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Chaotic bee colony algorithms for global numerical optimization

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ABSTRACT

Artificial bee colony (ABC) is the one of the newest nature inspired heuristics for optimization problem. Like the chaos in real bee colony behavior, this paper proposes new ABC algorithms that use chaotic maps for parameter adaptation in order to improve the convergence characteristics and to prevent the ABC to get stuck on local solutions. This has been done by using of chaotic number generators each time a random number is needed by the classical ABC algorithm. Seven new chaotic ABC algorithms have been proposed and different chaotic maps have been analyzed in the benchmark functions. It has been detected that coupling emergent results in different areas, like those of ABC and complex dynamics, can improve the quality of results in some optimization problems. It has been also shown that, the proposed methods have somewhat increased the solution quality, that is in some cases they improved the global searching capability by escaping the local solutions.

1. Introduction

An optimization problem is modeled in such a way that a classical algorithm, which requires several assumptions and/or modifications which might not be easy to validate in many situations, can handle it. These assumptions and/or modifications on the original optimization problem parameters (rounding variables, softening constraints, etc.) certainly affect the solution quality (Baykasoglu, Ozbakir, & Tapkan, 2007). They are insufficient if integer and/or discrete decision variables are required in optimization models (Baykasoglu et al., 2007). Namely, classical optimization algorithms are inflexible to adapt the solution procedure to an optimization problem.

Furthermore, solution strategies of classical optimization algorithms are generally depended on the type of objective and constraint functions (linear, non-linear, etc.) and the type of variables used in the problem modeling (integer, real, etc.). Their efficiency is also very much dependent on the size of the solution space, number of variables and constraints used in the problem modeling, and the structure of the solution space (convex, non-convex, etc.). Namely, they do not offer general solution strategies that can be applied to problem formulations where, different type of variables, objective and constraint functions are used. However, most of the optimization problems require different types of variables, objective and constraint functions simultaneously in their formulation (Baykasoglu et al., 2007).

Inefficiency of classical optimization algorithms in solving larger scale and/or highly non-linear problems forced researchers to find more flexible and adaptable, problem and model independent, general purpose heuristic algorithms. These algorithms are efficient and flexible and they can be modified and/or adapted to suit specific problem requirements. Researches on these algorithms are still continuing all around the globe. Fig. 1 shows the classifications of the heuristic algorithms.

Swarm intelligence that combines of biology and social based heuristics has become a research interest to many research scientists of related fields in recent years (Abbass, 2001). Particle swarm optimization, ant colony optimization, and bee colony algorithms can be considered as subfields of swarm intelligence. A few models have been developed to model the intelligent behaviors of honeybee swarms and applied for solving the problems (Abbass, 2001; Karaboga, 2005; Karaboga & Basturk, 2008; Pai, Yang, & Chang, 2009; Pham et al., 2006; Yang, 2005). Recently proposed artificial bee colony (ABC) algorithm has been inspired by the intelligent behavior of real honey bees and proven to be a better heuristic for global numerical optimization (Karaboga, 2005; Karaboga & Basturk, 2008).

Many chaotic maps in the literature possess certainty, ergodicity and the stochastic property. Recently, chaotic sequences have been adopted instead of random sequences and very interesting and somewhat good results have been shown in many applications. They have also been used together with some heuristic optimization algorithms (Alatas, Akin, & Ozer, 2009; Coelho & Mariani, 2008) to express optimization variables. The choice of chaotic sequences is justified theoretically by their unpredictability, i.e., by their spread-spectrum characteristic, non periodic, complex temporal behavior, and ergodic properties.

In this paper, sequences generated from different chaotic systems substitute random numbers for different parameters of ABC

