ASTRODYNAMICS SYMPOSIUM (C1)
Mission Design, Operations and Optimisation (2) (5)

Author: Mr. Mathavaraj S
ISRO Satellite Centre (ISAC), India, mathan.hce@gmail.com

Mr. N.S. Gopinath
ISRO Satellite Centre (ISAC), India, nsgopi@isac.gov.in
Dr. Pandiyan Ramalingam
ISRO Satellite Centre (ISAC), India, pandiyan@isac.gov.in
Mr. Nitin Ghatpande
Indian Space Research Organization (ISRO), India, gpande@isac.gov.in

A PREDICTIVE GUIDANCE SCHEME FOR SOFT LANDING OF A LUNAR MODULE

Abstract

Soft lunar landing problem has been dealt with different types of dynamical formulations and several types of solutions have been presented in references elsewhere. Alexander addresses three different guidance algorithms for a lunar landing module. Bong et.al. address lunar module landing at a particular landing site. Fahroo et.al. have used Pseudo-Spectral (PS) method for multi-phase optimal control problems while solving an optimal control problem. The governing dynamics of the total system considering a point mass model is formulated in the 3-D flight-path coordinate system by Vinh. In this paper, a variation of design of 3-D soft landing trajectory for the terminal descent phase has been presented. The vehicle is considered with circular velocity at the initial state. Our primary objective is to reduce the vehicle velocity to zero when it touches the ground along with optimum fuel consumption and desired landing site.

1. Newton's method: The Hamiltonian equation, co-state equation is formulated using the governing dynamical equations. Iteratively the initial value of the co-state variables and control profile is found from the Hessian matrix of cost function, which satisfies the terminal constraints.
2. Legendre PS method: The entire trajectory is divided into Legendre-Gauss-Lobatto points. At these points, the state differential equation is satisfied so that the solution obtained is dynamically constrained.

Concluding remarks: The main contribution of this paper is to bring out the different methods suitable for the constraint involved and the optimal solution depends on the initial conditions and the constraints. The solution of Newton's and Legendre's method is comparable with the results obtained in the references. The effects of rotational motion of Moon, rate of change of fuel mass depletion on the final solution characteristics have been studied. It is found that the optimum initial longitude point gets modified by the trajectory in order to reach the desired landing site using Legendre PS method.

References:

- Alexander I. Kozynchenko, 'Enhancing the Manoeuvring Capabilities of a Lunar Landing Module using Predictive Guidance Algorithms', Acta Astronautica, 2010.
- 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, 2011.

- Fariba Fahroo and Michael Ross, 'Pseudospectral method knotting methods for solving optimal control problems', Journal of Guidance, Control, and Dynamics, 2004.
- Vinh N.X., Busemann A. and Culp R.D., 'Hypersonic and Planetary Entry Flight Mechanics', 1980.