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GUIDANCE AND CONTROL FOR ACCURATE PLANETARY LANDING

Abstract

In the propulsive phase (after parachute release) of a planetary landing like Mars or Moon, horizontal motion is obtained by tilting the axial thrust and aligning either to the opposite of the velocity vector or to the requested acceleration vector. The first strategy -gravity turn -, employed in past planetary landing, automatically leads to vertical alignment of the velocity vector; vehicle braking together with appropriate touch-down artifacts achieves soft landing. Horizontal motion is constrained, but some freedom should be allowed just after parachute release for separating vehicle and backshell trajectories. The second strategy is assumed here, as it allows free horizontal motion and accurate landing. Trigonometric functions of tilt angles (pitch and yaw) times the vertical acceleration magnitude become the horizontal acceleration. Instead of designing a hierarchical guidance and control in which horizontal acceleration becomes the attitude reference, a unique control system is designed based on a fourth order dynamics from angular acceleration to position. Following the Embedded Model Control methodology, a unique discrete-time state equation is derived, encompassing horizontal, vertical and spin motions, to be used by guidance, navigation and control. Propulsion is split into a main assembly for CoM guidance and control (9 to 12 thrusters slighted canted from the axial direction) and a secondary assembly for spin damping. The latter could be used for the guided entry from the entry point to parachute deployment. Here guidance is presented with a brief mention to control strategies, as they have been treated elsewhere. Navigation concepts have ben presented elsewhere. Guidance has been designed to track a variable landing site, to reduce propellant consumption and to account for vehicle tilt limitations due to on board sensors like radar altimeter/velocimeter and camera. Guidance is recomputed during the descent until a minimum altitude is reached. Given the vertical guidance, the horizontal guidance is solved as a closed-form optimal control problem, with some iteration because of nonlinearities in the attitude-to-acceleration gain and of tilt bounds. Guidance is also in charge of real-time computing propellant ellipses, i.e. the elliptical ground regions that could be reached given the available propellant. The whole guidance, navigation and control algorithms have been tested on a fine descent simulator. Monte Carlo runs have been performed to assess performance versus requirements.