Computers and Structures 139 (2014) 98–112

Contents lists available at ScienceDirect

Computers and Structures

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

Symbiotic Organisms Search: A new metaheuristic optimization algorithm

Min-Yuan Cheng [1], Doddy Prayogo *

Dept. of Civil and Construction Engineering, National Taiwan University of Science and Technology, #43, Sec. 4, Keelung Rd., Taipei 106, Taiwan, ROC

ARTICLE INFO

Article history:
Received 23 May 2013
Accepted 24 March 2014
Available online 10 May 2014

Keywords:
Metaheuristic
Optimization
Symbiotic Organisms Search
Symbiotic interaction
Structural design problems

ABSTRACT

This paper applies a new robust and powerful metaheuristic algorithm called Symbiotic Organisms Search (SOS) to numerical optimization and engineering design problems. SOS simulates the symbiotic interaction strategies adopted by organisms to survive and propagate in the ecosystem. Twenty-six unconstrained mathematical problems and four structural engineering design problems are tested and obtained results compared with other well-known optimization methods. Obtained results confirm the excellent performance of the SOS method in solving various complex numerical problems.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

Engineering optimization is a challenging area of study that has attracted increasing attention in recent decades. Various gradient-based optimization methods have been developed to solve various engineering optimization problems. Most use analytical or numerical methods that require gradient information to improve initial solutions. However, gradient-based optimization methods are inadequate to resolve the complexities inherent in many of today's real-world engineering design problems. Moreover, gradient search in problems with greater than one local optimum is difficult and unstable [1]. Shortcomings in current gradient-based approaches to engineering optimization have thus encouraged researchers to develop better engineering optimization methods.

Research worldwide in the metaheuristic field has produced optimization methods that have proven superior to traditional gradient-based approaches. Osman and Laporte defined metaheuristic as an iterative generation process that integrates different concepts for exploring and exploiting the search space to guide a subordinate heuristic, with learning strategies used to structure information to find efficiently near-optimal solutions [2]. Examples of metaheuristic algorithms include: Genetic Algorithm (GA) [3], Particle Swarm Optimization (PSO) [4], Differential Evolution (DE) [5], Ant Colony Optimization (ACO) [6], Harmony Search (HS) [7], Artificial Bee Colony (ABC) [8], Bees Algorithm (BA) [9], Firefly Algorithm [10], Charge System Search (CSS) [11,12], Big Bang–Big Crunch (BB–BC) [13], Cuckoo Search (CS) [14], Mine Blast Algorithm (MBA) [15], Water Cycle Algorithm [16], Dolphin Echolocation [17], and Ray Optimization [18].

Nearly all metaheuristic algorithms share the same following characteristics: they are nature-inspired; they make use of random variables; they do not require substantial gradient information; and they have several parameters that need to be fitted to the problem at hand [19]. Each metaheuristic algorithm has unique advantages with respect to robustness and performance in noisy environments, in the presence of uncertain parameters, and in different problem spaces [20]. However, in line with the "no-free-lunch" theorem, it is impossible for one metaheuristic algorithm to optimally solve all optimizing problems [21]. Thus, new high-performance metaheuristic algorithms are continuously needed to handle specific optimizing problems.

This paper introduces a new simple and powerful metaheuristic algorithm called Symbiotic Organisms Search (SOS). This algorithm simulates symbiotic interaction strategies that organisms use to survive in the ecosystem. A main advantage of the SOS algorithm over most other metaheuristic algorithms is that algorithm operations require no specific algorithm parameters.

The rest of the paper is organized as follows: Section 2 introduces the SOS algorithm in detail; Section 3 compares SOS performance against well-known algorithms, including GA, DE, PSO, BA, MBA, and CS; Section 4 discusses SOS performance characteristics; and Section 5 presents conclusions.

* Corresponding author at: Dept. of Civil and Construction Engineering, National Taiwan University of Science and Technology, #43, Sec. 4, Keelung Rd., Taipei 106, Taiwan, ROC. Tel.: +886 981892384; fax: +886 2 27301074.

E-mail addresses: myc@mail.ntust.edu.tw (M.-Y. Cheng), doddyprayogo@ymail.com (D. Prayogo).

[1] Tel.: +886 2 27336596; fax: +886 2 27301074.

http://dx.doi.org/10.1016/j.compstruc.2014.03.007
0045-7949/© 2014 Elsevier Ltd. All rights reserved.

2. The Symbiosis Organisms Search (SOS) algorithm

The proposed SOS algorithm simulates the interactive behavior seen among organisms in nature. Organisms rarely live in isolation due to reliance on other species for sustenance and even survival. This reliance-based relationship is known as symbiosis. The following subsection clarifies the meaning of symbiosis, gives examples of symbiotic relationship archetypes, and describes the role of symbiosis in ecosystems.

2.1. The basic concept of symbiosis

Symbiosis is derived from the Greek word for "living together". De Bary first used the term in 1878 to describe the cohabitation behavior of unlike organisms [22]. Today, symbiosis is used to describe a relationship between any two distinct species. Symbiotic relationships may be either obligate, meaning the two organisms depend on each other for survival, or facultative, meaning the two organisms choose to cohabitate in a mutually beneficial but nonessential relationship.

