ASTRODYNAMICS SYMPOSIUM (C1)
Mission Design, Operations and Optimization (2) (9)

Author: Dr. Mauro Pontani
Sapienza University of Rome, Italy, mauro.pontani@uniroma1.it

Prof. Bruce Conway
University of Illinois at Urbana-Champaign, United States, bconway@uiuc.edu

PARTICLE SWARM OPTIMIZATION APPLIED TO ORBITAL TRANSFERS

Abstract

This research applies the particle swarm optimization (PSO) algorithm to the problem of optimizing impulsive and finite-thrust orbital transfers. The PSO technique is a population-based stochastic method developed in recent years and successfully applied in several fields of research. It mimics the unpredictable motion of bird flocks while searching for food, with the intent of determining the optimal values of the unknown parameters of the problem under consideration. The initial population that composes the swarm is randomly generated at the first iteration of the process. Each particle is associated with a position vector and a velocity vector at a given iteration. The position vector includes the values of the unknown parameters of the problem, whereas the velocity vector determines the position update. Each particle represents a possible solution to the problem, and corresponds to a specific value of the objective function. At the end of the process, the best particle (i.e. the best solution with reference to the objective function) is expected to contain the globally optimal values of the unknown parameters. The central idea underlying the method is contained in the formula for velocity updating. This formula includes three terms with stochastic weights: the first term is the so-called inertial component and for each particle is proportional to its velocity in the preceding iteration; the second component is termed the cognitive component, directed toward the personal best position, i.e. the best position experienced by the particle; and finally the third term is the social component, directed toward the global best position, i.e. the best position yet located by any particle in the swarm. The particle swarm algorithm appears as very intuitive and is extremely easy to program. In addition, this kind of method is well suited for finding the globally optimal solution to an optimization problem, and requires only the definition of the search space for the unknown parameters. Two-impulse orbital transfers between two coplanar and non-coplanar orbits (with arbitrary orbital elements) are considered and the related optimal transfers are determined, after formulating the problem as a nonlinear programming problem. The problem of optimizing low-thrust orbital transfers is formulated as a minimum-time optimal control problem. The related necessary conditions for optimality are employed to express the control variable as a function of the costate variables. Despite its intuitiveness and simplicity, the particle swarm optimization method proves to be capable of effectively solving orbital transfer problems with great numerical accuracy