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MULTIPLE-SLIDING-SURFACE GUIDANCE AND CONTROL FOR TERMINAL ATMOSPHERIC REENTRY AND PRECISE LANDING

Abstract

The development of an effective guidance and attitude control architecture for terminal descent and landing represents a crucial issue for the design of reusable vehicles capable of performing a safe atmospheric planetary entry. In these scenarios, different environmental conditions may significantly deviate the vehicle from the nominal conditions. The sliding mode control represents a robust nonlinear technique able to generate an effective real-time closed-loop guidance law, even in the presence of challenging contingencies. Only the instantaneous state and the desired boundary conditions are needed for online computation of the descent path leading to safe landing in a finite time. This work proposes a multiple-sliding-surface guidance control law that is able to drive a lifting vehicle toward safe landing conditions, associated with a desired downrange, crossrange, runway heading, and final vertical velocity at touchdown, even starting from challenging initial conditions. The reentry trajectory is divided into sample intervals, and in each of them the sliding mode control generates the desired trajectory, by identifying the commanded angle of attack and bank angle. With this intent, the time derivatives of lift coefficient and bank angle are used as the control inputs, whereas the sliding surfaces are defined so that these two inputs are involved simultaneously in the lateral and the vertical guidance. These two control variables are constrained to suitable intervals for practical feasibility, so that only realistic trajectories can be generated by the guidance algorithm. The desired angle of attack and bank angle identify the commanded attitude. This is in turn pursued by the attitude control system, which employs a feedback nonlinear control law that enjoys global stability properties. The attitude control algorithm at hand generates the commanded torque components, which are actuated through the aerodynamic surfaces of the reentry vehicle. Effectiveness and accuracy of the guidance and control strategy at hand is tested numerically by means of a Monte Carlo campaign, in the presence of stochastic wind shear and large dispersions on the initial conditions. These numerical simulations unequivocally demonstrate that the multiple-sliding-surface guidance strategy at hand is able to drive the lifting vehicle to safe landing, even in the most challenging scenarios, while guaranteeing a modest vertical velocity at touchdown, the correct heading angle, and a limited distance from the desired landing point.