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A NEW NEIGHBORING OPTIMAL GUIDANCE ALGORITHM FOR SPACE TRAJECTORIES

Abstract

Guidance approaches are usually classified as adaptive or perturbative techniques. Adaptive algorithms stem from the idea of re-defining the flight path at the beginning of each guidance interval, at which an updated trajectory (from the current to the desired final condition) is computed. Perturbative algorithms consider the perturbations from a specified nominal path, and define the feedback control corrections aimed at maintaining the vehicle in the proximity of the nominal trajectory. Neighboring Optimal Guidance (NOG) is a perturbative guidance concept that relies on the analytical second order optimality conditions. Only a limited number of works deal with this subject. This research proposes and describes a general-purpose neighboring optimal guidance scheme that is capable of driving a space vehicle along a specified nominal, optimal path. This goal is achieved by minimizing the second differential of the objective function (related to fuel consumption) along the perturbed trajectory. This minimization principle leads to deriving all the corrective maneuvers, in the context of a closed-loop guidance scheme. Several time-varying gain matrices, referring to the nominal trajectory, are defined, computed offline, and stored in the onboard computer. Original analytical developments, based on optimal control theory, constitute the theoretical foundation for three relevant features that characterize the guidance algorithm proposed in this work: (i) a new, efficient law for the real-time update of the time of flight (directly related to the time-to-go), (ii) an effective termination criterion, and (iii) a new formulation of the sweep method. These features allow overcoming the main difficulties related to the use of former NOG schemes, in particular the occurrence of singularities in the gain matrices and the lack of an efficient law for the iterative real-time update of the time of flight. As this work has the objective of illustrating the generality of the guidance algorithm, other than its effectiveness, two applications are considered: (a) minimum-time lunar ascent path, using the flat-planet approximation, and (b) minimum-time, low-thrust orbit transfer. Perturbations arising from the imperfect knowledge of the propulsive parameters and from errors in the initial conditions are assumed. Extensive robustness and Monte Carlo tests are performed, and prove the effectiveness, accuracy, and robustness of the neighboring optimal guidance proposed in this research.