Symbiotic Organisms Search Algorithm: theory, recent advances and applications

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Abstract. The symbiotic organisms search algorithm is a very promising recent metaheuristic algorithm. It has received a plethora of attention from all areas of numerical optimization research, as well as engineering design practices. it has since undergone several modifications, either in the form of hybridization or as some other improved variants of the original algorithm. However, despite all the remarkable achievements and rapidly expanding body of literature regarding the symbiotic organisms search algorithm within its short appearance in the field of swarm intelligence optimization techniques, there has been no collective and comprehensive study on the success of the various implementations of this algorithm. As a way forward, this paper provides an overview of the research conducted on symbiotic organisms search algorithms from inception to the time of writing, in the form of details of various application scenarios with variants and hybrid implementations, and suggestions for future research directions.

Keywords: symbiotic organisms search algorithm; swarm intelligence; metaheuristic algorithms; optimization.

1. Introduction

Several research contributions in the field of metaheuristics have produced numerous optimization methods (Yang, 2010c; Weise, 2011; Yang, 2013a; Yang, 2013b), which are more powerful than the traditional gradient-based (Haupt, 1995) or hessian matrix based methods (Tahk *et al.*, 2009). While these contributions can currently be considered optimum (Nowak and Cripka, 2004), most real-world problems are highly unpredictable and are often accompanied with numerous uncertainties, making the search for optimal solutions even more complex. Therefore, it may be said that while optimality is not the only focus of optimization, it also includes robustness, which is a key factor when dealing with most scientific and engineering problems. As an alternative to the classical optimization methods, scientists have succeeded in developing and using the nature inspired metaheuristic algorithms to circumvent the limitations of the traditional optimization techniques (Blum and Roli, 2003; Yang, 2010c; Weise, 2011). Metaheuristic algorithms are well known for their speed, robustness and near-optimal solution accuracy. Moreover, it is very common to use metaheuristic algorithms to efficiently and effectively solve most of the complex optimization problems that are difficult to solve by using the gradient descent algorithms (Clerc and Kennedy, 2002; Yang and Deb, 2010; Das *et al.*, 2011).

The term 'metaheuristic' which connotes 'higher level' is often seen as an iterative generation process that integrates different concepts for *exploring* and *exploiting* the search space to guide a subordinate heuristic 'lower level', with learning strategies used to structure information to find efficiently near-optimal solutions (Osman and Laporte, 1996; Yang, 2014). In general, while

searching for a global optimum solution, the efficiency of the search process of most metaheuristic algorithms, to some extent, greatly depends on their ability to strike a balance between exploration and exploitation. According to Tashkova *et al.* (2012) and Fister *et al.* (2013) the exploration process guides each metaheuristic in discovering the diverse solutions within the search space. In other words, the exploration process assists in enabling the metaheuristic to attain the new searching region of the search space. It helps to prevent the premature convergence into local optimum; however, it will slow the convergence rate. The exploitation process enables the metaheuristic to focus the search process within the neighborhoods of the current best solutions. It allows convergence rapidly to the optimum solution in the region, with a consequence of being trapped in local optimum prematurely. (Interested readers may consult Črepinšek *et al.* (2011) and Črepinšek *et al.* (2013) for more information about studies on exploration and exploitation in evolutionary algorithms).

It is noteworthy to mention here that despite the proliferations in the number of new metaheuristic algorithms, nearly all of them share the same common characteristics (Boussaid *et al.*, 2013; Ishibuchi *et al.*, 2013; Cheng and Prayogo, 2014). Some of the shared characteristics include the following: they all draw their inspirations from nature, they have parameters that need to be fine-tuned to make them adaptable for the problem at hand, and they do not require substantial gradient information. However, each metaheuristic possesses some unique advantages in terms of speed, accuracy, robustness and overall performances in different problem spaces. In addition, studies have shown that there is no single algorithm that is good enough to solve all the optimization problems with their unique problem features (Wolpert and Macready, 1997). Therefore, there is a need for a continuous search for the development of new metaheuristic algorithms to handle different specific optimization problems that emerge.

