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SUBOPTIMAL ROCKET LANDING GUIDANCE USING MODEL PREDICTIVE STATIC PROGRAMMING

Abstract

With the successful reuse of SpaceX's Falcon-9 1st stage and other commercial rockets reusability objectives, reusable rocket has gained significant attention worldwide in recent years and will continue acting as a focus of the space industry. One of the key technologies to achieve reuse is precise landing guidancewhich required to guide the rocket return to and land at the predetermined point with the minimum fuel consumption. The general strategy is to perform onboard real-time trajectory planning and feed the rocket with the most recently updated control commands. Due to its rapid and deterministic convergence properties most researchers adopt convex optimization as the planning method and plenty of studies focus on it. However, compared with Mars landing, owing to the fact that aerodynamics is not negligible and that the vehicle has a specific physical shape, the problem resolution faces more non-linearities and non-convex control constraints, so significant and complex "convexification" method have to be implemented. In this paper, an alternative and efficient computational method called "Model Predictive Static Programing" (MPSP) is adopted to solve the rocket landing guidance problem. Theoretically, the MPSP is a simpler method and is more convenient to implement, so the non-linear dynamics can directly be applied. In implementing the method, the aerodynamics and propulsion are also considered as the control force. As a result, the optimal problem is formulated with respect to the rocket's angle of attack, thrust magnitude and thrust direction angles as control inputs. Due to the end time is not determinedaltitude is used as the independent variable of the dynamic equation. At the same time, in order to handle the strict control constraints, the analytical solution in the original MPSP method is replaced using the "Internal Point" method solutionwhich is treated as a convex programming problem. The effectiveness of the proposed method and comparison with convex optimization based method is demonstrated by numerical computation. The result shows that the proposed method has a higher efficiency at the expense of a little more fuel consumption compared with convex based method, which has to be balanced with a landing risks reduction.