Algorithm For Space Related Multi – Objective Optimization Problems

A.Mancini - Second Level Master Student at La Sapienza University of Rome, M. Di Giacinto – Professor of Space Propulsion at La Sapienza University of Rome, M. Federici - Second Level Master Student at La Sapienza University of Rome.

All the engineering activities are fundamentally multi-objective in nature and these objectives are often conflicting. Some real world problems are simply too complex to be directly managed and an exhaustive analysis leading to the implementation of an optimal solution can be unfeasible to perform without the support of automated numerical methods. Is then of great interest the development and the use of robust and efficient optimization algorithms. In the aerospace field there are plenty of possible applications especially for preliminary analyses of complex systems. This paper presents an optimization tool intended to solve multi – objective, non – linear optimization problems linked to the space activities. The optimization algorithm is based on the Simplex method and it is presented along with two examples of application.
Optimization algorithms based on evolutions of the Simplex method are characterized by a wide range of application, a good convergence speed and the possibility of an easy and fast implementation of new features which makes these algorithms flexible and efficient. On the other hand major drawbacks for practical engineering applications are the strong dependence on the solutions distribution in the solutions space and the impossibility of obtaining a Pareto front for multi – objective problems, since the scalarization of the problem is needed for such algorithms.

The proposed algorithm, called ALZDoSS (Algorithm for Large Zones Downhill Simplex Searches), mitigates the limitations linked to the local minima/maxima and provides the possibility to obtain an approximate Pareto front for multi – objective problems. These features are implemented on a Downhill Simplex based algorithm which is an evolution of the Nelder – Mead algorithm proposed by Rahman. The code was validated for space propulsion related problems and crosschecked via commercial optimization software. In this paper an interdisciplinary problem will be discussed and solved with the code. As a support of the analyses a Genetic Algorithm developed within the Department of Mechanical and Aerospace Engineering of La Sapienza will be used.

The application that will be presented in this paper is related to the optimization of the design of a solid rocket motor (SRM) with the objective of minimizing the motor mass while designing the best feasible strategy during the ascent to orbit which presents fixed injection parameters. This application is a typical problem of the first phase of the development of new motors for launch vehicles. The geometry of the propellant grain directly defines the thrust – time history and it is then a key parameter in the planning of SRMs architecture. Besides this the overall dimensions of the motor and the design of the nozzle strongly affect the mass and performance of the launcher. The design has to be chosen in order to satisfy stringent requirements while minimizing or maximizing different objectives such as the motor mass and the specific impulse.

Since a deep and comprehensive investigation of the impact of slight changes in the SRM configuration on all its performance parameters is not a feasible task without an automated tool, the implementation of optimization algorithms for these complex analyses is of indubitable interest.