

06/4101 Global Trajectory Optimisation: Can We Prune the Solution Space when Considering Deep Space Manoeuvres?

Type of activity: Extended Study (6 months, 35 KEUR)

Background and Motivation

It has been recently shown [1,2] that the solution space of the multiple gravity assist optimisation problem (MGA) can be pruned considerably in polynomial time. The result coupled with a heuristic global optimisation technique allows to find optimal transfers in very short times. This brings a veil of optimism in the trajectory optimisation community traditionally convinced of the impossibility of fully automating the trajectory design problem. While this ultimate goal is still far to be achieved, we may argue that global optimisation, connected with a degree of domain knowledge, may be the correct tool to approach this problem. If we were able to prove that the problem of multiple gravity assist with deep space manoeuvres (MGADSM) may also be pruned as efficiently in polynomial time, the reward would be enormous. Not only, in fact, we could use such an algorithm to quickly find optimal trajectories for chemically propelled spacecrafts, but we would also have a way to select optimal fly-by sequences for an electrically propelled spacecraft by assuming that we can later spread the impulsive velocity change into a low-thrust arc.

The mathematical challenges introduced by going from the simple multiple gravity assist problem to the multiple gravity assist with deep space manoeuvre problem are enormous. The complexity of the problem increases considerably due to the necessarily added dimensions and to the larger number of local minima introduced. Besides, the generic trajectory leg is no longer described by only two parameters as in the MGA case, but by four (even five in some cases). It is therefore necessary to rethink the pruning process and how to automatize it in cases in which different kinds of trajectory phases are selected (as for example in the JPL code STOUR-LTGA where exponential sinusoids are used together with ballistic arcs [3])

Research and Study Objectives

The primary objective of the study should be to expand the results obtained on the multiple gravity assist problem [1,2] to the more complex case in which one or more trajectory legs include a deep space manoeuvre. In particular:

- Assessment of the possibility of pruning the solution space in case one or more deep space manoeuvres are included in the trajectory description;
- Development of new techniques to prune the space in these cases;
- Study of the integration between the various blocs building up a trajectory at the level of the developed space pruning strategy (e.g. one bloc could consist of a ballistic transfer Earth-Venus, the next one could be a Venus-Mars transfer with deep space maneuvers and so on; adaptation of the pruning strategy to all possible cases);

- Feasibility proof of such an integration for a number of agreed test cases (implementation of an automated tool that exploits the proposed pruning technique on a generic trajectory design problem constructed by a non expert user);
- Assessment of the automatisisation and optimisation of the trajectory option selection (fly-by sequence selection, choice between ballistic versus deep-space manoeuvre arcs)

A secondary objective of the study is to work on the global optimisation method applied to the pruned part of the solution space by using Particle Swarm Optimisation or one of its variants (including tuning of the relevant parameters as to make its performance adapted to a wide range of problems).

References

- [1] ESA contract AO4532/18138/04/NL/MV, Advanced Global Optimisation Tools for Mission Analysis and Design, Prime Contractor: University of Reading
- [2] Izzo, D., Becerra, V.M., Myatt D.R., Nasuto S.J., Bishop, J.M.: "Search Space Pruning and Global Optimisation of Multiple Gravity Assist Spacecraft Trajectories", accepted for publication in Journal of Global optimisation 2006
- [3] Petropoulos, A.E., Kowalkowski, T.D., Vavrina, M.A. Parcher, D.W., Finlayson, P.A., Whiffen, G.,J., Sims, J.A.: "1st ACT Global Trajectory Optimisation Competition: Results found at the Jet Propulsion Laboratory", to appear in Acta Astronautica
- [4] Kennedy, J., Eberhart, R., Particle swarm optimization, Proc. IEEE Int. Conf. on Neural Networks, pp. 1942-1948, (1995).