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GLOBAL AND LOCAL OPTIMIZATION APPROACHES FOR LAUNCH VEHICLES ASCENT TRAJECTORY DESIGN

Abstract

The paper presents the study on the ascent trajectory optimization problem accomplished during a research activity on Multidisciplinary Design Optimization (MDO) for launch vehicles, undertaken by Universität Bremen and Politecnico di Milano within ESA's PRESTIGE PhD program. The trajectory optimization problem represents just a part of the overall MDO process when the control variables are treated on the same level of the design variables in a black-box optimization approach. However, given an efficient problem formulation and optimization strategy, it can be inserted as a nested optimization loop in the overall process of design optimization of the entire launch vehicle. In order to tackle Mixed Integer Non Linear Programming problems required by a MDO framework, several optimization strategies have been integrated: from global and stochastic to local and deterministic, from single to multiobjective. In particular, population based stochastic global algorithms of the family of particle swarm, genetic algorithm and ant colony optimization are described, together with a self developed hybrid algorithm that steers the parent population towards the strategy that behaved better in the previous iterations. The large and sparse NLP solver available in the research group of Universität Bremen, WORHP (We Optimize Really Huge Problem) is also integrated. WORHP is a combined SQP (Sequential Quadratic Programming) and primal-dual IP (Interior-Point) method, and can be applied both to local refinements of the solutions returned by the global algorithm and to the trajectory optimization subproblem itself, that for its very nature can be handled employing efficient local optimization strategies on their own. The description of the optimization strategies is followed by an overview of the ascent trajectory model, constituted of 3-DoF simulation, a phase structure including standard guidance laws for the generation of first guess pitch and yaw profiles, variable thrust, coast phases, and definition of path and final orbit constraints. Results are presented for several test cases (Ariane 5, VEGA and DNEPR launch vehicles, GTO, LEO and SSO orbits), with a comparative analysis of those obtained with global and local optimization approaches, and with different formulations of the problem. Finally, lessons learned on particular modeling aspects that allow improving the problem's smoothness for more efficient and robust local optimization are discussed.