SPACE EXPLORATION SYMPOSIUM (A3)
Mars Exploration – Part 3 (3C)

Author: Mr. Ren Gaofeng
Deep Space Exploration Research Center, Harbin Institute of Technology, China, stone_breaker@126.com

Mr. Shengying Zhu
School of Aerospace Engineering, Beijing Institute of Technology, China, zhushengying@gmail.com
Prof. Pingyuan Cui
School of Aerospace Engineering, Beijing Institute of Technology, China, cuipy@bit.edu.cn
Mr. Luan Enjie
Commission of Science Technology and Industry for National Defence, China, luanenjie@126.com

NONLINEAR PREDICTIVE CONTROLLER FOR HEADING ALIGNMENT IN MARS ENTRY GUIDANCE

Abstract

To deliver the lander for the further Mars exploration missions which require a pin-point landing, one popular baseline guidance framework uses the drag-tracking law, which was used in Apollo second entry guidance, down to a specified velocity and then switches to heading alignment logic for supersonic phase to reduce the heading error and thus reduce the crossrange error. Smart chute logic may also be used to achieve the specified downrange accurately. Several problems will be caused during the supersonic phase. Firstly, the focus on downrange and crossrange errors result in the parachute deployment altitude being a couple kilometers off nominal. Secondly, the control authority, namely the available lift, is limited and saturation is likely to occur, especially for the Mars lander with low lift-to-drag ratio when the vehicle flies at a not very high speed during supersonic phase. Tracking laws derived from feedback linearization of the heading error dynamics may perform poorly in the event of saturation. The present study is to develop a heading alignment controller to compensate the aforementioned problems, and thus improve the performance of the guidance framework. A new controller of the model predictive type is proposed. The bank angle command at each guidance cycle is the value that minimizes a prescribed cost function. The cost function takes into account errors in heading error and its rate, as well as the altitude loss. There is also additional logic that modifies the controller to take into account downrange targeting. To improve the performance of the controller, a filter aimed to compensate the uncertainty of mars atmospheric model and the vehicle's atmospheric parameters is designed, which can update the model which is used in the controller for predicting. Mars entry simulations for a capsule-type lander are carried out to assess the performance of presented controller. The results show that the presented controller could reduce the altitude guidance error, while still achieving accurate downrange and crossrange control.