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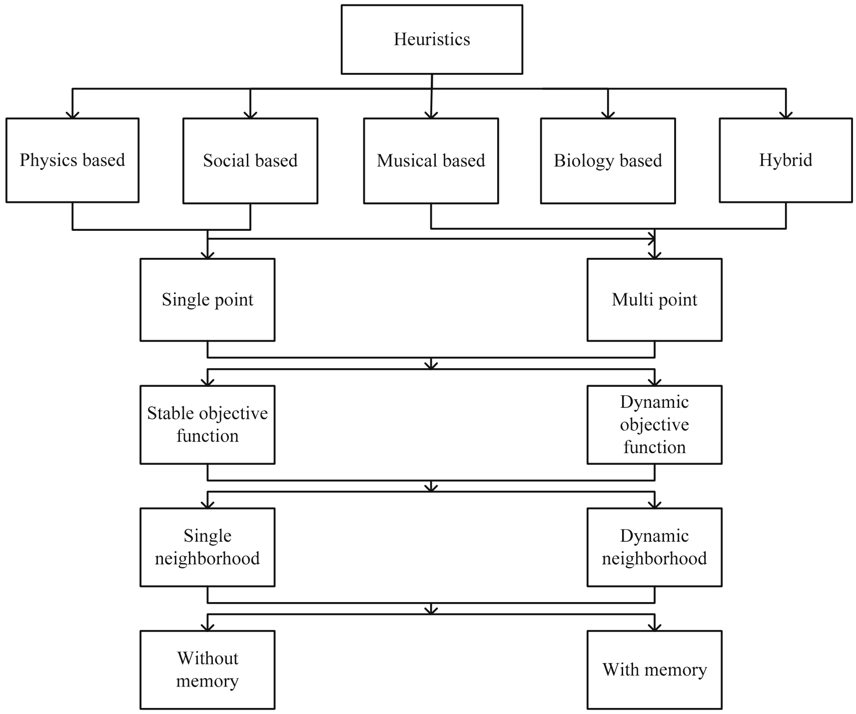

Fig. 1. Heuristic algorithms.

where it is necessary to make a random-based choice. For this purpose, different ABC methods that use chaotic maps as efficient alternatives to pseudorandom sequences have been proposed. By this way, it is intended to enhance the global convergence and to prevent to stick on a local solution. However, in general, it is hard to estimate how good most chaotic random number generator by applying statistical tests are, as they do not follow the uniform distribution. The simulation results show that the application of deterministic chaotic signals instead of random sequences may be a possible strategy to improve the performances of ABC.

The remaining of this paper is organized as follows. Review of ABC is summarized in Section 2. Section 3 describes the proposed methods, Chaotic bee colony algorithms, shortly CBCAs. Section 4 describes the benchmark problems used for comparisons of the proposed methods. In Section 5, the testing of the proposed methods through benchmark problems are carried out and the simulation results are compared. Finally, the conclusions are drawn based on the comparison analysis reported and presented in Section 6.

2. Artificial bee colony algorithm

ABC algorithm has been inspired by the intelligent behavior of real honey bees (Karaboga, 2005; Karaboga & Basturk, 2008). In the algorithm, the artificial bee colony consists of three groups of bees: employed bees, onlookers and scouts. The first half of the colony consists of the employed artificial bees and the second half includes the onlookers. For every food source, there is only one employed bee. In other words, the number of employed bees is equal to the number of food sources around the hive. The employed bee whose food source has been exhausted by the bees becomes a scout. The pseudo-code of the algorithm is given in Fig. 2.

Each cycle of the search consists of three steps after initialization step: moving the employed bees onto the food sources and calculating their nectar amounts; placing the onlookers onto the food sources and calculating the nectar amounts; and determining the scout bees and directing them onto possible food sources (Karaboga, 2005; Karaboga & Basturk, 2008). A food source position represents a possible solution of the problem to be optimized. The amount of nectar of a food source corresponds to the quality of the solution represented by that food source. Each employed bee is moved onto her food source area for determining a new food source within the neighborhood of the present one, and then its nectar amount is evaluated. If the nectar amount of the new one is higher, then bee forgets the previous and memorizes the new one. Onlookers are placed on the food sources by using a probability based selection process. As the nectar amount of a food source increases, the probability value with which the food source is preferred by onlookers increases similar to the natural selection process in evolutionary algorithms (Karaboga, 2005; Karaboga & Basturk, 2008).

Every bee colony has scouts considered as the colony's explorers that do not have any guidance while looking for food. They are primarily concerned with finding any kind of food source. As a result of such behavior, the scouts are characterized by low search costs and a low average in food source quality. Occasionally, the scouts can accidentally discover rich, entirely unknown food sources. In the case of artificial bees, the artificial scouts could have the fast discovery of the group of feasible solutions as a task. In ABC, one of the employed bees is selected and classified as the scout bee (Karaboga, 2005; Karaboga & Basturk, 2008). The selection is controlled by a control parameter called *limit*. If a solution representing a food source is not improved by a predetermined number of trials, then that food source is abandoned by its employed bee and the employed bee of this food becomes a scout. The number of trials for releasing a food source is equal to the value of *limit* which is an important control parameter of ABC. In a robust search process exploration and exploitation processes must be carried out together. In the ABC algorithm, while onlookers and employed bees carry out the exploitation process in the search space, the scouts control the exploration process. These three steps are repeated until the termination criteria are satisfied (Karaboga, 2005; Karaboga & Basturk, 2008).