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SPACE TRAJECTORY OPTIMIZATION OF COMPLEX COMBINATORIAL SEARCH USING CONTINUOUS PROBABILISTIC MAPPING

Abstract

The multi-flyby trajectory design is a variation of dynamic Travel Salesman Problem (TSP). The problem involves complex combinatorial decisions to choose which candidate to fly by. The dimension of search space increases exponentially with the number of candidate objects. Discrete design variables of the combinatorial search, e.g. integer identifiers of the objects partition the design space into sets of discontinuous subspaces, prevents designers from using advanced continuous computing methods. Conventional approaches to the dynamic TSP use breadth-first or deep-first mixed integer evolution to determine the optimal search tree. Methods include branch-and-bound searches, ant colony optimization, genetic algorithm, swarm intelligence, concurrent search, etc. No attempt has been made to introduce high efficiency continuous optimization in the complex combinatorial search. The TSP can be modeled as a weighted graph with nodes and transfer cost between nodes. Note that equations of motion provide not only deterministic characteristics of the trajectory, but the distribution information, e.g. variances along the trajectory. The TSP can then be structured using a Bayesian network $N := \{P, G\}$ over the weighted geometry G, where P is probabilistic measures associated to each node. An expected trajectory can be defined over $N := \{P, G\}$. The distance measure at each node are used as the band to adaptively filter and select the flyby object with priori probability. With the technique, the discrete ID variables are mapped into the continuous subspace consists of probability parameters. A Bayesian inference with likelihood analysis is then used to compute the accumulated posterior of the trajectory with respect to the targets. With the method, the combinatorial search is reformulated into a sequential continuous problem. Logarithms of accumulated posterior of trajectory are set to constraints to be maximized. Using penalties, a quasi-quadratic form objective function of the constrained problem is constructed. A gradient based optimizer such as SQP is used to search the optimal sequence. The proposed method works efficiently in GTOC-X optimal flyby sequence subproblem with 100,000 candidate stars. In GTOC-X, one needs to optimize not only the multi-flyby sequence but the settle tree satisfying specified distribution conditions at the final epoch. We attempt to extend the method for the optimal sequence to the whole settle tree optimization and hope to resolve the remaining issues in coming months. The multi-objective TSP with ToF vs. Fuel optimal problem are also considered.