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Author: Dr. Xu Liu
Nanjing University of Aeronautics and Astronautics, China, 2997978276@qq.com

Prof. Shuang Li
Nanjing University of Aeronautics and Astronautics, China, lishuang@nuaa.edu.cn
Dr. Hongwei Yang
Nanjing University of Aeronautics and Astronautics, China, hongwei.yang@nuaa.edu.cn

# FLATNESS-BASED PSEUDOSPECTRAL METHOD FOR SIX-DEGREE-OF-FREEDOM ATMOSPHERIC ENTRY TRAJECTORY PLANNING

**Abstract**

Constricted by the severe load and heating, the nonlinear atmospheric entry trajectory planning has been considered as a challenging task. Generally, this problem is solved as an optimal control problem (OCP). As a universal approach to OCP, the pseudospectral method has been widely employed to generate the optimal entry trajectory in numerous studies. Whereas the coupled nonlinear dynamics make this method highly sensitive to the initial guesses, which aggravates the convergence to the optimal solution. Moreover, most of existing publications investigate the atmospheric entry trajectory planning problem with the low-frequency translational equations while ignore the high-frequency rotational ones, which potentially leads to the attitude control saturation in a realistic mission. To overcome aforesaid defects caused by the dynamics, the pseudospectral method combined with differential flatness theory is proposed to address the six-degree-of-freedom atmospheric entry trajectory planning problem. Firstly, the trajectory planning problem is reconstructed into a two-timescale optimization problem according to the distinct timescales of the dynamics. Secondly, the differential flatness approach is employed to reformulate the two-timescale system. In specific, the flatness property of the translational dynamics is extended by introducing a virtual control along the opposite direction of aerodynamic drag. And the high-frequency dynamics can be directly rewritten in the flat output space. In this way, all the states and controls can be represented by flat outputs and their derivatives, and hence the dynamics constraint is entirely eliminated. Thirdly, the two-timescale optimization problem in the flat output space is converted into the nonlinear programming (NLP) one via the Chebyshev pseudospectral method, of which a series of interpolation points and polynomials are utilized. Finally, the transformed NLP problem is solved by sequence quadratic program technique. Then the states and controls are generated by the expressions of the flatness outputs. Simulation results demonstrate that the proposed algorithm has better computing efficiency compared to the conventional ones without losing the merits of high precision.