Advanced Global Optimisation Tools for Mission Analysis and Design

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ABSTRACT

Over the last 10-15 years global optimisation approaches, have been used extensively in different fields, ranging from theoretical ecology to process engineering, from hydroinformatics to medicine. In mission analysis however, global optimisation methods have been mainly investigated in the academic circles, while optimal control theory and NLP solvers have been extensively developed for professional and commercial applications. The early efforts to find global solutions in mission design were directed towards low thrust Earth-Mars transfers, while more recently, the solution of more complex trajectory transfers such as Weak Stability Boundaries (WSB), and Multiple Gravity Assists (MGA) has been attempted. The majority of global optimisation methods that have been proposed however, centre on genetic algorithms, often in combination with SQP, effectively discarding a number of approaches, such as branch & bound, simulated annealing and ant colony algorithms, which have proved successful in other fields of applications. It would therefore be hugely beneficial if mission designers could rely on a limited number of global optimisation methods depending on the type of trajectory design, which has to be accomplished. To achieve this ambitious goal, initially, a thorough identification and modelling of the main types of orbital transfers has been performed. The orbital transfer typologies have been identified both on the basis of the propulsive system (impulsive or low thrust) and on the number of planetary bodies contributing to the dynamics of the system. The models identified previously are then characterised, within the search space and within the objective function, in order to identify some common features. The aim is to identify different transfer families within the same transfer typology as a function of the parameters of the problem: mass parameters of the planets in an MGA transfer, parameters of the low thrust propulsion system, etc. The attempt here is two fold: to assess if commonly encountered problems in mission analysis are solvable in polynomial time, thus allowing a simple desktop solution; and to determine if a solution is available, if the global optimality of this solution can be verified in polynomial time, thus guaranteeing the goodness and repeatability of the result. Once this categorisation has been performed a variety of heuristic, approximation and systematic methods for global optimisation are used on the different orbital transfer manoeuvres. This will then allow the assessment of their respective performances, both computational and solution wise. The final goal being the identification of the best global optimisation method available for a particular orbital transfer problem. The justification for this comes from the No Free Lunch Theorem of Optimization (NFLT) which states that averaged over all problems, all search algorithms perform equally. It is therefore crucial to understand how to couple a particular mission analysis problem to a well-defined global optimisation algorithm.