Particle Swarm Optimization Research Base on Quantum Q-Learning Behavior

Lu Li, Information Center, Changsha Health Vocational College, Changsha, China
Shuyue Wu, School of Information Science and Engineering, Hunan International Economics University, Changsha, China

ABSTRACT

Quantum-behaved Particle Swarm Optimization algorithm is analyzed, contraction-expansion coefficient and its control method are studied. To the different performance characteristics with different coefficients control strategies, a control method of coefficient with Q-learning is proposed. The proposed method can tune the coefficient adaptively, and the whole optimization performance is increased. The comparison and analysis of results with the proposed method, constant coefficient control method, linear decreased coefficient control method and non-linear decreased coefficient control method is given based on CEC 2005 benchmark function.

KEYWORDS

Particle Swarm Optimization (PSO), Q-Learning, Quantum Behavior, Searching Model, Selecting Parameter

1. INTRODUCTION

Particle Swarm Optimization(PSO) is a colony optimization algorithm which was proposed by Kennedy, who was inspired by the foraging behavior of birds (Kennedy & Eberhart, 1995). Because the method is simple in PSO algorithm, it has fast convergence, PSO algorithm has been widely used; but the algorithm itself is concerned, PSO is not a global optimization algorithm (Van den Bergh, 2001), many scholars have proposed many improved methods, some improvement effects have made (Zheng, Ma & Zhang, 2003; Clerc, 2004). Sun et al. had studied the intelligent population evolution in-depth based on the analysis of particle swarm optimization algorithm, quantum theory was introduced into a PSO algorithm, quantum-behaved particle swarm optimization algorithm was proposed with a global search capability (Quantum-behaved Particle Swarm Optimization, QPSO) (Sun, Feng & Xu, 2004; Sun, Xu & Feng, 2004). Since the proposed PSO algorithm, it has the simple calculation program, and it is easy to implement, and there are less control parameters, etc., it caused research and attention of many scholars in related fields in home and abroad (Goh, Tan, Liu et al., 2010; Omranpour, Ebadzadeh, Shirt et al., 2012), but also it has been applied to some practical problems (Chen, Sun & Ding, 2008; Chai, Sun, Cai et al., 2009; Omkar, Khandelwal, Ananth et al., 2009). QPSO algorithm has only parameter (contraction expansion factor), Sun et al., used a fixed parameter control strategy (Sun & Wu, 2012; Sun, Fang, Wu et al., 2012), later Fang proposed increases evolutionary numbers, the linear or nonlinear decreasing parameter control method were used, the simulation results showed that good improvement effect are achieved in most of the test functions (Fang, 2008). For particle contribution differences in QPSO algorithm, Xi et al. proposed weighting coefficient control algorithm and search process improvement methods, but also it achieved some results (Xi, Sun, & Xu, 2008).
In QPSO algorithm, algorithm performance is heavily dependent on the contraction expansion factor parameters, a single parameter control strategy was used in the evolutionary process, the particles are inflexible, these parameters control methods are not valid at each step in the evolution of iteration. If the QPSO algorithm control strategy for a variety of parameters was applied simultaneously to parameter controls in the evolutionary process, and the most suitable parameter selection strategy is selected based on multi-step of (a few steps for forward study) results as the current particle evolutionary parameters, these are more conducive to the evolution of the algorithm. Based on this idea, as well as that inspiration by reinforcement learning literature (Sutton & Barto, 1998; Zhang & Lu, 2008), we propose a quantum particle swarm optimization based on reinforcement learning (Reinforcement Learning QPSO, RLQPSO), the overall performance of the algorithm is improved.

2. MATERIALS AND METHODS

2.1. Quantum Particle Swarm Optimization (QPSO)

In the PSO’s groups, individuals (particles) search the multidimensional problem solution space, their own position information (fitness) are evaluated in each round evolutionary iteration. In the search process of the whole group, particles share their “best” location information, and then their memory are used to adjust their own speed and position, and the candidate solutions are constantly compared and followed in the problem space, the optimal solution or local optima are eventually found.

PSO evolution equation:

\[ v_{id}(t+1) = v_{id}(t) + c_1 r_1(p_{id}(t) - x_{id}(t)) + c_2 r_2(P_{gd}(t) - x_{id}(t)) \]

\[ x_{id}(t+1) = x_{id}(t) + v_{id}(t+1) \]

The particle search path is analyzed, the convergence of particle swarm algorithm is ensured, in the particles’ search process, the particles are constantly close to their local attractor \( p_i = (p_{i,1}, p_{i,2}, \cdots, p_{i,n}) \). Equation definition:

\[ p_{i,j}(t) = \frac{c_1 P_{i,j}(t) + c_2 P_{g,j}(t)}{c_1 + c_2} \quad (j = 1, 2, \cdots, n) \]

or:

\[ p_{i,j}(t) = \phi P_{i,j}(t) + (1 - \phi) P_{g,j}(t) \]

\[ \phi \sim U(0,1) \quad (j = 1, 2, \cdots, n) \]

\( \phi \) is uniformly random distribution between [0,1].

Jun Sun et al. believed that random of particles is limited in such a search mechanism (Sun, Feng & Xu, 2004; Sun, Xu & Feng, 2004), algorithm can only describe groups of low intelligent animals, but random thought highly of human groups cannot be accurately described, and he found that human intelligent behavior was very similar with the behavior of quantum particles in space, so the quantum state particle behavior was introduced in the algorithm, then the probability density equation Q and
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