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CHALLENGES IN SPACE DYNAMICS MODELING, SIMULATION & VALIDATION OF LUNAR LANDER MOTIONS

Abstract

Modeling and simulation of lunar lander dynamics play a central role in the validation process of lander control system. The evaluation of response of control system to flexibility and disturbances over large input range, calls for modeling of complex space-system dynamics and space environment. Modeling these parameters on par with actual space scenario along with control elements including actuators and sensors, using practical formalism, involves high level of mathematical computation and programming complexity. Lunar lander motions from the time of separation from the orbiter to landing on the lunar surface are very complex. In order to precisely arrive at the landing point, accurate modeling of all the systems involved is required. The control environment in all the mission phases like earth bound, lunar transfer, lunar orbit insertion, Orbiter-Lander Separation and Descent Landing are to be modeled and validated. Each phase of the mission has to be extensively tested in a realistic dynamic test environment with various sensors and actuators and depicting lunar environment and surface for thorough evaluation of Guidance Navigation and Control algorithms and touchdown specifications. A distributed computing system solution is proposed for the modeling requirements of translational and rotational dynamics of lander, 50N thrusters, 800N Throttle-able engine, accelerometer and lunar gravity. A hybrid model using truncated Legendre's polynomial and a finite number of mascon terms are used to compute the lunar gravity, which reduces the required computational time, while maintaining nearly the same level of accuracy. Validation of image, RF and Laser based sensors calls for preparation of detailed lunar terrain database which include hazard maps, terrain map and crater catalogue. Processing of these maps and catalogue for reconstruction of stimuli for the respective sensor depending upon the instantaneous position and attitude of the lander craft is highly data intensive. This paper presents realization of computing models for space system dynamics simulating rigid/flexible body mechanics that includes control and disturbance torque computation, attitude estimation, simulation and validation of the lunar lander dynamics, modeling of accelerometer, attitude and range sensors, lunar gravity model etc. Modification in the computing framework can be accomplished quite easily in this model and various types of configurations can be simulated. All the real-time constraints involved are analysed bringing together the computational, timing and interface requirements.