Some of the notable examples of metaheuristic algorithms that are widely used to solve various optimization problems are the following: Variable Neighborhood Search (VNS) (Mladenović and Hansen, 1997), Tabu Search (TS) (Glover, 1989), Simulated Annealing (SA) (Kirkpatrick *et al.*, 1983), Particle Swarm Optimization (PSO) (Eberhart and Kennedy, 1995), Ant Colony Optimization (ACO) (Dorigo and Di Caro, 1999), Differential Evolution (DE) (Storn and Price, 1997), Cuckoo Search (CS) algorithm (Yang and Deb, 2009), Fire Fly Algorithm (FA) (Yang, 2010b), Flower Pollination Algorithm (FPA) (Yang, 2012), Invasive Weed Optimization (IWO) algorithm (Mehrabian and Lucas, 2006), Bat Algorithm (BA) (Yang, 2010a), Fruit Fly Optimization algorithm (FOA) (Pan, 2012), Artificial Bee Colony (ABC) algorithm (Teodorovic and Dell'Orco, 2005), Bacterial Foraging (BF) algorithm (Passino, 2002), Krill Herd (KH) algorithm (Gandomi and Alavi, 2012), Bees Algorithm (BeeA) (Pham *et al.*, 2011), Particle Bee Algorithm (PBA) (Cheng and Lien, 2012), Cat Swarm Optimization (CSO) algorithm (Chu *et al.*, 2006), Glowwarm Swarm Optimization (GSO) (Krishnanand and Ghose, 2009) and Symbiotic Organisms Search (SOS) algorithm (Cheng and Prayogo, 2014). (Interested readers may also consult the work of Fister Jr *et al.* (2013) for more details on some of the classifications of the nature inspired algorithms).

Among the notable and newly developed metaheuristic algorithms, the SOS algorithm has received significantly wider attention from the optimization research community and other related domains, as a result of the algorithm's implementation simplicity and stability, that results from its parameter-less nature. In addition, the algorithm has equally witnessed a drastic increase in its area of application to several optimization domains as compared to other alternative algorithms or

competitors, which include GA, ACO, PSO, and DE. Therefore, this paper presents a comprehensive review of the standard SOS algorithm, its basic concepts and structures, variants and hybrid implementations for handling constrained, unconstrained, single objective, multi-objective, large scale global optimization problems as well as practical oriented real world optimization problems. The main contribution of this paper consists of: -

- an exhaustive study of the classical SOS algorithm;
- a systematic review of up to date SOS variants and hybrid algorithms;
- an identification and presentation of the various application areas of SOS algorithm in solving both complex and non-linear scientific and engineering design problems;
- suggestions for further development and possible areas of improvement; and
- recommendations for novel application areas for the SOS algorithm.

The paper is structured as follows: The introduction is followed by Section 2 presenting background information including conceptual features and structures of the classical SOS algorithm. Section 3 presents a systematic review of studies on SOS algorithms covering variants and hybrid implementations of the standard algorithm, while in Section 4 the various applications of the SOS in different domains are discussed. Section 5 offers a discussion about the performance validation of the standard SOS algorithm. In Section 6, a discussion about further development and possible improvement on the standard SOS algorithm is presented. Then Section 7 covers critical remarks as well as future perspectives about the symbiotic organisms search algorithm. Lastly, a conclusion is given in Section 8.

2. Symbiotic Organisms Search Algorithm

The symbiotic organisms search (SOS) algorithm was first introduced by Cheng and Prayogo (2014). The standard algorithm is simple and powerful, and employs the perspective of a population-based search strategy by guiding a population of candidate solutions to search for promising optimum region iteratively until a global optimum solution to a given objective function is found. However, it was originally designed for dealing with numerical optimization problems in a continuous solution space, even though it has undergone several transformations that have made it more robust and adaptive to other problem spaces. SOS is inspired by the relationship among different organisms which live together in one ecosystem and continuously strive and compete for survival or to grow together. This phenomenon is referred to as 'symbiosis' in biology.

2.1. Symbiosis relationships

Symbiosis is a phenomenon used to describe the kind of adaptive relationships or interactions that often exist between any two distinctive organisms or species that cohabit in the natural ecosystem. This form of cohabitation between two different organisms is further subdivided into obligate and facultative types of relationships (Cheng and Prayogo, 2014). The obligate symbiosis defines the type of relationship between two different species of organisms that are inclusively dependent on each other for their survival, while the facultative variety of symbiosis defines a relationship method between two different species of organisms that decide to cohabit in a mutually beneficial but nonessential relationship (Cheng and Prayogo, 2014).

The three fundamental symbiotic relationships types found among organisms include mutualism, commensalism and parasitism. These three modes of interactive interrelationships are described

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