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Minimum-Fuel Optimal Trajectory for Reusable First-Stage Rocket Landing Using Particle Swarm Optimization

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Abstract : Reusable launch vehicles (RLVs) present a more environmentally-friendly approach to accessing space when compared to traditional launch vehicles that are discarded after each flight. This paper studies the recyclable nature of RLVs by presenting a solution method for determining minimum-fuel optimal trajectories using principles from optimal control theory and particle swarm optimization (PSO). This problem is formulated as a minimum-landing error powered descent problem where it is desired to move the RLV from a fixed set of initial conditions to three different sets of terminal conditions. However, unlike other powered descent studies, this paper considers the highly nonlinear effects caused by atmospheric drag, which are often ignored for studies on the Moon or on Mars. Rather than optimizing the controls directly, the throttle control is assumed to be bang-off-bang with a predetermined thrust direction for each phase of flight. The PSO method is verified in a one-dimensional comparison study, and it is then applied to the two-dimensional cases, the results of which are illustrated.

Keywords : minimum-fuel optimal trajectory, particle swarm optimization, reusable rocket, SpaceX
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