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Review Article

Evolutionary computation in China: A literature survey

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Abstract

Evolutionary computation (EC) has received significant attention in China during the last two decades. In this paper, we present an overview of the current state of this rapidly growing field in China. Chinese research in theoretical foundations of EC, EC-based optimization, EC-based data mining, and EC-based real-world applications are summarized.

Keywords: Evolutionary computation; Evolutionary algorithms; Optimization; Data mining

1. Introduction

Evolutionary computation (EC) uses computational models of evolutionary processes as key elements in the design and implementation of computer-based problem solving systems [1]. It has become an important part of computational intelligence. EC has received significant attention in China during the last two decades. Professor Guoliang Chen of the University of Science and Technology of China published the first Chinese book on EC in 1996 [2]. This book played an important role in introducing EC to Chinese researchers. Professor Lishan Kang, Zongben Xu, Xin Yao, Licheng Jiao, Zixing Cai, Jun Zhang, Zhi-Hua Zhou, Ling Wang, Jinhua Zheng, Dunwei Gong, Yongsheng Ding, Yuhui Shi, Ying Tan, Yuping Wang, Haibin Duan and their collaborators and successors paid attention to EC field one after the other. They have published a lot of papers and books related to EC. Among them, the papers published in international journals and conferences can be obtained all over the world. Chinese can read papers in English easily for English is the most popular language in the world, but the papers written in Chinese are difficult to be recognized by non-Chinese speakers. According to our statistic, a large number of books on EC have been published in Chinese. For example, Guoliang Chen and his collaborator published a book focused on genetic algorithm in 1996 [2]; Haibin Duan published a book focused on ant colony Algorithms [3]; Licheng Jiao et al. published a book focus on immunological computation [4]; Jinhua Zheng published a book focus on evolutionary multi-objective optimization [5]; Yuping Wang published a book focus on evolutionary algorithm [6]; Yaonan Wang et al. published a book focus on dynamical dynamic differential evolution algorithm [7]; Ying Tan published a book on the fireworks algorithm [8]. The EC papers published in Chinese Journals and conferences are also massive. Most of them focus on modifying existing EC algorithms or combining different algorithms to solve specifically problems. In recent years, more and more Chinese researchers prefer to publish their approving works in international Journals, such as IEEE Transactions on Evolutionary Computation, Evolutionary Computation Journal, IEEE Transaction on System, Man and Cybernetics series, and some main-stream international journals on various application fields. In the last two decades, more and more papers written by Chinese researchers have been published in these journals, which will be summarized in detail in the following sections. Furthermore, some international events related to EC, such as the International Workshop series on

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Nature Inspired Computation and Applications since 2004, the annual International Conference on Natural Computation since 2005, the annual International Conference on Computational Intelligence and Security since 2005, the 2008 and 2014 IEEE world congress on computational intelligence (WCCI), and the Annual Workshop on Evolutionary Computation and Learning (ECOLE) since 2014, to list only a few, were held in China. All of these show that Chinese researchers are more and more active in EC field.

In this paper, we will summarize the main contributions of Chinese researchers in EC field. From 1995, lots of Chinese researchers have focused on evolutionary algorithms and have published a great number of papers about evolutionary algorithms. In this paper, we select classic works that are well known or published in top journals or conferences, such as IEEE Transactions on Evolutionary Computation, Evolutionary Computation, IEEE Computational Intelligence Magazine and IEEE Congress on Evolutionary Computation and so on. All selected papers are written in English.

The remainder of this paper is organized as follows: Section 2 summarizes the theoretical foundation research, including time complexity analysis, convergence and diversity analysis. Section 3 summarizes the research results in evolutionary optimization, including global optimization, multi-objective optimization, many-objective optimization, constrained optimization and dynamic optimization. Section 4 describes the EC-based real-world applications. Finally, concluding remarks are presented.

2. Theoretical foundation research

2.1. Time complexity analysis

In EC, time complexity analysis and convergence analysis are considered to be two important issues in the basic theoretical analysis. However, convergence describes the behaviors at limit points of evolutionary algorithms (EAs). If an EA with convergence property has tremendous time complexity, it is useless for application. Therefore, it is important to develop a systematic theoretical tool investigating into the computational time or time complexity of EAs.

He and Yao introduced drift analysis in estimating average computational time of EAs [9]. In their paper, one-step mean drift at the t-th generation was defined and it could be classified into positive and negative drift, where the positive drift is the rate of the gain of a population towards the optimum and the negative drift is that away from the optimum. The authors analyzed a $(1 + 1)$EA on a linear function and a $(N + N)$EA on One-Max function. The upper bound of the mean first hitting times of EAs were presented. Besides, by drift analysis, they divided optimization problems into two classes (easy and hard) based on the mean number of generations needed to solve the problems. By their analysis, we could obtain that drift analysis is a useful tool in estimating the computational time of EAs. Drift analysis reduces the behavior of EAs in a higher-dimensional population space into one-dimensional space. Therefore, it is much easier than analysis of the original Markov chain to analyze the one dimension random walk. However, this approach requires a distance function which does not naturally exist in EAs.

He and Yao described a general analytic framework for analyzing first hitting times (FHTs) of EAs [10]. The FHT of EAs is the time that EAs find the optimal solution for the first time, while the expected first hitting time (expected FHT) is the average time that EAs require to find the optimal solution, which implies the average computational time complexity of EAs. The general framework they gave was based on a linear equation and its bounds of the FHT of an EA's Markov chain model. Under this framework, conditions under which an EA will need polynomial (or exponential) mean computational time to solve a problem were studied. A number of case studies were given to illustrate how different results can be established by verifying these conditions. They proved that hard problems to a simple $(1 + 1)$ EA can be classified into two classes: “wide gap” problems and “long path” problems. In addition to $(1 + 1)$ EAs, EAs with population size greater than 2 and EAs with and without crossover were also studied in their paper. However, since the analytical form was derived from homogeneous Markov chain models, only EAs with stationary reproduction operators could be analyzed, although EAs with time-variant operators or adaptive operators are very popular and powerful.

He and Yao also compared $(1 + 1)$ EAs and $(N + N)$ EAs theoretically by deriving their FHT on some problems [11]. In their paper, by rigorous theoretical analysis, they concluded that a population may bring benefits to an EA in terms of lower time complexity, higher first hitting probabilities, and shorter FHT. It was also shown that a population-based EA may take only average polynomial time to solve a problem that would take a $(1 + 1)$EA average exponential time to solve, given the same mutation operator in both algorithms.

He and Yao [12] analyzed the time complexity of EAs based on the maximum cardinality matching in a graph, which is a famous combinatorial optimization problem. They proved that the EA can find a matching with the early maximum cardinality in polynomial time. This was noteworthy as it was the first time complexity results on classical combinational optimization problems.

Zhou and He presented a time complexity analysis of EAs for solving constrained optimization [13]. The mean runtimes of the penalty function $(1 + 1)$EAs with local mutation and global mutation for two simple knapsack problems were analyzed respectively. In their paper, they concluded that EAs have benefited greatly from higher penalty coefficients in some examples, while in other examples, EAs benefit from lower penalty coefficients. The systematical analysis of the role of penalty coefficients in constrained optimization is original and beneficial for designing constraint optimization algorithms. However, we still can not predict how to choose penalty coefficients for various problems.

Yu and Zhou also established a bridge between the convergence rate and the expected FHT of EAs [14]. In their paper, non-homogeneous Markov chain model was employed and the expected FHT was derived from the convergence rate

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