Various Boundary Conditions in Particle Swarm Optimization: A Comparative Study

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As a newly emerging powerful stochastic evolutionary algorithm, the Particle Swarm Optimization (PSO) technique is noted for its effectiveness and efficiency of searching for the global optimum of complex problems, and has been widely applied to a variety of engineering fields. Four types of boundary conditions, namely absorbing, reflecting, invisible, and damping, are currently used in order to enforce particles to stay inside the allowable solution space of interest during the optimization procedure. However, the performances of these boundary conditions vary considerably with the dimensionality of the problem and the location of the global optimum in the solution space. The damping boundary condition is distinguished for its robust and consistent performance in different applications, while the invisible boundary condition is more valuable when the fitness evaluation is computationally expensive.

In this paper, efforts are made to improve the performance of the invisible boundary condition by proposing two hybrid boundary conditions in which the favorable characteristics of the damping and reflecting boundary conditions are introduced into the existing invisible boundary condition. The velocity of the errant particle is modified according to the principle of damping or reflecting boundary condition, and the fitness evaluation is skipped by simply assigning it with a bad fitness value.

All six different boundary conditions are categorized into two groups: the first group includes the absorbing, reflecting, and damping boundary conditions, which evaluate the errant particles and relocate them at the boundary, and the second one includes the invisible and two hybrid boundary conditions, which leave the errant particles unevaluated. The simulation results of a set of Rastigrin and Rosenbrock functions show that the hybrid boundary conditions are highly competitive with, or superior to the invisible counterpart. When the global optimum is close to the center of the solution space, the hybrid boundary conditions are comparable to the damping boundary condition. Meanwhile, when the global optimum approaches the boundary of the solution space, the hybrid boundary conditions deteriorate more than the damping boundary condition does as the dimensionality increases. These boundary conditions are also tested by applying them to a real-world electromagnetic problem: the optimization of a 16-element array antenna.