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OPTIMAL 3D LUNAR SOFT LANDING TRAJECTORY DESIGN AND PERFORMANCE EVALUATION OF EXPLICIT GUIDANCE LAWS

Abstract

For safe and precise lunar landing it is required to guide the landing module to a pre-specified target location within specified accuracy limits by bringing down the landing velocity to near zero level. To achieve this, the thrust vector needs to be steered in an optimum way to minimize the fuel consumption. In this paper, a set of lunar centered 3 dimensional cartesian coordinates are used as state variables to represent the landing module translational dynamics and to ensure the soft landing at specified target location. The precise landing trajectory design problem is formulated as an optimal control problem with constant thrust level and it is transformed into a two point boundary value problem(TPBVP) using the indirect approach based on Pontryagin's principle. The solution procedure of this TPBVP uses Differential Evolution, an evolutionary optimization technique. For real-time trajectory planning, few guidance laws are evaluated against the optimal control law obtained. The soft landing trajectory is propagated with control angles computed by the guidance algorithm to achieve the target conditions. The optimum fuel requirements with constant thrust to achieve different specified target conditions using the optimal control law are compared with fuel requirements obtained from simulated trajectory with guidance algorithm. Also the trajectory design is carried out with different constant thrust levels and the performance of the guidance laws is analyzed.