Initial Results of a New Method for Optimizing Low-thrust Gravity-assist Missions

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Missions like *Dawn*, *Rosetta*, or *Hayabusa*, aiming to further the exploration of our solar system are continuously becoming more ambitious and demanding. New technologies and smart mission design are required to meet these ambitions and allow missions to perform increasingly well. Since the early days of space exploration, the technique of employing gravity-assist maneuvers to accumulate "free energy" has granted us spectacular missions like *Voyager* and *Pioneer* and today these maneuvers are a typical element in the arsenal of mission enablers. More recently low-thrust propulsion has also become a major contributor to improve mission performance, due to the high specific impulse of the respective thrusters (typically several thousand seconds). Naturally, a combination of both has the potential to become an effective mission enabling technique.
Typically, mission optimization for low-thrust and gravity-assist is conducted only for the trajectory. The sequence of gravity-assist partners is submitted to the optimizer, see e.g. in [1]. It is however desirable to make the sequence finding part of the optimization process.
This paper presents a method designed with the intention of creating a tool that is able to quickly evaluate a large number of mission candidates, defined by gravity-assist maneuvers and the trajectories in between, where the gravity-assist partner is also one control variable. A heuristic search is conducted under application of a shape based trajectory model [2], which is applied to reduce the computation effort. The paper explains the structure of the control variables and their repercussions on the optimization and presents the initial results obtained with three major questions: Is the method overall usable? Can the search space be pruned with constraints based on the maximum obtainable Δv and the pool of possible gravity-assist partners? Can evolutionary algorithms be used to optimize such missions, when the gravity-assist partner is also a control variable?
It is shown that the basic methodology has been effective in finding optimal gravity-assist partners for single-gravity-assist missions (with Δv improvements of over 20% compared to non-gravity-assist missions) and shows potential for multi-gravity-assist missions as well. Derived from the optimization performance some conclusions about the search space topography are also drawn.

References

[1] McConaghy, T.T., Debban, T.J., Petropoulos, A.E., Longuski, J.M.; *Design and Optimization of low-thrust with gravity-assist*, Journal of Spacecraft and Rockets, Vol 40 (2003), No. 3, pp 380 – 387
[2] Wall, B., Conway, B.; *Shape-Based Approach to Low-Thrust Rendezvous Trajectory Design*; Journal of Guidance, Control and Dynamics, Vol. 32 (2009), No1., pp. 95-101