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Author: Prof. Liqiang Hou
Shanghai Jiaotong University, China, houliqiang@sjtu.edu.cn

Prof. Shufan Wu
Shanghai Jiaotong University, China, shufanwu@sjtu.edu.cn
Prof. Arun Misra
Mc Gill Institute for Aerospace Engineering (MIAE), Canada, arun.misra@mcgill.ca

OPTIMAL DEBRIS REMOVAL SEQUENCE WITH MULTIPLE SPACECRAFTS USING NON-POPULATION GRADIENT SEARCH

Abstract

A new approach for debris removal sequence optimization with multiple spacecrafts is developed and tested. The motion planning involves a complex Traveling Salesman Problem (TSP) combinatorial decision, in which both the continuous parameters and integer index of the debris are determined. Dimension of the mixed integer search space of the space mission increases exponentially if numbers of targets are involved. Recent studies of the TSP are designed mainly using population and branch and bound based methods. In these methods, evolutionary mechanisms are used to explore mixed integer search space and generate new individuals using heuristic of branch and bound. We note that the motion planning shares similarities to sequential parameter estimation given the fact that states of targets are varied and conditioned on preceding operations of the targets. We therefore introduce expected transfer trajectory, to measure not only deterministically but probabilities level of varied debris visits. Expected value and variance of trajectory conditioned on preceding visit, not the state of target itself, are propagated and analysed. With the metric, likelihood of expected trajectory can be given, and the mixed integer problem is reformulated into continuous parameter estimation with maximum likelihood; a non-population and gradient based method is then used to search the target sequence. Using this method, a sequential visit of near-earth debris considering J2 effects with a single spacecraft was implemented in a recent study, also set of the classic static TSP-LIB benchmarks were tested. We extend in this paper the method to a more complex and practical scenario of the sequential debris visits. In this task, multiple spacecrafts are launched and assigned to remove a set of debris. Each spacecraft is assigned automatically the target and minimizes ΔV of the whole mission. Error ellipsoids of the spacecrafts are propagated and priority level of each spacecraft is analysed. Likelihood of targets with respect to the error ellipsoid are analysed and accumulated with the ΔV cost. A gradient based search is used to determine the whole sequence. Potential extension of proposed method to the scenarios with discontinuous cost function, e.g. risk level of a target is also discussed.