The most common symbiotic relationships found in nature are mutualism, commensalism, and parasitism. Mutualism denotes a symbiotic relationship between two different species in which both benefit. Commensalism is a symbiotic relationship between two different species in which one benefits and the other is unaffected or neutral. Parasitism is a symbiotic relationship between two different species in which one benefits and the other is actively harmed.

Fig. 1 illustrates a group of symbiotic organisms living together in an ecosystem. Generally speaking, organisms develop symbiotic relationships as a strategy to adapt to changes in their environment. Symbiotic relationships may also help organisms increase fitness and survival advantage over the long-term. Therefore, it is reasonable to conclude that symbiosis has built and continues to shape and sustain all modern ecosystems.

2.2. The Symbiotic Organisms Search (SOS) algorithm

Current metaheuristic algorithms imitate natural phenomena. For example, Artificial Bee Colony (ABC) simulates the foraging behavior of honeybee swarms, Particle Swarm Optimization simulates animal flocking behavior, and the Genetic Algorithm simulates the process of natural evolution. SOS simulates the symbiotic interactions within a paired organism relationship that are used to search for the fittest organism. The proposed algorithm was developed initially to solve numerical optimization over a continuous search space.

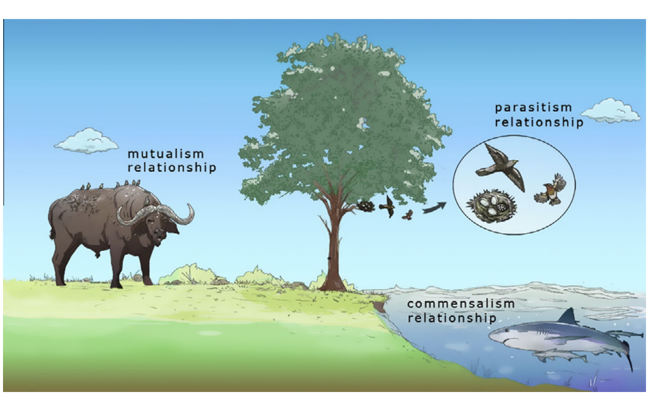

Fig. 1. Symbiotic organisms live together in an ecosystem.

Similar to other population-based algorithms, the proposed SOS iteratively uses a population of candidate solutions to promising areas in the search space in the process of seeking the optimal global solution. SOS begins with an initial population called the ecosystem. In the initial ecosystem, a group of organisms is generated randomly to the search space. Each organism represents one candidate solution to the corresponding problem. Each organism in the ecosystem is associated with a certain fitness value, which reflects degree of adaptation to the desired objective.

Almost all metaheuristic algorithms apply a succession of operations to solutions in each iteration in order to generate new solutions for the next iteration. A standard GA has two operators, namely crossover and mutation. Harmony Search proposes three rules to improvise a new harmony: memory considering, pitch adjusting, and random choosing. Three phases were introduced in the ABC algorithm to find the best food source. These were the employed bee, onlooker bee, and scout bee phases. In SOS, new solution generation is governed by imitating the biological interaction between two organisms in the ecosystem. Three phases that resemble the real-world biological interaction model are introduced: mutualism phase, commensalism phase, and parasitism phase.

The character of the interaction defines the main principle of each phase. Interactions benefit both sides in the mutualism phase; benefit one side and do not impact the other in the commensalism phase; benefit one side and actively harm the other in the parasitism phase. Each organism interacts with the other organism randomly through all phases. The process is repeated until termination criteria are met. The following algorithm outline reflects the above explanation:

- Initialization
- REPEAT
  – Mutualism phase
  – Commensalism phase
  – Parasitism phase
- UNTIL (termination criterion is met)

Fig. 2 describes detailed SOS algorithm procedures and the next section provides further details on the three phases.

2.2.1. Mutualism phase

An example of mutualism, which benefits both organism participants, is the relationship between bees and flowers. Bees fly amongst flowers, gathering nectar to turn into honey – an activity that benefits bees. This activity also benefits flowers because bees distribute pollen in the process, which facilitates pollination. This SOS phase mimics such mutualistic relationships.

In SOS, X_i is an organism matched to the ith member of the ecosystem. Another organism X_j is then selected randomly from the ecosystem to interact with X_i. Both organisms engage in a mutualistic relationship with the goal of increasing mutual survival advantage in the ecosystem. New candidate solutions for X_i and X_j are calculated based on the mutualistic symbiosis between organism X_i and X_j, which is modeled in Eqs. (1) and (2).

$$X_{inew} = X_i + rand(0,1) * (X_{best} - Mutual\_Vector * \mathrm{BF}_1) \quad (1)$$

$$X_{jnew} = X_j + rand(0,1) * (X_{best} - Mutual\_Vector * \mathrm{BF}_2) \quad (2)$$

$$Mutual\_Vector = \frac{X_i + X_j}{2} \quad (3)$$

$rand(0,1)$ in Eqs (1) and (2) is a vector of random numbers.

The role of BF_1 and BF_2 is explained as follows. In nature, some mutualism relationships might give a greater beneficial advantage for just one organism than another organism. In other words,

Download English Version:

https://daneshyari.com/en/article/509726

Download Persian Version:

https://daneshyari.com/article/509726

Daneshyari.com