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Ant colony optimization for finding the global minimum

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Abstract

The ant colony optimization (ACO) algorithms are multi-agent systems in which the behaviour of each ant is inspired by the foraging behaviour of real ants to solve optimization problem. This paper presents the ACO based algorithm to find global minimum. Algorithm is based on that each ant searches only around the best solution of the previous iteration. This algorithm was experimented on test problems, and successful results were obtained. The algorithm was compared with other methods which had been experimented on the same test problems, and observed to be better.

Keywords: Ant colony optimization; Global minimum; Metaheuristics; Random optimization

1. Introduction

Many heuristic methods such as random search technique (ARSET) [1], heuristic random optimization (HRO) [2] and David–Fletcher method were developed to find global minimum. In this paper, ACO based algorithm will be suggested to find global minimum. ACO belong to class of biologically inspired heuristics. The basic idea of ACO is to imitate the cooperative behaviour of ant colonies.

The function should have many local minimum points, but only one of them is the global minimum. If $F(x_{\min}) \leqslant F(x)$ for all x values, $x_{\min}$ value is defined as the point makes the function minimum. If $F(x)$ is continuous and differentiable, the minimum value can be found on the point $\frac{dF}{dx}$. However, wherever the function is not differentiable, it could prove more advantageous to utilize stochastic methods instead of deterministic ones [1].

The paper is organized as follows. First, ACO will be explained shortly. The proposed ACO based algorithm to find global minimum will be detailed in Section 3. In Section 4, the algorithm will be solved on five benchmark problems. Finally, the proposed algorithm will be compared with other heuristic methods.

2. Ant colony optimization (ACO)

The idea of imitating the behaviour of ants for finding good solutions to combinatorial optimization problems was initiated by Dorigo [3]. The principle of these methods is based on the way ants search for food and

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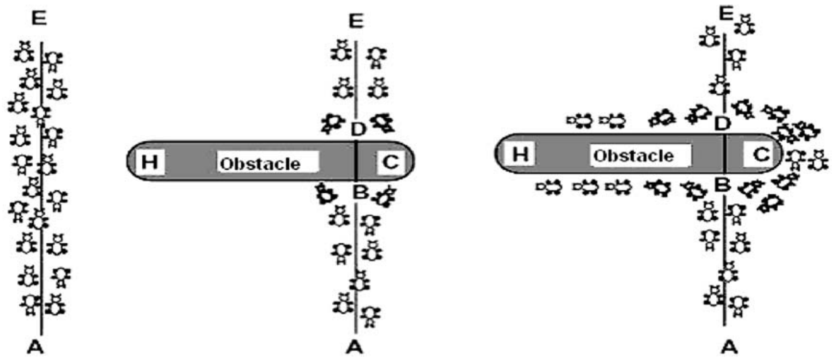

Fig. 1. Ants finding the shortest path around an obstacle.

Step 1. Initialization
- Initialize pheromone trail

Step 2. Solution construction
- For each ant Repeat
  Solution construction using the pheromone trail

Step 3. Update the pheromone trail
  Until stopping criteria

Fig. 2. A generic ACO algorithm.

find their way back to the nest. During trips of ants a chemical trail called pheromone is left on the ground. The role of pheromone is to guide the other ants towards the target point. For one ant, the path is chosen according to the quantity of pheromone.

As illustrated in Fig. 1, when facing an obstacle, there is an equal probability for every ant to choose the left or right path. As the left trail is shorter than the left one and so required less travel time, it will end up with higher level of pheromone. More the ants will take the right path, higher the pheromone trail is. This fact will be increased by the evaporation stage.

The general ACO algorithm is illustrated in Fig. 2. The procedure of the ACO algorithm manages the scheduling of three activities [4,5]: The first step consists mainly in the initialization of the pheromone trail. In the iteration (second) step, each ant constructs a complete solution to the problem according to a probabilistic state transition rule. The state transition rule depends mainly on the state of the pheromone. The third step updates quantity of pheromone; a global pheromone updating rule is applied in two phases. First, an evaporation phase where a fraction of the pheromone evaporates, and then a reinforcement phase where each ant deposits an amount of pheromone which is proportional to the fitness of its solution. This process is iterated until a stopping criterion.

3. Ant colony optimization to find global minimum

The ACO algorithm has been used to find global minimum. In the proposed algorithm, first, number of m ants being associated with m random initial vectors (x^k_{initial}, $(k = 1, 2, \ldots, m)$) (or all of them may be set to the same value) (Fig. 3a).

Then, modifications based on the pheromone trail are then applied to each vector. In the proposed ant colony based algorithm, quantity of pheromone (τ_t) only intensifies around the best objective function value obtained from the previous iteration and all ants turned towards there to search a solution (Fig. 3b). The solution vector of each ant is updated at the beginning of each iteration using the following formula:

$$x^k_t = x^{\text{best}}_{t-1} \pm \mathrm{d}x \quad (t = 1, 2, \ldots, I), \tag{3.1}$$