Paper ID: 99253
interactive
student

23rd IAA SYMPOSIUM ON SPACE DEBRIS (A6)
Interactive Presentations - 23rd IAA SYMPOSIUM ON SPACE DEBRIS (IP)

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ACTIVE DEBRIS REMOVAL MISSION PLANNING: AN INTEGRATED DEEP REINFORCEMENT LEARNING AND GENETIC ALGORITHM APPROACH

Abstract

With the development of aerospace technology, the scale of space debris has been rapidly increasing, which has become a significant factor affecting space safety. Current active debris removal technologies require close-range operations by spacecraft. The active debris removal strategy adopted in this paper is to drive a spacecraft to achieve rendezvous with the space debris and capture it, then transfer the debris to the graveyard orbit to disposal it . Repeating the above process until the mission is completed. In this mission, planning fuel-optimal orbital maneuvers for active debris removal remains a key research focus. This problem is NP-hard, which indicates that the optimal solution is difficult to obtain, while existing algorithms require multiple iterations with low solving efficiency and unstable solution accuracy. This paper proposes a mission planning algorithm combining Deep Reinforcement Learning (DRL) with Genetic Algorithm (GA), enabling rapid generation of fuel-optimal orbital maneuver sequences for a single spacecraft removing multiple space debris. In the algorithm design, a rapid transfer cost estimation method for spacecraft targeting individual debris is first developed. Then, a policy gradient reinforcement learning algorithm based on attention networks is employed to train an end-to-end neural network solver that rapidly predicts rendezvous sequences. Finally, genetic algorithms are used to iteratively refine the initial solutions generated by the neural network solver, incorporating crossover and mutation mechanisms for local fine-grained searches to obtain improved overall maneuver schemes. Simulation results demonstrate that initial solutions from the trained neural network solver significantly reduce search time and enhance planning efficiency. Comparisons with various existing mission planning algorithms show that the proposed method achieves better efficiency and higher accuracy, verifying the effectiveness and rapidity of the designed algorithm.