Applied Soft Computing 30 (2015) 614–627

Contents lists available at ScienceDirect

Applied Soft Computing

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

A social spider algorithm for global optimization

James J.Q. Yu *, Victor O.K. Li

Department of Electrical and Electronic Engineering, The University of Hong Kong, Pokfulam, Hong Kong

ARTICLE INFO

Article history:
Received 19 August 2014
Received in revised form 23 January 2015
Accepted 9 February 2015
Available online 17 February 2015

Keywords:
Social spider algorithm
Global optimization
Swarm intelligence
Evolutionary computation
Meta-heuristic

ABSTRACT

The growing complexity of real-world problems has motivated computer scientists to search for efficient problem-solving methods. Metaheuristics based on evolutionary computation and swarm intelligence are outstanding examples of nature-inspired solution techniques. Inspired by the social spiders, we propose a novel social spider algorithm to solve global optimization problems. This algorithm is mainly based on the foraging strategy of social spiders, utilizing the vibrations on the spider web to determine the positions of preys. Different from the previously proposed swarm intelligence algorithms, we introduce a new social animal foraging strategy model to solve optimization problems. In addition, we perform preliminary parameter sensitivity analysis for our proposed algorithm, developing guidelines for choosing the parameter values. The social spider algorithm is evaluated by a series of widely used benchmark functions, and our proposed algorithm has superior performance compared with other state-of-the-art metaheuristics.

© 2015 Elsevier B.V. All rights reserved.

1. Introduction

With the fast growing size and complexity of modern optimization problems, evolutionary computing is becoming increasingly attractive as an efficient tool for optimization. Depending on the nature of phenomenon simulated, evolutionary computing algorithms can be classified into two important groups: evolutionary algorithms (EAs) and swarm intelligence based algorithms. EAs, which mainly draw inspiration from nature, have been shown to be very successful for optimization among all the methods devised by the evolutionary computation community. Currently several types of EAs have been widely employed to solve real world combinatorial or global optimization problems, including genetic algorithm (GA), genetic programming (GP), evolutionary strategy (ES) and differential evolution (DE). These algorithms demonstrate satisfactory performance compared with conventional optimization techniques, especially when applied to solve non-convex optimization problems [1,2].

In the past two decades, swarm intelligence, a new kind of evolutionary computing technique, has attracted much research interest [3]. The term swarm is employed in a general manner to refer to any collection of interactive agents. Swarm intelligence is mainly concerned with the methodology to model the behavior of social animals and insects for problem solving. Researchers devised optimization algorithms by mimicking the behavior of ants, bees, bacteria, fireflies and other organisms. The impetus of creating such algorithms was provided by the growing needs to solve optimization problems that were very difficult or even considered intractable.

Among the commonly seen animals, spiders have been a major research subject in bionic engineering for many years. However, most research related to spiders focused on the imitation of its walking pattern to design robots, e.g. [4]. A possible reason for this is that a majority of the spiders observed are solitary [5], which means that they spend most of their lives without interacting with others of their species. However, among the 35 000 spider species observed and described by scientists, some species are social. These spiders, e.g. *Mallos gregalis* and *Oecobius civitas*, live in groups and interact with others in the same group. Based on these social spiders, this paper formulates a new global optimization method to solve optimization problems.

Spiders are air-breathing arthropods. They have eight legs and chelicerae with fangs. Spiders have been found worldwide and are one of the most diverged species among all groups of organisms. They use a wide range of strategies for foraging, and most of them detect prey by sensing vibrations. Spiders have long been known to be very sensitive to vibratory stimulation, as vibrations on their webs notify them of the capture of prey. If the vibrations are in a defined range of frequency, spiders attack the vibration source. The social spiders can also distinguish vibrations generated by the prey with ones generated by other spiders [6]. The social spiders passively receive the vibrations generated by other spiders

* Corresponding author. Tel.: +852 64301673.
E-mail addresses: jqyu@eee.hku.hk (J.J.Q. Yu), vli@eee.hku.hk (V.O.K. Li).

http://dx.doi.org/10.1016/j.asoc.2015.02.014
1568-4946/© 2015 Elsevier B.V. All rights reserved.

on the same web to have a clear view of the web. This is one of the unique characteristics which distinguishes the social spiders from other organisms as the latter usually exchange information actively, which reduces the information loss to some degree but increases the energy used per communication action [7].

The group living phenomenon has been studied intensively in animal behavior ecology. One of the reasons that animals gather and live together is to increase the possibility of successful foraging and reduce the energy cost in this process [8]. In order to facilitate the analysis of social foraging behavior, researchers proposed two foraging models: information sharing (IS) model [9] and producer–scrounger (PS) model [10]. The individuals under the IS model perform searching and seek for opportunity to join other individuals simultaneously. In the PS model, the individuals are divided into leaders and followers. Since there is no leader in social spiders [11], the IS model is more suitable to formulate the foraging behavior of social spiders, and we use this model to control the searching pattern of our proposed algorithm.

