An Improved PSO with Small-World Topology and Comprehensive Learning

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ABSTRACT

Particle swarm optimization (PSO) is a heuristic global optimization method based on swarm intelligence, and has been proven to be a powerful competitor to other intelligent algorithms. However, PSO may easily get trapped in a local optimum when solving complex multimodal problems. To improve PSO’s performance, in this paper the authors propose an improved PSO based on small world network and comprehensive learning strategy (SCPSO for short), in which the learning exemplar of each particle includes three parts: the global best particle (gbest), personal best particle (pbest), and the pbest of its neighborhood. Additionally, a random position around a particle is used to increase its probability to jump to a promising region. These strategies enable the diversity of the swarm to discourage premature convergence. By testing on five benchmark functions, SCPSO is proved to have better performance than PSO and its variants. SCPSO is then used to determine the optimal parameters involved in the Van-Genuchten model. The experimental results demonstrate the good performance of SCPSO compared with other methods.

Keywords: Comprehensive Learning, PSO, Small-World, Van-Genuchten Model

1. INTRODUCTION

Particle swarm optimization (PSO) algorithm is one of evolutionary algorithms (EAs). It was first proposed by Kenney and Eberhart based on the metaphor of social behavior of birds flocking and fish schooling (Kennedy & Eberhart, 1995). It is easy to implement PSO to solve optimization problems, but when solving multimodal problems, it may be easily trapped into a local minimum. Furthermore, most real-world optimization problems are multimodal problems.

In the population of a PSO, each particle searches for a better position according to its previous best success and the success of some other particles with one type of population topology which impacts the PSO’s performance (Kennedy, 2002). Therefore, researches were launched about population topology. For example, Clerc indicated that a constriction factor may help to ensure the convergence (1999). Mendes and Kennedy introduced a fully
informed PSO to update the particle velocity where all the neighbors of the particle are used to update the velocity (Mendes & Kennedy, 2004). Peram proposed the fitness-distance-ratio-based PSO (FDR-PSO) with near neighbor interactions (Peram, 2003). When updating each dimension of the velocity for a particle, the FDR-PSO algorithm selects a particle, which has a higher fitness value and is nearer to the particle being updated. Liang proposed an improved PSO called CLPSO, which uses a novel learning strategy (Liang, 2006). Liu and Zhao proposed an improved PSO based on dynamic neighborhood to improve particles’ ability to escape from local optima (Liu & Zhao, 2013).

Altogether, the above improved PSOs have achieved satisfactory results, but with regards to convergence and accuracy, there are shortages, therefore, there is still space to improve. Additionally, Jiang proposed a novel age-based particle swarm optimization with age-group topology, where the swarm is separated by different age-groups’ ages, and an age group based parameter setting method was devised (Jiang, 2013). Lim proposed a new variant of particle swarm optimization with increasing topology connectivity that increases the particle’s topology connectivity with time as well as performs the shuffling mechanism (Lim, 2013). A particle swarm optimizer was developed, which reduces the probability of premature convergence to local optima in the PSO by exploiting the particle’s local social learning based on the idea of cyclic-network topology (Maruta, 2013). Zhang proposed an improved PSO to solve bilevel multi-objective programming problem in which, the proposed algorithm directly simulates the decision process of bilevel programming by a global topology (Zhang, 2012). A modified hybrid Nelder-Mead simplex search and PSO was proposed for solving parameter estimation problems in which PSO adopted a special topology to improve the efficiency of hybrid algorithm to solve engineering optimization problems (Zhang, 2012; Liu, 2012). A variant of particle swarm optimizer based on the simulation of the human social communication behavior topology is presented in which each particle initially joins a default number of social circles and its learning exemplars include three parts to improve the algorithm’s performance (Liu, 2012). Ghosh proposed a novel optimization technique hybridizing the concepts of genetic algorithm and Lbest particle swarm optimization in which a new topology, namely ‘dynamically varying sub-swarm’, was incorporated in the search process and some selected crossover and mutation techniques were used for generation updating (Ghosh, 2012).

Small-world network is a type of mathematical graph in which most nodes are not neighbors to each other, but most nodes can be reached from any other node with a small number of hops or steps. In the idea (Kennedy, 1999), the author manipulated the neighborhood topologies of particle swarm optimization and several social network structures were tested on randomized “small-world” with a specified number of links. As a result, the author concluded that sociometric structure and the small-world manipulation will produce a significant effect on the performance. It shows that a PSO with small-world topology can effectively improve its performance, so in this paper, based on thought of the previous work (Liu, 2012), we propose an improved PSO with small world topology and comprehensive learning to improve the proposed PSO’s performance.

In recent years, how to effectively solve some problems in science and engineering fields based on intelligence algorithm has become a hot issue in PSO domain. A typical application in agriculture engineering fields is the soil water characteristic curve that is used to describe the relation curve between the soil water content and matric potential. It reflects the functional relationship between soil water energy and soil water content, and the reliability of the utilized model directly affects the prediction results of the soil water movement model (Van, 1980).

Van-Genuchten model usually is used to describe the change process of soil moisture because its model character is similar to fitting curve of measured data and the meaning of its parameters is clear. Therefore, many scholars proposed methods to determine the
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