Applied Mathematics and Computation 214 (2009) 108–132

Contents lists available at ScienceDirect

Applied Mathematics and Computation

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

A comparative study of Artificial Bee Colony algorithm

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ARTICLE INFO

Keywords:
Swarm intelligence
Evolution strategies
Genetic algorithms
Differential evolution
Particle swarm optimization
Artificial Bee Colony algorithm
Unconstrained optimization

ABSTRACT

Artificial Bee Colony (ABC) algorithm is one of the most recently introduced swarm-based algorithms. ABC simulates the intelligent foraging behaviour of a honeybee swarm. In this work, ABC is used for optimizing a large set of numerical test functions and the results produced by ABC algorithm are compared with the results obtained by genetic algorithm, particle swarm optimization algorithm, differential evolution algorithm and evolution strategies. Results show that the performance of the ABC is better than or similar to those of other population-based algorithms with the advantage of employing fewer control parameters.

1. Introduction

Population-based optimization algorithms find near-optimal solutions to the difficult optimization problems by motivation from nature. A common feature of all population-based algorithms is that the population consisting of possible solutions to the problem is modified by applying some operators on the solutions depending on the information of their fitness. Hence, the population is moved towards better solution areas of the search space. Two important classes of population-based optimization algorithms are evolutionary algorithms [1] and swarm intelligence-based algorithms [2]. Although Genetic Algorithm (GA) [3], Genetic Programming (GP) [4], Evolution Strategy (ES) [5,6] and Evolutionary Programming (EP) [7] are popular evolutionary algorithms, GA is the most widely used one in the literature. GA is based on genetic science and natural selection and it attempts to simulate the phenomenon of natural evolution at genotype level while ES and EP simulate the phenomenon of natural evolution at phenotype level. One of the evolutionary algorithms which has been introduced recently is Differential Evolution (DE) algorithm [8–10]. DE has been particularly proposed for numerical optimization problems. In the basic GA, a selection operation is applied to the solutions evaluated by the evaluation unit. At this operation the chance of a solution being selected as a parent depends on the fitness value of that solution. One of the main differences between the GA and the DE algorithm is that, at the selection operation of the DE algorithm, all solutions have an equal chance of being selected as parents, i.e. the chance does not depend on their fitness values. In DE, each new solution produced competes with its parent and the better one wins the competition. In recent years, swarm intelligence has also attracted the interest of many research scientists of related fields. Bonabeau has defined the swarm intelligence as "...any attempt to design algorithms or distributed problem-solving devices inspired by the collective behaviour of social insect colonies and other animal societies..." [11]. Bonabeau et al. focused their viewpoint on social insects alone such as termites, bees, wasps and different ant species. However, a swarm can be considered as any collection of interacting agents or individuals. An ant colony can be thought of as a swarm whose individual agents are ants; a flock of birds is a swarm of birds. An immune system [12] can be considered as a swarm of cells and molecules as well as a crowd is a swarm of people. A popular swarm-intelligence-based algorithm is the Particle Swarm Optimization (PSO) algorithm which was introduced by Eberhart and Kennedy in 1995 [13]. PSO is also a population-based stochastic optimization technique and is well adapted to the optimization of nonlinear functions in multidimensional space. It models

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0096-3003/$ - see front matter
doi:10.1016/j.amc.2009.03.090

the social behaviour of bird flocking or fish schooling. PSO has received significant interest from researchers studying in different research areas and has been successfully applied to several real-world problems [14].

