An Improved PSO with Small-World Topology and Comprehensive Learning

Yanmin Liu, School of Mathematics and Computer Science, Zunyi Normal College, Zunyi, China

Ben Niu, School of Economics and Management, Tongji University, Shanghai, China

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

DOI: 10.4018/ijsir.2014040102
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 im-
proved 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 short-
age, 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 dif-
f erent 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 topo-
logy 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 par-
ticle’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 estima-
tion 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 vari-
ant 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 optimi-
ization technique hybridizing the concepts of
genetic algorithm and Lbest particle swarm
optimization in which a new topology, namely
dynamically varying sub-swarm, was incor-
porated 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 math-
ematical 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 speci-
fied number of links. As a result, the author
concluded that sociometric structure and the
small-world manipulation will produce a signifi-
cant 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 to-
pology 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 fit-
ting curve of measured data and the meaning
of its parameters is clear. Therefore, many
scholars proposed methods to determine the
Adaptive Neuro-Fuzzy Control Approach Based on Particle Swarm Optimization
Gomaa Zaki El-Far (2012). Innovations and Developments of Swarm Intelligence Applications (pp. 81-98).
www.igi-global.com/chapter/adaptive-neuro-fuzzy-control-approach/65807?camid=4v1a