An Improved Particle Swarm Optimization Algorithm based on Quotient Space Theory

Yuhong Chi, Tsinghua University & Unit 65053, PLA, China
Fuchun Sun, Tsinghua University, China
Weijun Wang, Unit 65053, PLA, China
Chunming Yu, Unit 65053, PLA, China

ABSTRACT

To control the swarm to fly inside the limited search space and deal with the problems of slow search speed and premature convergence in particle swarm optimization algorithm, the authors applied the theory of topology, and proposed a novel quotient space-based boundary condition named QsaBC by using the properties of quotient space and homeomorphism in this paper. In QsaBC, Search space-zoomed factor and Attractor factor are introduced according to analyzing the dynamic behavior and stability of particles, which not only reduce the subjective interference and enforce the capability of global search, but also enhance the power of local search and escaping from an inferior local optimum. Four CEC’2008 benchmark functions were selected to evaluate the performance of QsaBC. Comparative experiments show that QsaBC can get the satisfactory optimization solution with fast convergence speed. Furthermore, QsaBC is more effective to do with errant particles, easier to calculate and has better robustness than other experienced methods.

Keywords: Boundary Condition, Particle Swarm Optimization, Quotient Space, Search Space, Topology

INTRODUCTION

Particle swarm optimization (PSO) (Bratton & Kennedy, 2007) proposed by Kennedy and Eberhart (1995) is a powerful evolutionary computation technique, inspired by social behaviors of organisms of fish schooling and bird flocking. In almost two decades, the fast developments and performance improvements of PSO in different ways have been achieved, and Cognitive Informatics (CI) is a transdisciplinary enquiry of computer science, cognitive science, and intelligence science (Wang, Widrow et al., 2011).

DOI: 10.4018/jssci.2012040101
In PSO, particles are free to fly inside the defined D-dimensional space dictated by optimization problems, where it is assumed that global optimum is inside, so that particles moving outside search space can’t find global optimum. So that it is necessary to control particles moving inside the limited search space by some way which is called boundary condition.

Though in the canonical PSO method is confessedly that nothing can prevent particles from going outside search space at anytime, and it is usually thought that it is just the behavior of few particles (Kennedy, 2005, 2008), Helwig and Wanka (2008) derived some surprised conclusions and proved that all particles leave search space in the first iteration with overwhelming probability when using uniform velocity initialization and if velocities are initialized to zero, all particles which have a better neighbor than themselves leave search space in the first iteration with overwhelming probability. More details can be found in Helwig and Wanka (2008). Various boundary conditions are proposed to enforce particles to move inside search space, among them, such as velocity-clipping and position-clipping (Eberhart & Shi, 2001) are simple and common boundary conditions widely used in PSO literatures, but velocity-clipping can’t prevent particles from flying outside search space. To solve this problem, three kinds of boundary condition walls, namely, Absorbing, Reflecting, and Invisible, are imposed by Robinson and Yahya (2004), and Damping reported to provide robust performance by Huang and Mohan (2005) is a hybrid boundary condition that combines the characteristics offered by the Absorbing and Reflection. As cited in Xu and Yahya (2007), four kinds of walls are summarized and tested, among which the only difference is the way of treating errant particle’s velocity. To address the invariant maximum velocity in the previous methods, the Random Velocity method is introduced by Li, Ren, and Wang (2007), where the upper and lower velocity boundaries keep on altering during the whole evolution. Different with other boundary conditions which keeping particles lying inside search space, the Periodic mode (Zhang, Xie, & Bi, 2004) provides an infinite search space for the flying of particles. Because all boundary conditions strongly influence particle behavior, which means that they actually strongly influence the swarm performance, in a word, they are important for PSO, and significant performance differences when varying boundary conditions.

The purpose of this paper is to report an efficient and simple quotient space-based boundary condition for PSO, named QsaBC, by using the advantages of quotient space and homeomorphism, and where the swarm is not bounded by the end points. By analyzing the dynamic behavior and stability of particles, Search space-zoomed factor and Attractor are introduced in QsaBC which deal with the problem of errant particles, at the same time avoid premature convergence and improve search speed of convergence.

**QUOTIENT SPACE**

It is well known that one can form a circle from a closed segment by bending the segment around and gluing the ends together, as shown in Figure 1(a), and form a cylindrical pipe from a rectangular by bending the rectangle around and welding two edges together, by further bending the cylinder around and welding the two circular rims together, one obtains a doughnut, or torus, as shown in Figure 1(b). Space obtained from a given space by welding or gluing subsets together are called quotients of the given space. Thus the torus is the quotient space of a rectangle, and the circle is the quotient space of a closed line.
Related Content

Evolutionary Optimization of Artificial Neural Networks for Prosthetic Knee Control
[www.igi-global.com/chapter/evolutionary-optimization-artificial-neural-networks/76473?camid=4v1a](www.igi-global.com/chapter/evolutionary-optimization-artificial-neural-networks/76473?camid=4v1a)

Learning with Querying and its Application in Network Security
[www.igi-global.com/chapter/learning-querying-its-application-network/67713?camid=4v1a](www.igi-global.com/chapter/learning-querying-its-application-network/67713?camid=4v1a)

Feature Based Rule Learner in Noisy Environment Using Neighbourhood Rough Set Model
[www.igi-global.com/article/feature-based-rule-learner-noisy/43898?camid=4v1a](www.igi-global.com/article/feature-based-rule-learner-noisy/43898?camid=4v1a)
Nature-Inspired Toolbox to Design and Optimize Systems

www.igi-global.com/chapter/nature-inspired-toolbox-design-optimize/67709?camid=4v1a