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Author: Dr. Francesco Marchetti
German Aerospace Center (DLR), Bremen, Germany

Mr. Jose Luis Redondo Gutierrez
German Aerospace Center (DLR), Germany
Dr. David Seelbinder
German Aerospace Center (DLR), Bremen, Germany

GENETIC PROGRAMMING GUIDANCE FOR THE REENTRY TRAJECTORY OF THE REFEX VEHICLE

Abstract

In this work Genetic Programming (GP) is used to obtain an alternative guidance law for online trajectory adaptation for the Reusability Flight Experiment (ReFEx) reentry vehicle. The closed-loop performance of the new guidance law is compared against the performance of the baseline guidance law, which solves a parametrized optimal control problem through successive linearization. The German Aerospace Center (DLR) ReFEx aims at demonstrating the Guidance, Navigation, and Control capabilities for an aerodynamically controlled Reusable Launch Vehicle (RLV) stage. After successfully completing the Critical Design Review (CDR), the vehicle is currently being integrated and tested at the Institute of Space Systems. The guidance algorithms are responsible for planning and updating a feasible trajectory reaching the target state, correcting for the divergence w.r.t. the nominal trajectory due to the accumulated effects of control and navigation errors and model uncertainties. GP is an Evolutionary Algorithm (EA) capable of producing interpretable mathematical models that satisfies user defined objectives and constraints. Traditionally used for regression tasks, it can also be applied in a guidance setting, by finding the guidance law to steer the vehicle towards the successful satisfaction of the mission in the presence of disturbances or uncertainties. The use of a GP-based guidance algorithm can lead to greater robustness against uncertainties w.r.t traditional methods, by exploiting the nonlinearities of the used models. In fact, the application of GP does not require linearization, and can easily include nonlinear constraints. Moreover, to the best of the authors knowledge, GP was never tested on a flight-ready vehicle. Although GP will not be the algorithm used during the real mission, its application and testing on a realistic model in the loop simulator represents an innovative application to assess its feasibility for this type of vehicles and missions and to increase its TRL. GP is applied to design offline a guidance law to guide the ReFEx vehicle towards a desired final position in the presence of uncertainties in the atmospheric and aerodynamic models. The performance of the GP-based guidance law is compared against the current baseline, which defines the trajectory correction as an optimal control problem and reduces it to a nonlinear unconstrained optimization problem, which is then solved using a successive linearization strategy. The performance comparison between the two methods utilizes high fidelity 6-DoF Monte Carlo simulations. Capabilities, advantages and disadvantages of both methods are discussed and conclusions on the viability of the investigated GP approach are drawn.