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OPTIMISATION TOOL FOR LOW THRUST ORBIT RAISING BASED ON THE SEQUENTIAL GRADIENT RESTORATION ALGORITHM

Abstract

Low-thrust orbit transfers are becoming increasingly attractive thanks to the mass savings they offer and the maturity of electric propulsion technology. For this reason, there is an interest in developing fast, but still reliable trajectory optimisation methods that can be applied in the preliminary phase of the design of a mission.

The tool presented in this paper is based on the averaging of the equations of motion written in equinoctial elements over true longitude. The calculus of variations is used to identify the optimal control law. In particular, the indirect optimisation method used here is based on a sequential gradient-restoration algorithm. This alternates phases where the minimisation/maximisation of the objective function is sough and phases where fulfilment of the differential equations, equality and inequality path constraints and boundary conditions is imposed.

As any other indirect algorithm, the presented method requires an initial solution. However, and contrarily to some other indirect approaches, it does not need a good initial solution: a feasible trajectory is derived after several restoration iterations in case the initial solution does not respect any (or none) of the differential equations of motion, boundary conditions or path constraints.

The effect of perturbations such as zonal gravity harmonics (J_2 and higher) are included as well as shadowing effects, considering that typically during eclipses solar electric propulsion is switched off. For the eclipse detection algorithm, the Sun position can be obtained by analytical ephemerides or by interpolated ones, based on the evolution of the Sun position over the expected duration of the transfer. An analytical formulation for the extreme points of the eclipse is also proposed and its accuracy is assessed considering different launch epochs, considering different geometries between the satellite, the Earth and the Sun.

Further, third bodies gravity, air drag (for LEO initial orbits) and Solar Radiation Pressure are included in the list of selectable perturbations. Path constraints related to the maximum angular rate and maximum / minimum apogee and perigee heights are included in the current version of the tool.

Finally, the capabilities of the developed tool are illustrated with a collection of examples, including the transfer from LEO or GTO to MEO or GEO.