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Particle Swarm with Radial Basis Function Surrogates for Expensive Black-Box Optimization

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Abstract

This paper develops the *OPUS (Optimization by Particle swarm Using Surrogates)* framework for expensive black-box optimization. In each iteration, OPUS considers multiple trial positions for each particle in the swarm and uses a surrogate model to identify the most promising trial position. Moreover, the current overall best position is refined by finding the global minimum of the surrogate in the neighborhood of that position. OPUS is implemented using an RBF surrogate and the resulting OPUS-RBF algorithm is applied to a 36-D groundwater bioremediation problem, a 14-D watershed calibration problem, and ten mostly 30-D test problems. OPUS-RBF is compared with a standard PSO, CMA-ES, two other surrogate-assisted PSO algorithms, and an RBF-assisted evolution strategy. The numerical results suggest that OPUS-RBF is promising for expensive black-box optimization.

Keywords: Particle swarm optimization, surrogate model, radial basis function, expensive function, groundwater bioremediation, watershed model calibration

- New surrogate-assisted particle swarm optimization method called OPUS is developed.
- Surrogate model is used to identify the most promising among multiple trial positions.
- OPUS finds minimum of surrogate in neighborhood of current overall best position.
- A radial basis function (RBF) surrogate is used to implement OPUS.
- OPUS-RBF outperforms alternatives on two environmental problems and ten test problems.

1. Introduction

Particle swarm optimization (PSO) is among the most popular black-box optimization methods. It is a numerical algorithm that simulates the behavior of a swarm of agents or particles, such as a flock of birds or a school of fish, as they collectively attempt to find some optimal state. PSO has been shown to be effective on a wide variety of practical optimization applications and this paper extends its usefulness to computationally expensive black-box optimization problems.