Expert Systems with Applications 38 (2011) 12214–12220

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

Improved framework for particle swarm optimization: Swarm intelligence with diversity-guided random walking

Chen-Yu Chen [a,*], Kuo-Chou Chang [a,b], Shing-Hua Ho [a]

[a] Innovative DigiTech-Enabled Applications and Services Institute, Institute for Information Industry, Kaohsiung City, Taiwan, ROC
[b] Department of Information Management, National Sun Yat-sen University, Kaohsiung City, Taiwan, ROC

ARTICLE INFO

Keywords:
Particle swarm optimization
Swarm intelligence
Random walking
Bilateral objective function

ABSTRACT

The work and contribution of this study is not only to devise an improved PSO framework that is capable of wider search area and better fitness values, but also to realize a system that possesses the particle swarm intelligence via high diversity preserving and individual random walking. The purpose of this study is to interpret the processes of how to approach this framework, which consists of bilateral objective function (BOF) and random walking swarm intelligence (RW-PSO), and to provide the distinction from the current problems of PSO technique. Hence, this paper will present the ability of particles escaping from local optimum can be greatly improved because of the increase of exploration stage and scope and the global optimum can be obtained easily with the hybrid of BOF and RWSI, which may involve in searching for the solution from a more complicated test function. Subsequently, the results revealed the advantages of the proposed framework for improving the particle swarm optimization: (a) preserving the simple spirit of the conventional PSO; (b) achieving effective solutions for benchmark functions efficiently; (c) increasing no additional parameters to gain fitness improvement. Moreover, the superiority of the proposed framework has also been demonstrated the results via seven test functions defined to simulate some of complicated real-world problems and the better performance according to the experimental results with several benchmark functions.

1. Introduction

Various optimization techniques have been used for real-world complicated problems, including genetic algorithms (GA), simulated annealing (SA), tabu search (TS) and particle swarm optimization (PSO). The common objective of these techniques is to find the generation scheduling such that the total operating cost can be minimized as subjected to a variety of constraints. GA uses chromosomes to represent the ON/OFF status of generators and searches for a solution using the iteration method with natural section, crossover and mutation. According to the literature (Hong & Li, 2002), the optimal solution of UCP was provided by GA with varying the weighting coefficients for penalty functions. The two-stage framework based on the improved convergence of GA-based techniques was proposed and 5–10% gain was obtained for dispatch among cogeneration systems (Eldin, El-sayed, & Youssef, 2008). SA reaches the minimum energy state through modeling the gradual decrease in molecular vibration when liquid steel is cooled and solidified into a solid state. In addition, Viana, de Sousa, and Matos (2001) gave a simulated annealing method for being flexible, effective and able to handle variations on the problem structure by two coding schemes and new neighborhood structure. As for TS, it seeks only new solutions by repeating local search around a solution and by prohibiting a return from one of previous solutions. In Mitani, Mishima, Satoh, and Nara (2006), TS was combined with Lagrangian decomposition to solve the UC problem. The PSO algorithm is a method for optimization of hard numerical functions. Particles designate to simulate the social behavior among a group and to interact with one another for the convergence on the optimal regions of the problem space. Kitagawa et al. (2005) developed the FeTOP system based on PSO algorithm for optimal operational planning of energy plants. Moreover, the Adaptive-PSO (Yamaguchi & Yasuda, 2006) was proposed for adaptively tuning of the parameters of the PSO with self-coordinating mechanism.

Comparing with the above-mentioned methods, PSO can provide good quality solutions within a short amount of time for mixed-integer nonlinear optimization problems, for which solutions where difficult to obtain with conventional methods (Kitagawa, Takenaka, & Fukuyama, 2004). However, PSO also suffers from premature convergence, same as the major problem of evolutionary algorithms, especially for multimodal or complex search space problems. To avoid the problem of premature convergence, increasing exploration in search space will be an effective strategy to find better solutions.

* Corresponding author. Tel.: +886 7 5366360x6029; fax: +886 7 5366160.
E-mail addresses: cy.chen@iii.org.tw, cy.chency@gmail.com (C.-Y. Chen), d974020001@student.nsysu.edu.tw (K.-C. Chang), hosh@iii.org.tw (S.-H. Ho).

0957-4174/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.eswa.2011.03.086

According to the literature (Burke, Gustafson, & Kendall, 2004), the correlation between population diversity and individual fitness was investigated with several diversity measures for evolutionary algorithm. The investigation of the correlation could help us improve the fitness values with diverse controlling. Besides, the ARPSO (Monson & Seppi, 2006) was shown increasing the performance of exploration of individuals by triggering modes of attraction or repulsion when the diversity of population exceeds the predefined threshold. The algorithm will outperform the basic PSO and the implemented GA on the truly multimodal test problems. In the literature (Krink, Vesterstrom, & Riget, 2002), Krink et al. proposed the SE-PSO artificially injecting diversity into the population with particle collision. The crucial advantage of the SE-PSO is presented as the approach can keep improving on all test problems even conventional methods got stagnated. It was confirmed by the results of the corresponding experiments, which the revised PSO were better than the algorithm based on a complicated search space for obtaining better optimum.

In the above paragraph, we reviewed the classic PSO and its variants for solving the problem of premature convergence. Unfortunately, the diversity required to improve exploration of individuals using the discussed methods will increase restrictedly if only minority of particles bounce off one another at a time. Specially, it is difficult to simulate the total situation of particle collision during implementation. Besides, repulsion operator in AR-PSO is activated to repel particles when they each other stay next to close. Owing to the goal of repulsion operators being to maintain search diversity, they are not allowable to compare to the approach of our research since high diversity is only a byproduct. Therefore, a new PSO framework has to be proposed to overcome the above mentioned drawbacks.

