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PARTICLE SWARM/DIFFERENTIAL EVOLUTION OPTIMIZER FOR CONSTRAINED SLEW MANEUVERS

Abstract

Various heuristic optimization methods, differential evolution (DE) , particle swarm optimization (PSO), fireworks, bacteria foraging, etc., have proven to be useful in generating near-optimal solutions to the constrained, minimum-time slew maneuver problem. A continuing challenge with heuristic methods is the likely occurrence of stagnation, in which the optimization process appears to reach convergence. In the time-optimal slew problem, this behavior is complicated by the presence of many local minima. Whether the stagnation indicates a true local minimum or not, a procedure is needed to explore other parts of the search space while retaining the information thus far obtained.

This paper examines the time-optimal slew maneuver problem with path constraints, comparing two different approaches to resolving the stagnation issue, using PSO as the principal optimizer. An inverse-dynamics formulation is employed, in which the kinematics are modeled using B-splines and the control torques are then determined directly from Euler's equations of rigid-body motion. The unknowns in the optimization problem are the control point locations for the B-splines and the duration of the slew maneuver. When stagnation is detected, the PSO algorithm is temporarily suspended and a specified fraction of the swarm population is explored differently. In one approach, that subpopulation is simply reinitialized within the bounds of the search space using a uniform probability density distribution and the PSO algorithm continues. In the second approach, a small number of DE steps is used, redirecting the search within the subpopulation; then the PSO algorithm resumes. In each approach, the remainder of the population, along with information about the global-best particle and the individual-best particles, remains unchanged during the PSO suspension.

Although the combined PSO/DE approach requires somewhat longer computation time, it demonstrates superior performance statistically in two notable ways: the mean final value of the objective function is lower, and the mean value in the rate of convergence is higher (important when only an approximate solution is required). The choice of DE parameters CR (crossover probability) and F (differential weight) are also examined. It is found that reducing CR from the typical value of 0.9 and making the value of F random in the range [0.5, 1] significantly reduces the mean value and variance in the final value of the objective function. The implications of this with regard to treating the objective function as noisy are examined.