Chapter 38
Dynamic Particle Swarm Optimization with Any Irregular Initial Small-World Topology

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ABSTRACT

It is realized that the topological structure of the particle swarm optimization (PSO) algorithm has a great influence on its optimization ability. This paper presents a new dynamic small-world neighborhood PSO (D-SWPSO) algorithm whose neighbourhood structure can be constructed with any irregular initial networks. The choice of the learning exemplar is not only based upon the big clustering coefficient and the average shortest distance for a regular network, but also based upon the eigenvalues of Laplacian matrix for irregular networks. Therefore, the D-SWPSO is a PSO algorithm based on small-world topological neighbourhood with universal significance. The proposed algorithm is tested by some typical benchmark test functions, and the results confirm that there is a significant improvement over the basic PSO algorithm. Finally, the algorithm is applied to a real-world optimization problem, the economic dispatch on the IEEE30 system with wind farms. The results demonstrate that the proposed D-SWPSO is a practically feasible and effective algorithm.

1. INTRODUCTION

Particle swarm optimization algorithm (PSO) is a stochastic global optimization algorithm which came of the research on bird flock preying behavior by sharing information and competing between individuals in the population (Kennedy & Eberhart, 1995). Using particles to represent potential solutions within the search space, PSO is a good candidate for dealing with collaborative optimization problem because of its simplicity and fast convergence to the optimum (Barrera & Coello, 2009). Although it is possible to solve the problems that the function to be optimized has multiple global optima or one global
optimum with many local optima in the search space, when solving complicated large-scale nonlinear programming or multimodal problems, it may be easily trapped in a local minimum (Liang, 2006; Passaro, 2008; Liu, 2009).

The topological structure plays a key role in information flowing and transferring within a particle swarm. By use of the hybrid algorithm on simulated annealing and heuristic search to randomly generate 1343 kinds of topologies in particle swarm network, and after testing for different ones, Kennedy & Mendes (2006) revealed that the topology structure of the particles’ neighborhood has considerable influence on optimization performance of the PSO algorithm, and the best neighborhood topology of the particle is not fixed. Subsequently, they confirmed five kinds of basic topology structure were All, Ring, Square, Four clusters and Pyramid type. As Kennedy & Mendes (2002) proved that the higher the connectivity of particle swarm network topology is, the more unfavorable its global optimization ability would be, Mendes et al. (2004) further proposed a local neighborhood topology structure. Although its convergence speed is slow, it is doubtlessly uneasy to fall into local bests and avoided the premature phenomenon. Afterwards, researches concerning population topology were focused. For example, Haruna and Yoshifumi (2009) proposed a network-structured PSO (NS-PSO) with various neighborhood topologies; Lu and Chen (2014) introduced a fuzzy logic parameter tuning system to adjust the constraints in PSO. More results concerning connected topology had better abilities to improve the performance of PSO algorithms (Marco, 2009; Ni, 2013; Chen, 2012).

Recently, studies based on small-world model are getting more and more attention. Cui et al. (2009) proposed a nearest neighbor interaction PSO based on small-world model. Gong & Zhang (2013) presented a small-world particle swarm optimization with topology adaptation. Liu & Niu (2014) examined an improved PSO with small-world topology and comprehensive learning strategy in which the learning exemplar of each particle includes the global best particle, personal best particle, and the best particle of its neighborhood.

However, previous studies on the local neighborhood topology structure did not give the quantitative analysis of correlation and coordination between individual particle and other particles. Besides, they did not construct the neighborhood structure based on any irregular initial networks. How to get a way to design the topological structure according to the concept of complex network or method of graph theory and explore the potential of PSO for multimodal optimization is a key problem we are going to tackle.

Small-world network (Watts & Strogatz, 1988) is a kind of network which changes the reconnection way in regular network on probability $p\ (0<p<1)$. It has the high clustering feature of the regular network ($p=0$) and shorter average path characteristic in random network ($p=1$). Due to that the WS small-world network proposed by Watts and Strogatz (1988) is prone to generate the isolated node in generating the network, Newman and Watts (1999) further improved it using the random bordering method to replace the random reconnection in WS model and proposed the NW small-world network.

Combining the NW small-world network with the principles of social psychology in PSO, as of the way of information dissemination, a new NW dynamic small-world PSO (D-SWPSO) is constructed in this paper, such that their neighborhood can be formed based on arbitrary irregular initial networks. The strategy of the learning exemplar choice of the particle is not only based upon the degree and degree distribution, average shortest path, clustering coefficient for a regular network, but also based upon the eigenvalues of Laplacian matrix for irregular networks. Therefore, the method of the small-world