profiles for the acceleration of the pursuer and the speed of the target. It is assumed that for maneuvering the pursuer uses a pre-determined axial thrust, and rotation of the vehicle is achieved either by thrusters or thrust vector control. We derive the guidance law utilizing a single-loop integrated guidance-autopilot approach considering simultaneously the engagement kinematics and pursuer's dynamics. The engagement kinematics and pursuer's dynamics are re-linearized throughout the engagement about the instantaneous collision-triangle configuration and the nominal required relative intercept angle. The optimal control problem is then formulated using a quadratic cost function, penalizing miss distance and the deviation from the desired relative intercept angle; while minimizing the control effort, which is taken to be the squared pitch moment acting on the pursuer. A closed-form solution is obtained for the guidance command, expressed explicitly in terms of the reduced order states of zero-effort miss and zero-effort relative angle error between the pursuer's axial axis and the target's velocity vector. The time varying guidance gains on these reduced order states are studied and analyzed analytically for a few limit cases. The performance of the proposed guidance law is evaluated through two-dimensional nonlinear simulations for a variety of initial conditions in representative head-on, tail-chase, and head-pursuit engagements showing the viability of the proposed guidance approach.

Minimum-Time Two-Phase Trajectories with Fixed Acceleration Magnitude

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This paper investigates minimum-time trajectories within a prescribed class of two-phase maneuvers for a planar vehicle with constant acceleration magnitude. In the first phase, the angle between the acceleration and velocity vectors remains constant; in the second phase, the vehicle proceeds along a straight line to a stationary target. Unlike a circular turn, in which the speed is preserved, the proposed trajectory allows the vehicle to accelerate or decelerate during the turn. Closed-form state propagation and a scalar line-of-sight alignment condition reduce the trajectory selection problem to a one-dimensional search. Analytical stationarity is used for regular candidates, while singular controls, stopping limits, and relevant boundaries are treated explicitly. Numerical results show that the proposed trajectory reduces the travel time relative to a circular-turn trajectory and remains close to the unrestricted constant-acceleration time optimal solution over broad regions. For some vehicle platforms, maintaining a constant acceleration-to-velocity angle can offer a simpler control structure than continuously varying the relative acceleration direction. In addition, the straight terminal segment can be beneficial in mission profiles that favor a straight final approach to the target.