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Efficient Ascent Trajectory Optimization Using Convex Models Based on the Newton-Kantorovich/Pseudospectral Approach

Xiaoming Cheng[a,*], Huifeng Li[a], Ran Zhang[a]

[a] *School of Astronautics, Beihang University, Beijing, People's Republic of China, 100191*

Abstract

This paper presents an iterative convex programming algorithm for the complex ascent trajectory planning problem. Due to the nonlinear dynamics and constraints, ascent trajectory planning problems are always difficult to be solved rapidly. With deterministic convergence, convex programming is becoming increasingly attractive to such problems. In this paper, first, path constraints (dynamic pressure, load and bending moment) are convexified by a change of variables and a reasonable approximation. Then, based on the Newton-Kantorovich/Pseudospectral (N-K/PS) approach, the dynamic equations are transcribed into linearized algebraic equality constraints with a given initial guess, and the ascent trajectory planning problem is formulated as a convex programming problem. At last, by iteratively solving the convex programming problem with readily available convex optimization methods and successively updating the initial guess with the Newton-Kantorovich iteration, the trajectory planning problem can be solved accurately and rapidly. The convergence of the proposed iterative convex programming method is proved theoretically, and numerical simulations show that the method proposed can potentially be implemented onboard a launch vehicle for real-time applications.

Keywords: Ascent trajectory optimization; Newton-Kantorovich/Pseudospectral approach; Path constraints; Convergence analysis

1. Introduction

Ascent flight refers to the movement that a vehicle flies from the launch site to a specified terminal state (the orbital insertion state or the payload delivery state) under the thrust of the engine [1]. Traditional launch vehicle has employed open-loop guidance in the atmospheric ascent phase, for the reason that there are no optimizations can satisfy the real-time requirement for the complex ascent trajectory planning problem with strong nonlinear dynamics and complex constraints. In this paper we present an iterative convex programming algorithm for the onboard ascent trajectory planning problem. The research on this topic is motivated by the demand for intelligentization of the future reusable access to space and the necessity for aerospace missions where ground support is unavailable or badly delayed. As a result, the solution algorithm can be

* Corresponding author.

E-mail address: chengxiaoming@buaa.edu.cn (X. Cheng), lihuifeng@buaa.edu.cn (H. Li), zhangran@buaa.edu.cn (R. Zhang)