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基于协同进化粒子群和Pareto最优解的卫星编队队形重构方法

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Satellite Formation Reconfiguration Using Co-evolutionary Particle Swarm Optimization and Pareto Optimal Solution

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摘要 针对卫星编队自主队形重构问题,提出了基于协同进化粒子群优化(CPSO)和Pareto最优解的求解方法。首先,使用Legendre伪谱法(LPM)将队形重构问题离散化为非线性规划(NLP)问题;其次,根据卫星编队的特点及碰撞规避的需要,使用CPSO算法对重构问题采用既独立又集中的求解方式,避免了传统优化方法对梯度的求解;然后,使用一种深度-广度优先搜索(D-BFS)算法,能够高效地找到CPSO进化中所有Pareto最优解,提升了算法的效率。仿真结果表明,该方法快速有效,能够满足实时性的要求,使得卫星编队的自主运行成为可能。

关键词: 队形重构 碰撞规避 伪谱法 协同进化粒子群优化 Pareto最优解

Abstract: This paper proposes an optimal trajectory planning method for satellite formation reconfiguration using co-evolutionary particle swarm optimization (CPSO) and Pareto optimal solution. First, the Legendre pseudospectral method (LPM) is employed to transform the reconfiguration problem into a parameter optimization nonlinear programming (NLP) problem. Next, according to the features of satellite formation and the constraints of collision avoidance, a CPSO algorithm is used to solve the reconfiguration problem separately in a centralized way to avoid the computational complexity of calculating the gradient information with traditional optimization methods. Then, a depth-breadth first search (D-BFS) algorithm is used to search all the Pareto optimal solutions needed by the CPSO, with which the entire redundant search could be avoided. Simulations show that the method could solve the reconfiguration problem in real time, and guarantee collision avoidance during the entire reconfiguration process even when the number of collocation points or number of satellites increases.

Keywords: formation reconfiguration collision avoidance pseudospectral method co-evolutionary particle swarm optimization Pareto optimal solution

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