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Artificial cooperative search algorithm for numerical optimization problems

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ABSTRACT

In this paper, a new two-population based global search algorithm, the *Artificial Cooperative Search Algorithm* (ACS), is introduced. ACS algorithm has been developed to be used in solving *real-valued* numerical optimization problems. For purposes of examining the success of ACS algorithm in solving numerical optimization problems, 91 benchmark problems that have different specifications were used in the detailed tests. The success of ACS algorithm in solving the related benchmark problems was compared to the successes obtained by PSO, SADE, CLPSO, BBO, CMA-ES, CK and DSA algorithms in solving the related benchmark problems by using *Wilcoxon Signed-Rank Statistical Test* with *Bonferroni-Holm* correction. The results obtained in the statistical analysis demonstrate that the success achieved by ACS algorithm in solving numerical optimization problems is better in comparison to the other computational intelligence algorithms used in this paper.

1. Introduction

In general, population based *computational intelligence* algorithms [6,7,10,29,31,35,36,47] are based on searching the *global minimum* value that belong to a numerical problem by means of natural or artificial agents by employing collective methods. Fast advancing technology and ongoing scientific research studies lead to the emergence of new and ever more complex numerical optimization problems creating the need for developing new optimization algorithms based on different techniques.

In their natural habitat the living beings make use of various *social behavior models* [1,3,20,26,32] that they instinctively possess the ability to solve the problems they are faced with. Various population based *computational intelligence* algorithms that are developed on the basis of the subject matter *behavioral methods* are being widely used for many years in solving numerical optimization problems (i.e., *Ant-Colony Optimization Algorithm* (ACO) [18,19], *Artificial Bee Colony Algorithm* (ABC) [29], *Particle Swarm Optimization Algorithm* (PSO) [7,10], *Cuckoo-Search Algorithm* (CK) [45], *Differential Evolution Algorithm* (DE) [7,35], *Biogeography-Based Optimization* (BBO) [38], etc.).

The scientific research studies for population based *computational intelligence* algorithms to search for the related search space that belong to a problem relatively in a more effective manner are ongoing. The *social behavior strategies* observed in living beings are very promising where studies are concerned with the development of new artificial *agent interaction* strategies to render population based *computational intelligence* algorithms relatively more effective.

The social beings that have the ability to collectively solve problems in nature, use their skills to solve problems that may prove to be very difficult in relative terms to solve for a single lonely individual, with ease, such as, *accommodation*,

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reproduction, *care of off-springs*, *finding food*, *defending oneself* and similar. In nature one can observe different socialization strategies employed by different living beings; although the *presocial* living beings [12,13,44] were in possession of basic social functions such as collective living arrangements, reproduction mechanism, they would not be able to create new generations without the cooperation of their social groups. *Subsocial* species [12,13,44] show interest in the *feeding*, *care*, *protection* and *education* of their off-springs while the ones that are not *sub-social* show no interest at all. *Parasocial* living beings [12,13,44] generally prefer to lead a lonely life. In general, the socialization behavior plays a determining role on the level and methods of information sharing among living beings.

The hierarchical social organizations established between living beings (i.e. *eusociality* [12,13,44]) display three main qualities; (1) In these social-being groups, an adult class is included, (2) Only a specific group is responsible from reproduction, and (3) The care of the next generation is under the social assurance of the group. The *duties* and *status* within a group of the individuals in an eusocial group are determined by means of a complex hierarchical network. The known most advanced living superorganisms are mainly created by eusocial beings (i.e. *human beings*, *ants*, *termites*, *honey bees*). Artificial eusocial bees used in ABC algorithm (i.e., *employed bee*, *scout bee* and *onlooker bee*) have different duties in the artificial colony [29].