The classical example of a swarm is bees' swarming around their hive but it can be extended to other systems with a similar architecture. Some approaches have been proposed to model the specific intelligent behaviours of honeybee swarms and they have been applied for solving combinatorial type problems [15–23]. Tereshko considered a bee colony as a dynamical system gathering information from an environment and adjusting its behaviour in accordance to it [15]. Tereshko and Loengarov established a robot idea on foraging behaviour of bees. Usually, all these robots are physically and functionally identical, so that any robot can replace any other robot. The swarm possesses a significant tolerance; the failure of a single agent does not stop performance of the whole system. Like insects, the robots individually have limited capabilities and limited knowledge of the environment. On the other hand, the swarm develops collective intelligence. The experiments showed that insect-like robots are successful in real robotic tasks. Tereshko and Loengarov also developed a minimal model of forage selection that leads to the emergence of collective intelligence which consists of three essential components: food sources, employed foragers, and unemployed foragers, and defines two leading modes of the behaviour: recruitment to a nectar source and abandonment of a source [16,17]. Teodorović suggested to use bee swarm intelligence in the development of artificial systems aimed at solving complex problems in traffic and transportation [19,18]. Once more Teodorović proposed the Bee Colony Optimization (BCO) Metaheuristic which is capable of solving deterministic combinatorial problems, as well as combinatorial problems characterized by uncertainty [20]. Drias et al. introduced a new intelligent approach or meta-heuristic called Bees Swarm Optimization (BSO) and adapted it to the features of the maximum weighted satisfiability (max-sat) problem [21]. Similarly, Benatchba et al. introduced a metaheuristic based on the process of bees' reproduction to solve a 3-sat problem [22]. Wedde et al. presented a novel routing algorithm, called BeeHive, which was the inspiration gained from communicative and evaluative methods and procedures of honeybees [23]. In BeeHive algorithm, bee agents travel through network regions called foraging zones. On their way their information on the network state is delivered for updating the local routing tables.

The works mentioned in the previous paragraph introduced the algorithms of bees proposed for the combinatorial type problems. There are three continuous optimization algorithms based on intelligent behaviour of honeybee swarm [24–26] in the literature. Yang developed a Virtual Bee Algorithm (VBA) [24] to optimize only two-dimensional numeric functions. A swarm of virtual bees is generated and started to move randomly in two-dimensional search space. Bees interact when they find some target nectar and the solution of the problem is obtained from the intensity of these bee interactions. Pham et al. introduced the Bees Algorithm in 2005, which employs several control parameters [25]. For optimizing multi-variable and multi-modal numerical functions, Karaboga described an Artificial Bee Colony (ABC) algorithm [26] in 2005. Basturk and Karaboga compared the performance of ABC algorithm with those of GA [27], PSO and PS-EA [28]; and DE, PSO and EA [29] on a limited number of test problems. They have extended ABC algorithm for constrained optimization problems in [30] and applied ABC for training neural networks [31,32]. ABC algorithm was used for designing IIR filters in [33] and for the leaf-constrained minimum spanning tree problem in [34].

In this work, a comprehensive comparative study on the performances of well-known evolutionary and swarm-based algorithms for optimizing a very large set of numerical functions is presented. In Section 2, ES, GA, PSO and DE algorithms are briefly summarized. In Section 3, the foraging behaviour of real bees and then ABC algorithm simulating this behaviour are described. Finally, in Section 4 and Section 5, the simulation results obtained are presented and discussed, respectively.

2. Evolution strategies, genetic algorithm, differential evolution algorithm, particle swarm optimization algorithm

2.1. Evolution strategies

Evolution Strategy has been proposed for numerical optimization problems and it is one of the oldest evolutionary algorithms. Evolution Strategy produces n-dimensional real-valued vector by mutating its parent with identical standard deviations to each vector element. The produced individual is evaluated and a selection scheme is applied to determine which one will survive in the next generation and the other one will be discarded. This simple selection mechanism is expressed as (1 + 1)-selection. In a $(\mu+1)$-ES, which is a multi-membered evolution strategy, μ parent individuals recombine to form one offspring, which after being mutated eventually replaces the worst parent individuals, if it is better [35]. The canonical versions of the ES (CES) are denoted by $(\mu/\rho,\lambda)$-ES and $(\mu/\rho+\lambda)$-ES. Here μ indicates the number of parents, $\rho \leqslant \mu$ is the number of parents involved in the generation of an offspring, and λ is the number of offspring produced. The parents are deterministically chosen from the set of either the offspring (referred to as comma-selection and $\mu<\lambda$ must hold) or both the parents and offspring (referred to as plus-selection). Selection is based on the fitness of individuals. The main steps of ES are given below:

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1: Initialize Population
2: repeat
3:    Recombination
4:    Mutation
5:    Evaluation
6:    Selection
7: until requirements are met
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