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AUTONOMOUS GUIDANCE AND CONTROL ALGORITHM FOR LUNAR LANDING WITH HAZARD AVOIDANCE

Abstract

Interest has returned for lunar robotic and human missions, where the autonomous lunar soft-landing is a challenging problem. Even assuming the approximation of a uniform lunar gravitational constant field, the problem of steering and controlling a space vehicle in the descending phase is nonlinear. In addition, the guidance and control solution needs to satisfy the initial conditions, which are only known with uncertainties, and the final conditions related to the selected landing site. Moreover, in the last descending phase, hazard avoidance maneuvers could be needed for a safe landing. The goal of the present study is to achieve a guidance and control algorithm to be implemented on-board of the lander. We address the problem by considering a non-throttleable engine, for which the on-off sequence has to be computed. For this purpose, the time-of-flight is divided into time-steps, where the duration of the constant thrust impulse is determined. The proposed algorithm is constituted of two parts: an estimation of the time-of-flight, based on the analytical solution of the time-optimal control approach and, the computation of the guidance law with the on-off control sequence based on the linear programming theory. The dynamics is discretized and re-formulated in order to have linear equations for landing. The result is a linear discrete model where the control variables are computed according to the initial and final conditions with linear constraints that take into account the available thrust level and the feasible direction of the thrust; that is, no downward thrust is allowed. The solution leads to a pulse-width-modulated control sequence, suitably modified to reach a soft touch-down. We devised a back-step procedure to compute the guidance law and the engine ignition sequence going from the above solution to the original nonlinear problem. It is demonstrated how the proposed algorithm is capable of dealing with re-targeting maneuvers during the landing phase. The presented numerical test cases show the algorithm performance. Experimental tests of the algorithm have been conducted using the simulation facility developed at the Automation, Robotics and Control for Aerospace lab (ARCAlab). The facility is a robotic system built over a simulated lunar surface (scale 1:1500), for testing hardware-in-the-loop, optical navigation and control algorithms for landing.