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ATMOSPHERIC POWERED DESCENT GUIDANCE FOR ROCKETS PRECISION LANDING ON EARTH

Abstract

During the past decades, precision landing on Earth for commercial reusable rockets has attracted significant attention and research, largely driven by the requirement of decreasing the cost of space transportation. One of the most important challenges is powered descent guidance (PDG) in the final landing burn, which needs real-time generation of a feasible and optimal trajectory to a prescribed location on Earth without violating fuel limits or any state constraints and hard control constraints, including minimum and maximum thrust magnitudes and a minimum glide-slope angle. Convex optimization approaches to PDG have emerged in recent years to hold the potential to become the next generation PDG for planet precision landing. To the authors' knowledge, current state-of-the-art public works on convex optimization applied to PDG usually treat aerodynamic forces as disturbances for Mars landing. Consequently, these methods can only solve the vacuum powered descent guidance (VPDG) problem in each guidance update cycle. However, Earth's atmosphere is 100 times as dense as that of Mars and thus aerodynamic forces become the indispensable concern rather than a disturbance which is so small that it can be ignored in the trajectory planning phase of VPDG. In this paper, a comprehensive treatment to the atmospheric powered descent guidance (APDG) problem of landing rockets subject to constraints on the propellant, the control inputs, and the states is presented. Specifically, two related but different versions of APDG problems are firstly formulated. Comparison and relationships among the solutions to these problems are analyzed. Furthermore, the convex-optimization-based approach is then extended to find the solutions to these problems. Once the problems are convexified using a simple yet efficient strategy, the existing interior point methods can be used to find the global solutions to the APDG problems. Numerical simulation is shown at last to demonstrate that the proposed APDG algorithm is successfully applied on a rockets recovery mission and shows improved performance compared with current VPDG algorithms.