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LOW-THRUST INTERPLANETARY TRANSFER DESIGN BY EVOLVING FREEFORM ARTIFICIAL NEURAL NETWORKS

Abstract

Optimizing the transfer trajectories for spacecraft has been one of the major challenges in interplanetary travel and deep space exploration mission. Intelligent control methods, such as artificial neural networks (ANNs), have great potentials to deal with this issue. The evolutionary computation methods, such as Genetic Algorithms (GA), Genetic Programming (GP) and Evolution Strategies (ES) etc., could be applied to evolve an ANN controller on its topological architecture, connection weights and activation functions, or even a group of learning rules. Previous works have successfully optimized different interplanetary trajectories for both nuclear electric propulsion (NEP) and solar sail spacecraft by evolutionary ANNs method. However, the controllers' structures were predefined and they limited the recurrences and feedbacks between neurons. An initial range of connection weights was also needed.

In this paper, we focus on optimizing interplanetary trajectories for NEP based spacecraft through evolving the freeform ANNs. To generate an optimal trajectory, we propose a pure topological recurrent networks controller accompanying with an evolutionary training method. We first divide the transfer period into a limited time steps. Within a simulation loop, the input neurons receive the states of spacecraft at current step and the output neurons give the control commands, namely the direction and level of thrust for next step. Then the current state's feedbacks can be obtained by the motion equations. At the end of loop, the controllers will be evolved following a common process of evolutionary computation.

We validated and assessed our method through two NEP based very-low-thrust interplanetary missions: Jupiter flyby and Mercury rendezvous. For the Jupiter flyby mission, the optimization objective is to minimize the used propellant mass, with the constraints of the maximum transfer time of 10000 days and the final distance to Jupiter less than 1E+6 km. For the Mercury rendezvous mission, the optimization objective is also to minimize the used propellant mass, with the constraints of the maximum transfer time of 2600 days, the final distance to Mercury less then 1E+6 km, and the final relative velocity less than 0.25 km/s. The launch date for the Jupiter flyby mission is optimized within a one year interval, while the launch date for the Mercury rendezvous mission is adopted from a reference mission. The results show that the low-thrust interplanetary transfer trajectories could be well optimized by the proposed method.