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A CLOSED FORM GUIDANCE SCHEME FOR LUNAR LANDING

Abstract

Most soft lunar landing solutions are studied as an open loop guidance problem; however, for practical implementation, closed loop analysis is recommended. Generally, lunar landing is split into four phases – rough braking phase, hazard detection phase, pitch-up phase, vertical descent phase. In rough braking phase, reaching desired altitude, velocity, body attitude for camera imaging are the terminal constraints. In hazard detection phase, body is held constant with appropriate attitude in order to image the landing site. In pitch-up phase, terminal constraints are met by orienting the Lander vertically for final descent. In vertical descent phase, the objective is to kill the residual velocity gain due to gravity while descending to land.

Using nominal initial conditions, Legendre Pseudo-spectral method is used to generate guidance scheme for rough braking phase. Real time dispersions in initial conditions viz. altitude, velocity, and thrust result in not satisfying terminal constraints for this phase. Neighboring optimal control (NOC) scheme is implemented for handling these dispersions [1]. By imposing perturbations in initial states of offline optimal trajectory, neighboring feasible trajectory is computed online by using NOC.

Once the hazard detection phase has detected a hazard and suggested an alternate feasible landing site, a closed form Lander guidance algorithm should guide for online update to reach the new landing site [2] during pitch-up phase. A second degree Legendre polynomial has been used for acceleration profiles. The three unknown coefficients are solved from acceleration, velocity, and distance equations. At time-to-go, the final target conditions are known. The only unknown variable is time-to-go which is calculated using first order polynomial for acceleration profile that in turn results in closed form solution for time-to-go.

Linear fixed final state Linear Quadratic control [3] is implemented for vertical descent phase. In this method, Riccati-type matrix differential equation is solved and the gain coefficients are stored offline and in real time the required control input vector at every sample time is computed using current state vector, final desired state and coefficients. The three schemes together provide a veritable closed-form guidance scheme for soft lunar landing.

References:

1. Barbee, “Automated Real-Time Targeting and Guidance for Lunar Descent and Precision Landing”, American Astronautical Society, AAS 10-035.

2. Jiang, “Trajectory Generation on Approach and Landing for RLVs Using Motion Primitives and Neighboring Optimal Control”, American Control Conference USA, 2007.

3. Parsley, “Near Optimal Feedback Guidance for Accurate Lunar Landing”, MS Thesis, University of Alabama, 2012.