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Author: Ms. Shayna Hume
University of Colorado Boulder, United States, shayna.hume@gmail.com

ON-BOARD GUIDANCE GAIN OPTIMIZATION FOR MARS EDL TRAJECTORY SHAPING

Abstract

A major goal of both the public and private space industry is to continue to push the boundaries on the Entry, Descent, and Landing (EDL) technologies that serve as the cornerstone for enabling new interplanetary missions. In particular, the area of on-board, autonomous descent guidance, used during landings like the recent Mars 2020, will continue to become more important for upcoming in-development missions such as Sample Return Lander (SRL) and Earth Return Orbiter (ERL). Those missions seek to increase the mass by 20-25% while decreasing the landing ellipse to less than or equal to 20 meters. The powered descent laws used for this phase of flight have a significant impact on such abilities. In recent literature, the A^2PDG law that encompasses E-guidance, an explicit method based on a linear thrust acceleration profile, and Apollo Lunar Descent Guidance, an implicit method based on a quadratic thrust acceleration profile, is validated as a guidance option with the strength of Apollo powered descent with the flexibility to tune not previously acquired. The two aforementioned sub-cases are found when the controller gain, k_r is tuned to a value of 6 or 12, respectively. Further research examined the inherent structure of these laws and the notable improvements of targeting reached through A^2PDG, and found a family of powered descent guidance laws with the ability to shape trajectories while preserving accuracy. Tracking control law performance has been shown to heavily depend on gains above threshold values, leading to a constant gain being optimized, historically. Unlike other trajectory shaping options, modifications to the k_r and k_v gains cause the trajectory to behave sporadically, no longer as an extrema-bounded envelope. This research examines the question of whether and to what extent optimal gain values change over the course of entry and descent trajectory phases, and as well how the trajectory shape envelope can be controlled. This paper gives an overview of several methods employed to optimize k-gains, an examination of the sensitivity of controller gains to external uncertainty, and a performance comparison for a gain-varying guidance algorithm to current A^2PDG state-of-the-art. The results from this effort will demonstrate the viability and significance of varying-gain optimization as it is applied to the precision of on-board Martian landing systems.