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MODEL PREDICTIVE CONTROL FOR REUSABLE LAUNCHER GUIDANCE IMPROVEMENT

Abstract

This paper aims to demonstrate the benefits and limitations of an on-board Guidance for reusable launch vehicles, as well as to tradeoff different Model Predictive Control (MPC)-based Guidance and Control (G&C) architectures, exploiting, in particular, recent advances on successive convexification algorithms for optimization problems. Leading space agencies and private companies are investing on the development of reusable space launchers to reduce the cost to access the space. Indeed, that cost is one of the major deterrents in space exploration and space utilization. Reusability is, therefore, the unanimous solution to lower costs, and get a reliable and fast space access. Among many technological enhancements, the guidance, navigation control plays a crucial role: precise pinpoint landing capabilities or mid-air recovery, in fact, are mandatory. Indeed, the capability for generating re-optimized guidance trajectories on-board in real-time based on current flight conditions promises to improve the system performance, allows for fault tolerance capabilities and reduces mission preparation costs. The paper focuses especially on the implementation of a successive convexification Model Predictive Control guidance algorithm which solves the 6 Degree-of-Freedom (DoF) Powered Descent Guidance problem (PDG) and the Ascent Guidance as well. The novelty in this paper is applying a model predictive technique to a complex dynamic environment. The robustness of the proposed approach is tested in several operative scenarios and the feasibility for a real-time implementation is studied. The main bottleneck of such online implementation is the (guaranteed) computation time to obtain a solution. To ensure that a solution to the optimization is obtained in real-time, the formulation of the problem, while initially being non-convex, is convexified. This is performed by implementing a successive convexification algorithm, which obtains a sub-optimal solution of the original problem in a fraction of the time required by a global optimizer, by solving a Second Order Cone Programming (SOCP) problem. This method allows coping with different kinds of dynamics nonlinearities, as well as cost functions and constraints. By presenting the approach and critically discussing the obtained results, the paper provides an overview of the different methodologies available in the literature and assesses the limits of those approaches when applied to highly nonlinear scenarios, with large dispersions of uncertain parameters, as it is the case of reusable launch vehicles.