ASTRODYNAMICS SYMPOSIUM (C1)
Interactive Presentations (IP)

Author: Mr. Albert Wai Kit Lau
The Hong Kong University of Science and Technology, Hong Kong SAR, China

Dr. Chit Hong Yam
ispace, Inc, Japan
Mr. Ming Tony Shing
The Hong Kong University of Science and Technology, Hong Kong SAR, China

SEARCHING REACHABLE REGION OF LOW-THRUST TRAJECTORIES BY SUPERPOSITION AND GREEDY OPTIMIZATION

Abstract

During the design of space trajectories, it is crucial to know where the spaceship can go within the given fuel and time, and this is known as the reachability problem. In ballistic trajectories, the analytical solution of reachable region exists as function of the initial states. For low-thrust trajectories, the problem of computing the accurate reachable region in reasonable time remain unsolved. The low-thrust reachability problem is of interest to the planning of future missions as many low-thrust missions have been launched in the past two decades and more are expected in the near future.

One straightforward way to find the reachable region is to perform a grid search on all possible control combinations at any given time of the trajectory. However this approach is extremely computational demanding as $O(N^k)$ iterations are required, with N being the number of segments and k being number of possible thrust angles. A linearized algorithm that can quickly estimate the reachable region was developed recently in the literature, which has good accuracy for short duration orbit but fails to perform well in long duration orbit since it can only give symmetrical solutions, which may not be true in real orbits.

To obtain a better estimation for long duration orbits, we observe the patterns in results of grid search and found that the final position of a multiple-thrust trajectory can be estimated using the linear combination of single-thrust trajectories. The number of iteration needed is then reduced to $O(kN)$. To find the boundary of a reachable region from the $O(N^k)$ of possible choices, we adopted the optimization approach with greedy algorithm. For each direction, we construct a trajectory from combining optimal single-thrust trajectories. To reduce the error in long duration mission, the chosen constant number of trajectories are reiterated. From the above method, we can obtain the high accuracy reachable region of an extended space journey with hundreds of segments in seconds, as compared with hours/days using the traditional method.

Searching for the reachable region of continuous thrust problem is essential in the design of low-thrust missions. Using our novel algorithm, we can solve the low-thrust reachability problem with reasonable computational time and high accuracy. The potential applications of our algorithm includes optimizing low-thrust missions with multi-body flybys, selection of asteroid targets among millions of possible combinations, Jovian moons tour, and estimating the flyby B-plane reachable region for CubeSat missions with small thrusters.