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A novel meta-heuristic optimization algorithm inspired by group hunting of animals: Hunting search

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ABSTRACT

A novel optimization algorithm is presented, inspired by group hunting of animals such as lions, wolves, and dolphins. Although these hunters have differences in the way of hunting, they are common in that all of them look for a prey in a group. The hunters encircle the prey and gradually tighten the ring of siege until they catch the prey. In addition, each member of the group corrects its position based on its own position and the position of other members. If the prey escapes from the ring, hunters reorganize the group to siege the prey again. Several benchmark numerical optimization problems, constrained and unconstrained, are presented here to demonstrate the effectiveness and robustness of the proposed Hunting Search (HuS) algorithm. The results indicate that the proposed method is a powerful search and optimization technique. It yields better solutions compared to those obtained by some current algorithms when applied to continuous problems.

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1. Introduction

Classical methods often face great difficulties in solving optimization problems that abound in the real world. In order to overcome the shortcomings of traditional mathematical techniques, nature-inspired soft computing algorithms have been introduced.

Several evolutionary or meta-heuristic algorithms have since been developed which combine rules and randomness mimicking natural phenomena. These phenomena include biological evolutionary processes (e.g., the evolutionary algorithm proposed by Fogel et al. [1], De Jong [2], and Koza [3] and the genetic algorithm (GA) proposed by Holland [4] and Goldberg [5]), animal behavior (e.g., the tabu search proposed by Glover [6]), the physical annealing process (e.g., simulated annealing proposed by Kirkpatrick et al. [7]) and the musical process of searching for a perfect state of harmony (proposed by Geem et al. [8], Lee and Geem [9] and Geem [10] and proceeded with other researchers [11,12]).

Many researchers have recently studied these meta-heuristic algorithms, especially GA-based methods, to solve various optimization problems. However, new heuristic algorithms are needed to solve difficult and complicated real-world problems.

The method introduced in this paper is a meta-heuristic algorithm which simulates the behavior of animals hunting in a group (lions, wolves, etc.). Group hunters have certain strategies to encircle the prey and catch it. Wolves, for instance, rely on this kind of hunt very much, so they can hunt animals bigger or faster than themselves. They choose one prey and the group gradually moves toward it. They do not stand in the wind such that the prey senses their smell. We employ this idea in constrained problems to avoid forbidden areas. In our algorithm, each of the hunters indicates one solution for a particular problem. Like real animals which hunt in a group, artificial hunters cooperate to find and catch the prey; i.e., the optimum point in our work.

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2. Hunting search meta-heuristic algorithm

Meta-heuristic algorithms imitate natural phenomena, e.g. physical annealing in simulated annealing, human memory in a tabu search, and evolution in evolutionary algorithms. A new Hunting Search (HuS) meta-heuristic algorithm is conceptualized here using the hunt process in catching a prey in the group hunting. Cooperation of the members of the group called hunters leads to encircling a prey and catching it (the group's food), similar to the optimization process which results in finding a global solution (a perfect state) as determined by an objective function. The position of each hunter compared to the prey determines its chance of catching the prey. Similarly, the objective function value is determined by the set of values assigned to each decision variable. The new HuS meta-heuristic algorithm is derived based on a model of group hunting of animals when searching for food such as the way in which wolves hunt.

In continuous optimization problems, the estimation of a solution is carried out by putting values of decision variables into the objective function or fitness function. This evaluates the function value, which includes cost, efficiency, and/or error. Therefore, a model for a continuous optimization problem may be formally defined as follows.

Definition 2.1. A model of a continuous optimization problem, generally shown as $Q = (\boldsymbol{S}, \boldsymbol{\Omega}, f)$, has the following features.

- A search space defined over a finite set of continuous decision variables ($\boldsymbol{S}$).
- A set of constraints among the variables ($\boldsymbol{\Omega}$).
- An objective function to be minimized ($f : \boldsymbol{S} \to \mathbb{R}_{\boldsymbol{0}}^{+}$).

The search space ($\boldsymbol{S}$) is defined as a set of N continuous variables ($x_i,\ i = 1, \dots, N$ with values $v_i \in \boldsymbol{D}_i \subseteq \mathbb{R}$), where N is the number of design variables. A solution $s \in \boldsymbol{S}$ which satisfies all the constraints in the set $\boldsymbol{\Omega}$ is a feasible solution. Q is called an unconstrained problem if the set $\boldsymbol{\Omega}$ is empty; otherwise, it is called a constrained problem. A solution $s^* \in \boldsymbol{S}$ is called a global minimum if and only if $f(s^*) \le f(s)\ \forall s \in \boldsymbol{S}$. Solving a continuous optimization problem requires at least one global minimum.

Compared to group hunting, in a continuous optimization problem each 'hunter' is replaced with a 'solution' of the problem (or as we call it an 'artificial hunter'). Note that group hunting of animals and our meta-heuristic algorithm have a primary difference. In group hunting of animals (our emphasis is on animals that hunt on land such as wolves and lions), hunters can see the prey or when they hunt at night at least they can sense the smell of the prey and determine its position. In contrast, in optimization problems we have no indication of the optimum solution/point. In group hunting of animals, however, the solution (prey) is dynamic and the hunters (based on the current position of the prey) must correct their position. In optimization problems instead, the optimum solution is static and does not change its position during the search process. In fact, both real and artificial group hunting have their own difficulties. To resemble this dynamics of the hunting process in our algorithm, artificial hunters move towards the leader. The leader is the hunter which has the best position at the current stage (the optimum solution among current solutions at hand). In fact, we assume that the leader has found the optimum point and other members move towards it. If any of them finds a point better than the current leader, it becomes leader in the next stage.

Real animals not only gradually move toward the prey but also (based on the position of other hunters and the position of the prey) correct their position. Therefore, in this algorithm, after moving toward the previous leader, the hunters correct their position based on the position of other members. This is accomplished by introducing the 'hunting group consideration rate' (HGCR), which is defined later.

In addition in the group hunting of real animals, if the prey escapes out of the ring, the hunters organize themselves to encircle the prey again. In the HuS algorithm, the ability will be given to hunters, so they can search out of the ring of siege.

In the algorithm, if the positions of the hunters/solutions are too close to each other, the group is reorganized to find the optimum point in the next effort.

Fig. 1 displays the procedure of the Hunting Search algorithm, which consists of the following steps.

Step 1. Specify the optimization problem and parameters of the algorithm.
Step 2. Initialize the hunting group (HG).
Step 3. Move toward the leader.
Step 4. Correct the positions (cooperation between members).
Step 5. Reorganize the hunting group.
Step 6. Repeat Steps 3, 4 and 5 until the termination criterion is satisfied.

The details follow.

Step 1. *Initialize the optimization problem and algorithm parameters*.
The problem is defined as the model that is presented in Definition 2.1. The HuS algorithm parameters that are required to solve the optimization problem are also specified in this step: hunting group size (number of solution vectors in hunting group HGS), maximum movement toward the leader (MML), and hunting group consideration rate (HGCR), which varies between 0 and 1. The parameters MML and HGCR are parameters that are used to improvise the hunter position (solution vector) that are defined in Steps 3 and 4.

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