Paper ID: 83481
oral
student

IAF ASTRODYNAMICS SYMPOSIUM (C1)
Guidance, Navigation and Control (2) (4)

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SPACECRAFT TRAJECTORY OPTIMISATION USING DIFFERENTIAL DYNAMIC PROGRAMMING

Abstract

Spacecraft trajectory optimisation represents a pillar for space mission development, as it allows the design of more cost-effective and high-performance operational concepts. In this context, the Mars exploration race, best epitomised by the Mars Sample Return mission, has highlighted the need to optimise not only the Keplerian phase trajectory, but also the proximity dynamics and the atmosphere environment one. In this paper, the Differential Dynamic Programming (DDP) optimisation algorithm is initially introduced as a proven second-order technique that relies on Bellman's Principle of Optimality and successive minimisation of quadratic approximations. Then, a collection of modified DDP methods is presented for the purpose of enhancing the classic DDP weaknesses. Subsequently, a Constrained DDP algorithm is implemented and applied to two case studies: a deep space rendez-vous and a martian soil landing manoeuvre. The choice is to test the algorithm in different environments, showing the influence of gravity and atmosphere on the convergence properties. For both problems, a parametric and a convergence analysis is carried out to identify the best input parameters and the resulting trajectory optimisation process is displayed. Satisfactory results on the position and velocity errors are achieved, proving the validity of the algorithm. Furthermore, its adaptability allows to satisfy diverse requirements depending on the type of manoeuvre performed, extending its application field. Lastly, some algorithm's features are pointed out, investigating the influence of regularisation parameters and time of flight on the convergence process.