Particle Swarm Optimization Algorithms Inspired by Immunity-Clonal Mechanism and Their Applications to Spam Detection

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ABSTRACT

Compared to conventional PSO algorithm, particle swarm optimization algorithms inspired by immunity-clonal strategies are presented for their rapid convergence, easy implementation and ability of optimization. A novel PSO algorithm, clonal particle swarm optimization (CPSO) algorithm, is proposed based on clonal principle in natural immune system. By cloning the best individual of successive generations, the CPSO enlarges the area near the promising candidate solution and accelerates the evolution of the swarm, leading to better optimization capability and faster convergence performance than conventional PSO. As a variant, an advance-and-retreat strategy is incorporated to find the nearby minima in an enlarged solution space for greatly accelerating the CPSO before the next clonal operation. A black hole model is also established for easy implementation and good performance. Detailed descriptions of the CPSO algorithm and its variants are elaborated. Extensive experiments on 15 benchmark test functions demonstrate that the proposed CPSO algorithms speedup the evolution procedure and improve the global optimization performance. Finally, an application of the proposed PSO algorithms to spam detection is provided in comparison with the other three methods.

Keywords: Advance-and-Retreat, Black Hole, Clonal Particle Swarm Optimization, Immune Clonal Strategy, Particle Swarm Optimization, Spam Detection

INTRODUCTION

Particle swarm optimization (PSO) is a stochastic global optimization technique inspired by social behavior of bird flocking or fish schooling. In the conventional PSO suggested in Kennedy and Eberhart (1995) and Eberhart and Kennedy (1995), each particle in a population adjusts its position in the search space according to the best position it has found so far, and the position of the known best-fit particle in the entire population. Compared to other population-based algorithms, i.e., genetic
algorithms, the PSO does not need genetic operators such as crossover and mutation. Thus it has advantages of easy implementation, fewer parameters to be adjusted, strong capability to escape from local optima as well as rapid convergence. As a result, the PSO outperforms other population-based algorithms in many real-world application domains.

In recent years, the PSO has been increasingly used as an efficient technique for solving complicated and hard optimization problems, such as function optimization, evolving artificial neural networks, fuzzy system control, optimization in dynamic and noisy environments, blind source separation, machine learning, games, to name a few. Furthermore, the PSO has also been found to be robust and fast in solving non-linear, non-differentiable and multi-modal problems (Ge & Zhou, 2005). Therefore, it is very important and necessary to exploit some new mechanisms and principles to improve and promote the performance of the conventional PSO for a variety of problems in practice. In this article, the clonal mechanism found in natural immune system of creatures is introduced into the PSO, resulting in a novel clonal PSO (CPSO, for short). In addition, in order to improve the CPSO further, an advance-and-retreat (AR) strategy and the concept of random black hole (RBH) are then introduced into the CPSO, resulting in two variants of the CPSO, called CPSO with AR strategy (AR-CPSO, for short) and RBH model (RBH-PSO, for short).

This article is an extended version of our earlier short paper (Tan & Xiao, 2007), in which a basic idea of the CPSO is briefly presented. Here, we have extended it substantially and included two variants with some deep discussions, comprehensive experimental studies as well as our application to spam detection.

The remainder of this article is organized as follows. Section II describes the conventional PSO algorithm and its related modification versions. Section III presents the proposed CPSO by introducing the clonal mechanism in NIS into the conventional PSO and its implementation. Section IV improves the CPSO by introducing the AR strategy and the RBH model. Section V gives several experimental results to illustrate the effectiveness and efficiency of the proposed algorithms in comparison with the conventional PSO. An application of spam detection is also given in details in section VI. Finally, concluding remarks are drawn in Section VII.

**RELATED WORKS**

**Conventional PSO**

In the conventional PSO algorithm, each potential solution to an optimization problem is considered as a particle in the search space, and a population of particles called a swarm is used to explore the search space. All of particles in the swarm have their fitness values which are evaluated by a fitness function related to the optimization problem to be solved. Therefore, the PSO algorithm is originally initialized with a swarm of particles randomly placed on the search space. Then the randomly initialized swarm is getting to start to search for the optimal solution to the optimization problem by evolving iteratively. In each iteration, the position and the velocity of each particle are updated according to its own previous best position ($P_{i_{bd}}(t)$) and the current best position of all particles ($P_{g_{bd}}(t)$) in the swarm. The update formula for the velocity and position of each particle in the conventional PSO is written as

$$V_{id}(t+1) = wV_{id}(t) + c_{1}r_{1}(P_{i_{bd}(t)} - X_{id}(t)) + c_{2}r_{2}(P_{g_{bd}(t)} - X_{id}(t)),$$

(1)

$$X_{id}(t+1) = X_{id}(t) + V_{id}(t+1),$$

(2)

where $i=1, 2, \cdots, n$, $n$ is the number of particles in the swarm, $d=1, 2, \cdots, D$, and $D$ is the dimension of solution space.

In Eqs. (1) and (2), the learning factors $c1$ and $c2$ are nonnegative constants, $r1$ and $r2$ are random numbers uniformly distributed in the interval $[0,1]$, $V_{id} \in [-V_{\text{max}}, V_{\text{max}}]$, where $V_{\text{max}}$ is a designated maximum velocity which is a constant preset by users according to the objec-
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