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Author: Dr. Jiateng Long
Beijing Institute of Technology, School of Aerospace Engineering, China, jiatenglong123@126.com

Prof. Pingyuan Cui
School of Aerospace Engineering, Beijing Institute of Technology, China, cuipy@bit.edu.cn
Dr. Shengying Zhu
School of Aerospace Engineering, Beijing Institute of Technology, China, zhushengying@gmail.com
Dr. Wenbo Xiu
Beijing Institute of Technology (BIT), China, xiuwenbo1996@foxmail.com

SECOND-ORDER CONE PROGRAMMING BASED MARS POWERED DESCENT TRAJECTORY PLANNING WITH OBSTACLE AVOIDANCE CONSTRAINTS

Abstract

Motivated by the excellent real-time performance obtaining optimal solution with the deterministic convergence properties, in recent years, the aerospace community emerges great enthusiasm on both of the research and application field of convex optimization. By transforming the objective optimization problems into proper convex forms, convex optimization has revolutionized the optimal problem solving in different backgrounds such as atmospheric entry, powered descent, rocket ascending, etc. Although the convex optimization has shown great advantages on real-time solving and convergence, the objective problem can only be solved through convex optimization after it is convexified. A lot of optimization problems in aerospace engineering, however, contains non-convex performance index, dynamics and constraints, which severely limits the application of convex optimization. To facilitate the application, techniques such as sequential convex optimization, slack variables have been introduced to deal with highly nonlinear and constrained problems. However, convex optimization based fuel-optimal trajectory planning with obstacle avoidance constraints are remain unsolved. To enhance the onboard real-time replanning capability of the fuel-optimal powered descent trajectory when unexpected hazardous Mars terrain is detected, this paper aims at solving the non-convex obstacle avoidance constraint in Mars powered descent phase through second-order cone programming (SOCP). As illustrated in the literature that geometrically convex trajectory shows excellent performance on avoiding obstacles. However, the non-convex constraint form of geometric convex trajectory is the bottleneck of this problem. To this end, the concept of pseudo-velocity vector and pseudo-acceleration (PA) vector are firstly defined, which are utilized to transform the geometric convex constraint into the angle constraint between these two vectors. Then, by introducing slack variable, this angle constraint can be transformed into a form of SOCP. For the applicability of the proposed trajectory planning method, control constraint is also considered in the objective problem. To validate the performance of the proposed SOCP based Mars powered descent trajectory planning method on obstacle avoidance, MSL mission based numerical simulation is presented. Scenarios with different initial conditions are conducted. To simulate the potential hazardous obstacles, the predesigned landing site is set to be surrounded with random scattered peaks and cliffs. Numerical simulation result illustrates the effectiveness of proposed trajectory planning on obstacle avoidance. Compared with the classical fuel-optimal powered descent trajectory without the capability of obstacle avoidance, the fuel consumption of the proposed method is higher but acceptable. The numerical result also shows the advantage of the proposed method on fuel saving compared with the Apollo-derived powered descend method.