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OPTIMIZATION OF THREE DIMENSIONAL TRAJECTORY USING LEGENDRE PSEUDO-SPECTRAL METHOD FOR LUNAR SOFT LANDING

Abstract

Considering three dimensional model for Moon, an optimal control problem for Chandrayaan-2 mission has been formulated. The cost function considered is minimum fuel spent for satisfying all mission constraints. A Legendre Pseudo-spectral method is used to discretize the trajectory optimization as a nonlinear programming problem. The method guarantees enforcing terminal mission constraints as part of the formulation.

The mission constraints for these problem are reaching the desired landing site with desired altitude, attitude, velocity, latitude and longitude of the moon from a specified perilune height. At touchdown, the lander orientation should be vertically up favoring landing leg of the Lander to touch the moon's surface as desired. The commanded acceleration should be in the limit of the main engine thruster saturation limit which enforces maximum and minimum thrust constraints.

In order to generate the precise trajectories to land at desire site, the co-ordinates of the landing site must be considered as terminal constraint and three dimensional approach is must since landing site is determined by latitude and longitude of the moon. Moon's angular velocity is considered because the landing site moves relative to an inertial frame.

Legendre PS method was applied to approximate the state as well as control variables and the state differential equations as algebraic equations using a PS differentiation matrix. After converting the optimization problem into NLP, Sequential Quadratic Programming is used to solve for optimal solutions.

Control variables in the formulation are thrust and its direction (right ascension and declination). Optimal solutions of the above problem are those control variables which dynamically satisfying all mission constraints. As part of the formulation thrust bounds as well as direction bounds are incorporated.

Because the initial longitude, latitude and transverse velocity at optimal perilune altitude affect the design of the optimal trajectory for lunar landing at desired landing site, the values are obtained from the optimization results. Based on these information, de-boost can be designed to reach these initial conditions at perilune.

References:

- S Mathavaraj, "A Predictive Guidance Scheme for Soft Landing of a Lunar Module", International Astronautical Congress, 2012.

- Bong-Gyun Park, Jong-Sun Ahn and Min-Jea tahk, 'Two-Dimensional Trajectory Optimization for Soft Lunar Landing Considering a Landing site', International Journal of Aeronautical Space Science, Vol 12 (3), pp 288-295, 2011.
- Fariba Fahroo and Michael Ross, 'Pseudospectral method knotting methods for solving optimal control problems', Journal of Guidance, Control, and Dynamics, Vol 27, pp 397-405, 2004.