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COMPUTATIONALLY EFFICIENT LANDING GUIDANCE FOR REUSABLE ROCKET

Abstract

The successful reusability achievements of SpaceX's Falcon-9 1st stage and other commercial rockets have garnered significant global attention in recent years, solidifying reusable rocket technology as a focal point in the space industry. Precise landing guidance is critical for guiding rockets to return and land at predetermined points with minimal fuel consumption. The general approach involves onboard real-time trajectory planning and updating the rocket with the latest control commands.While convex optimization is commonly used for trajectory planning due to its rapid and deterministic convergence properties, resolving the landing guidance problem faces more complex challenges, particularly when considering aerodynamics and non-convex control constraints. In contrast to missions like Mars landing, where aerodynamics plays a minimal role and the vehicle has a distinct physical shape, addressing the nonlinearities and non-convex control constraints requires the implementation of significant and intricate "convexification" methods.In this paper, we introduce an alternative and efficient computational method called "Model Predictive Static Programming" (MPSP) to tackle the rocket landing guidance problem. The MPSP method offers a simpler and more practical approach, allowing for the direct application of nonlinear dynamics. By incorporating aerodynamics and propulsion as control forces, the optimization problem is formulated based on the rocket's angle of attack, thrust magnitude, and thrust direction angles as control inputs. Utilizing altitude as the independent variable in the dynamic equation, as the end time is undetermined, the MPSP method addresses the strict control constraints by replacing the analytical solution with the "Interior Point" method solution.Numerical simulations demonstrate the effectiveness of the proposed MPSP method and compare it with convex optimization-based methods. The results indicate that the proposed method achieves higher efficiency at the cost of slightly increased fuel consumption compared to convex-based methods, highlighting the need to balance efficiency gains with reduced landing risks.