The *gene variety* available in social-being groups is very important to ensure sustaining the healthy existence of the group. Although all of our off-springs get their genes from us, they also possess their own unique genetic characteristics. A living being is the result of basic genetic processes taking place in the society such as gene variety, *crossover*, *mutation*, and *selection*. The genetic algorithms [15,24,27] and its derivatives solve numerical optimization problems on the basis of basic genetic rules (i.e., *crossover*, *mutation*, *adaptation*, *selection*). There are many metaheuristic optimization algorithms based on basic genetic rules (i.e., *Covariance Matrix Adaptation Evolution Strategy* (CMA-ES) [23], Differential Evolution and their derivatives [33]; *Self-Adaptive Differential Evolution Algorithm* [6], *Adaptive Differential Evolution Algorithm* [47], *Strategy Adaptation Based Differential Evolution Algorithm* (SADE) [36]).

Eusocial living beings can live in large social colonies including vast number of individuals (i.e., *superorganism*) [21,28]. Therefore, the problem and challenge solving skills of superorganisms are highly developed. The superorganism concept is the equivalent of *distributed intelligence* in swarm intelligence. *Computational Swarm Intelligence* algorithms simulate the superorganism mechanism that is observed in eusocial beings, by means of a population where each member matches a random solution of the related numerical optimization problem [7,29,30,33].

Many researchers, for purposes of developing new artificial *agent-interaction* and *agent-evolution* models, take advantage of behavior models that are inspired of natural behavioral patterns that are sometimes overly simplified and isolated of their details such as *food searching*, *communication*, *joint caring* for *off-springs*, *superorganism creation* of eusocial living beings. (i.e., ABC [7,8,29], ACO [17–19], *Comprehensive Learning Particle Swarm Optimizer* (CLPSO) [31], PSO2011 [8,34], CK [7,45]). For this reason there might be definitive differences between the artificial-agent behavioral model that a *computational swarm algorithm* is based on and the actual behavioral patterns of the living beings existing in nature. *Artificial agent behavioral* models used in *computational swarm intelligence* based optimization algorithms are very useful tools that basically are based on *smart random search* algorithms and explain the functioning of the algorithms better [7,8].

In general it is considered that a living being has either a short or long span individual memory capacity. *Individual memory* ensures that the person can take advantage of the experiences accumulated in solving a problem. On the other hand *social memory* is necessary to ensure that all the other members of a society take advantage of the experiences of an individual that achieve the best solution among all the other members of the mentioned society. PSO algorithms [7,8,10,34] are based on searching a solution for a problem by taking advantage of individual and social experiences of agents making up the artificial superorganism.

Bio-geographic research studies [2,38,39] have shown how important *biological interaction* is for living being groups. Biological interaction means the interaction among living beings for purposes of meeting their varied needs such as *reproduction*, *food search*, *accommodation* and *protection from hunters*. Biological interaction can be between the same or different species. There are many biological interaction methods with very different functioning mechanisms (i.e., *Neutralism*, *Amensalism*, *Commensalism*, *Competition*, *Mutualism*, and *Parasitism*) [12,13,44]. The CK [7,45] is based on *parasitism* as the biological interaction model [7,45].

The interactions between living beings inspired the development of various biogeography-based global search algorithms [2,38,39]. A new global search algorithm that is based on biogeography (i.e., Biogeography-Based Optimization (BBO)) is provided under [38]. As a philosophy BBO is strongly influenced by geographical distribution of biological species [2,38,39].

In nature there is *mutualism* based biological interaction between many species of living beings. A biological interaction that does not affect any one of the species involved adversely is called *neutralism*. On the other hand, in *amensalism* that is another type of biological interaction, at least one of the species is affected adversely from others. During *commensalism* based biological interaction, the species neither benefit from or are damaged by each other. The living beings involved in a *mutualism* based biological interaction try to derive mutual benefits from the mentioned interaction [12,13,44]. The most common type of biological interaction among living beings in nature is *mutualism*. In *mutualism* based biological interaction two different species groups derive benefits from each other. The groups of living beings with mutualism as biological interaction between each other can have their independent food search mechanism and from time to time they can subsist independent of each other. The *mutualism* based biological interaction between the species that are connected to each other by means of a link such as food chain may cause *coextinction* if any one of the related species becomes extinct. The *mutualism* based biological interaction among two species with either *predator*/*prey* or *parasite*/*host* relationship between each other is