The work and contribution of the study is not only to present an improved PSO framework that is capable of wider search area and better fitness values, but also to realize a system that possesses the particle swarm intelligence via high diversity preserving and individual random walking. The purpose of this study is to interpret the processes of how to approach this framework, which consists of bilateral objective function (BOF) and random walking swarm intelligence (RW-PSO), and to provide the distinct solutions from the current problems of PSO technique. The BOF is developed based on the design of minimized cost value and widely distributed (diversity-guided) individuals. The distribution degree of individuals in the iterative process means the ability of searching for optimal solution. Instead of using only cost value down for the objective function as in the case of the conventional optimization techniques, which the proposed PSO framework employs both minimized cost value and promoted solution search ability achieved by exploring more wider search space. Moreover, by allowing particles to be collided each other, the RW-PSO is capable of exploring a wider area. From the point of a single individual, the moving trajectory is joined by straight line segments within certain number of successive collisions. From the view point of the overall population, however, the distribution is then observed as a continuous-time stochastic process. Therefore, the ability of particles escaping from local optimum can be greatly improved because of the increase of exploration stage and scope. The global optimum would be obtained easily after the combination of bilateral objective function and random walking swarm intelligence, which involves searching for the solution from a more complicated test function. The flowchart of the proposed framework is shown in Fig. 1. The picture provides detailed workflow of the conventional PSO algorithm, which is associated the new added gray blocks for the bilateral objective function and random walking swarm intelligence.

In summary, the findings in this study are to present the advantages of the proposed framework improving the prior particle swarm optimization, which includes (a) preserving the simplicity of the conventional PSO; (b) achieving the more effective solutions on benchmark functions, especially for multi-dimension $D \geqq 30$; (c) adopting concise parameters to gain fitness improvement. The superiority of the proposed framework has been demonstrated by implementing seven functions of experimentation so as to simulate some empirical problems on high power consumption industry, such as energy saving issue for steel manufacture companies.

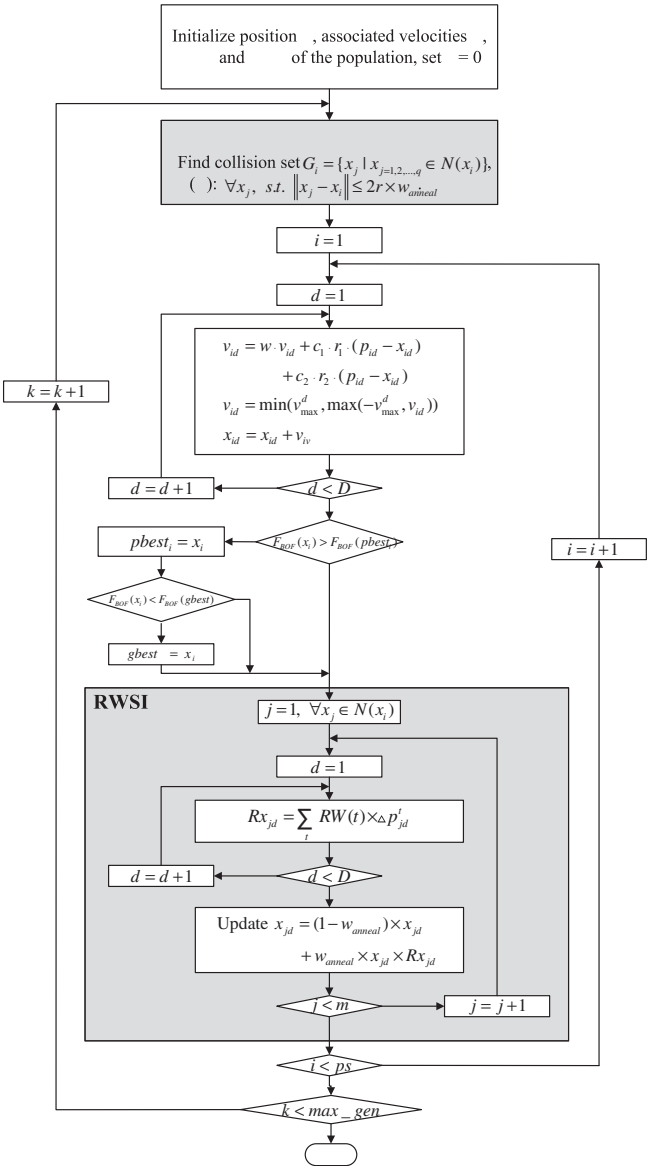

Fig. 1. Flowchart of the proposed framework.

The rest of this paper is organized as follows. Section 2 describes the main tasks performed in the bilateral objective function (BOF). Section 3 discusses the random walking swarm intelligence (RWSI). Subsequently, experimental results are provided in Section 4. Finally, conclusions are drawn in Section 5.

2. Bilateral objective function in PSO

2.1. Conventional PSO and mutation operator

The PSO theory is a new heuristics-based optimization technique and has drawn much attention on this topic in recent years (Eberhart & Shi, 2006; Kennedy & Eberhart, 1995). Let the objective function to be optimized is defined as $f(x)$, $x = [x_1, x_2, \ldots, x_D]^T \in R^D$.