In this paper, inspired by the social behavior of the social spiders, especially their foraging behavior, we propose a new metaheuristic for global optimization: the social spider algorithm (SSA). The foraging behavior of the social spider can be described as the cooperative movement of the spiders towards the food source position. The spiders receive and analyze the vibrations propagated on the web to determine the potential direction of a food source [12]. We utilize this natural behavior to perform optimization over the search space in SSA.

The contribution of this paper is threefold:

- We propose a new nature-inspired swarm intelligence algorithm based on social spiders. This population-based general-purpose metaheuristic demonstrates outstanding performance in the global optimization benchmark tests.
- We introduce a new social animal foraging model into metaheuristic design. This is the very first attempt of employing the IS model to solve optimization problems. We also incorporate the information loss schemes in the algorithm, which is a unique design of our proposed algorithm.
- We perform a series of experiments to investigate the impact of different parameters and searching schemes on the performance of the algorithm. The result of these experiments may serve as important inputs for further research.

The rest of this paper is organized as follows. We will first present some related work on swarm intelligence and bio-inspired metaheuristics in Section 2. Then we will formulate and elaborate on SSA by idealizing and imitating the foraging behavior of social spiders in Section 3. Section 4 introduces the benchmark functions we use for testing the performance of SSA, with the experimental settings. Section 5 presents the simulation results of SSA on the benchmark functions and the comparison with other popular metaheuristics. Finally we will conclude this paper in Section 6 and propose some future work.

2. Background

Swarm intelligence algorithms mimic the methods in nature to drive a search for the optimal solution. At the very beginning there are two major methods for this kind of algorithms: ant colony optimization (ACO) [13] and particle swarm optimization (PSO) [14].

ACO is inspired by the foraging behavior of ants, whose goal is to find a shortest path from their colony to food sources. In this metaheuristic, feasible solutions of the optimization problem to be solved are represented by the paths between the colony and food sources. The ants communicate with and influence others using pheromone, a volatile chemical substance. When an ant finds a food source, it deposits certain amount of pheromone along the path and the amount is positively correlated with the quality of the food source. The pheromone laid down biases the path selection of other ants, providing positive feedback. Using the scheme of positive feedback, the algorithm leads the ants to find the shortest path to a best food source [13].

PSO is motivated by the movement of organisms as a group, as in a flock of birds or a school of fishes. The group is represented by a swarm of particles and PSO uses their positions in the search space to represent the feasible solutions of the optimization problem. PSO manipulates the movement of these particles to perform optimization, utilizing the information of individual experience and socio-cognitive tendency. These two kinds of information correspond to cognitive learning and social learning, respectively, and lead the population to find a best way to perform optimization [14].

The above two metaheuristics have been applied to solve a vast range of different problems, e.g. [15,16]. Motivated by such success, swarm intelligence algorithm design has attracted many researchers and several new algorithms were devised. The most widely studied organism in swarm intelligence is the bee [3]. Abbass proposed a Marriage in honey Bees Optimization (MBO) in [17] and this algorithm was applied to solve propositional satisfiability problems (3-SAT problems). In MBO, the mating flight of the queen bee is represented as the transitions in a state space (search space), with the queen probabilistically mating with the drone encountered at each state. The probability of mating is determined by the speed and energy of the queen, and the fitness of the drone. Karaboga and Basturk proposed an Artificial Bee Colony optimization (ABC) in [18]. ABC classifies the bees in a hive into three types: “scout bees” that randomly fly without guidance, “employed bees” that search the neighborhood of their positions, and “onlooker bees” that use the population fitness to select a guiding solution for exploitation. The algorithm balances exploration and exploitation by means of using employed and onlooker bees for local search, and the scout bees for global search. It also demonstrates satisfactory performance in applications [19,20].

Besides the bees, other organisms have also been widely studied [3]. Krishnanand and Ghose proposed a Glow-worm Swarm Optimization (GSO) [21] based on the behavior of the firefly. In GSO, each firefly randomly selects a neighbor according to its luminescence and moves toward it. In general the fireflies are more likely to get interested in others that glow brighter. As the movement is only conducted locally using selective neighbor information, the firefly swarm is able to divide into disjoint subgroups to explore multiple optima. Another firefly-based technique is proposed by Yang et al. [22]. He reformulated the co-movement pattern of fireflies and employed it in optimization. Passino devised a Bacterial Foraging Optimization (BFO) [23] based on the bacterial chemotaxis. In BFO, possible solutions to the optimization problem are represented by a colony of bacteria. It consists of three schemes, i.e., chemotaxis, reproduction, and elimination-dispersal. The exploitation task is performed using the first two schemes and the last one contributes to exploration [24]. Researchers have also devised swarm intelligence algorithms based on other organisms and they can also generate satisfactory optimization performance [3]. To the best of our knowledge, only one spider-inspired metaheuristic aiming at solving optimization problem has been proposed, i.e. the social spider optimization [25] devised by Cuevas et al., which divides the spiders into different genders and mimics the mating behavior for optimization. However, our proposed algorithm is totally different from this algorithm in their biological backgrounds, motivations, implementations, and search behaviors. We will further reveal the differences in Section 3.4.

Download English Version:

https://daneshyari.com/en/article/495093

Download Persian Version:

https://daneshyari.com/article/495093

Daneshyari.com