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SAFE LANDING AREA DETERMINATION FOR A MOON LANDER BY REACHABILITY ANALYSIS

Abstract

In the last decade developments in space technology paved the way to more challenging missions like asteroid mining, space tourism and human expansion into to Solar System. These missions result in difficult tasks such as guidance schemes for re-entry, landing on celestial bodies and implementation of large angle maneuvers for spacecrafts. There is a need for a safety system to increase robustness and success of these missions. Reachability analysis meets this requirement by obtaining the set of all achievable states for a dynamic system starting from a set of initial conditions for the admissible control inputs and possible uncertainties in the parameters affecting the dynamics of the system.

This paper proposes an algorithm for the approximation of nonconvex reachable sets by using optimal control. The state space is discretized by equidistant points and for each grid point a distance function is defined resulting in an optimal control problem. The continuous optimal control problem is transcribed into a Nonlinear Programming Problem (NLP) by using Pseudo Spectral methods. Finally the NLP is solved using available tools resulting in approximated reachable sets with information about the states of the dynamical system at these grid points.

The algorithm is applied on a generic moon landing mission. An optical navigation system is able to detect an available landing area within the field of view of the onboard sensors. In order to ensure safe landing during the terminal landing phase, all achievable candidate landing points must be identified considering the current attitude, path constraints and control constraints. If the candidate landing area is not suitable due to terrain conditions, the control system must steer the spacecraft to another emergency landing point or implement another maneuvering scheme. The proposed method computes approximated reachable sets which provide information about this attainable safe landing region with time and propellant costs.

Additionally, interpolation of 2 sets with different initial conditions is introduced. Approximated reachable sets are obtained for different initial altitudes. Trajectories belonging to 2 distinct approximated sets are then interpolated to obtain an interpolated reachable set. The Hausdorff distance between the interpolated reachable set and the approximated reachable set is used to assess the quality of the result.