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SPACE LAUNCHER GUIDANCE BASED ON DISCRETE NONLINEAR MODEL PREDICTIVE CONTROL

Abstract

This work presents a guidance law for the exo-atmospheric trajectory of a space launcher. The proposed law is based on nonlinear model predictive control (NMPC) to track a referential trajectory. The model used to calculate the predictions is the Euler discretization of the continuous pseudo-five degrees of freedom equations of motion. The guidance around an elliptical Earth, with second zonal harmonic gravity approximation, is possible with this discrete NMPC. Furthermore, in this formulation, the controlled variables are the orbital parameters instead of the usual speed and radius vectors. This approach allows the problem to be formulated in a dual-mode NMPC. This scheme, based on the use of a static linear feedback controller when inside an invariant terminal region, ensures stability of the closed loop. The last important advantage of the proposed law is the division of the burn-coast-burn problem into two consecutive NMPC problems. The objective of the first problem is to inject the last stage of the launcher on the coast orbit. During the second burn, the NMPC guidance goal is to inject the payload on the desired orbit. This division diminishes the prediction horizon and the computational time of the optimisation.

The proposed guidance law is implemented on a three-stages-to-orbit launcher and tested in simulation. These tests demonstrate the viability of a discrete NMPC trajectory tracking for space launcher guidance. The simulations also allow investigating the effects of a criterion with time-varying weighting matrices and of the addition of input shaping constraints. Varying weighting matrices decrease input vector variations after large deviations from the nominal trajectory. Input shaping constraints mainly help by reducing computational time of the guidance law. They also slightly diminish input vector variations after large deviations. Therefore, on the basis of computation time and input variations, the formulation with input shaping constraints is the most useful NMPC guidance law. Future work in this direction could study if it can be a worthwhile alternative to the classical guidance laws of a space launcher.