03/4101 Advanced Global Optimisation Tools for Mission Analysis and Design

Type of activity: Extended Study (6 months, 35 KEUR)

An important part of the mission design process consists of designing the trajectory. Traditionally this task has been accomplished using gradient methods, optimal control theory or mathematical tool specifically dedicated to each particular problem. All this approaches can be generally classified as local optimisation methods where the term optimisation is intended not just for finding the minimum or the maximum but more in general for finding a solution. Since the problem is generally highly non-linear and not necessary differentiable in all the solution space, a significant part of the work is to formulate appropriately the problem to make it amenable to a solution using local optimisation tools and to produce a reasonably good initial guess. In fact it is likely that, despite the global convergence properties of many software tools (like most of NLP solvers available at present), the analysts find a local minimum every time they seek for a solution, eventually finding the global optimum. This is quite a time consuming process that can lead even to a unsatisfactory result. Furthermore due to the relatively poor robustness of some approaches (like indirect methods) a good initial guess is required though often quite hard to find. In addition a global search on all the solution space could procure a large volume of information regarding the number of potential solutions, their robustness and characteristics, leading even to unexpected discoveries. Finally a complete and sophisticated formulation of the problem can generally include discontinuities or integer variables or non-differentiable functions impossible to handle with standard gradient methods.

The importance of having an effective and efficient global optimisation approach, well known, understood and studied in many other fields like chemistry, biology and electronic engineering, is emerging also in the space field with studies on procedure and optimisation methods to procure a solution or even just a first guess solution to complex problems as WSB (Weak Stability Boundaries) transfer design, the design of trajectories involving multiple swing-bys or a combination of swing-bys and low thrust propulsion.

The first successful attempts of using global techniques for trajectory design date back to the early 90’s and since then several authors have worked on the problem. However it is well known that the effectiveness of present global approaches strongly depends on the problem that has to be solved.

Thus it appears necessary an identification of most common problems in mission analysis followed by an analysis of the NP-complexity of each problem. This analysis would lead to the identification of the more appropriate approaches to mission design related problems.

In general global optimisation techniques can be classified in two main groups: deterministic (systematic) and stochastic (or heuristic) approaches. Among deterministic methods promising area of research are interval analysis based methods, branch and bound approaches, tunnelling techniques and quantum optimisation. Among stochastic methods evolution programming and clustering techniques appear to be the most promising.

It is however likely that already existing approaches are not suitable or cannot directly be applied without a proper implementation. Therefore a second part of the study should aim to procure an innovative approach specifically dedicated to solve the classes of problems commonly encountered in mission analysis.

In summary the study objectives are as follows:

- Identification of the most common classes of problems in mission analysis
- Analysis of the NP-complexity of each class
- Assessment of the most suitable global approach to solve the classes of problems commonly encountered in mission analysis.
- Development of an innovative approach specifically dedicated to mission analysis if necessary

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