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Optimization of the quadratic assignment problem using an ant colony algorithm

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Abstract

Ant algorithm is a multi-agent systems inspired by the behaviors of real ant colonies function to solve optimization problems. In this paper an ant colony optimization algorithm is developed to solve the quadratic assignment problem. The local search process of the algorithm is simulated annealing. In the exploration of the search space, the evaluation of pheromones which are laid on the ground by ants is used. In this work, the algorithm is analyzed by using current problems in the literature and is compared with other metaheuristics.

Keywords: Ant colony optimization; Simulated annealing; Metaheuristics; Quadratic assignment problem; Combinatorial optimization

1. Introduction

Ant colony optimization (ACO) is a metaheuristic, which is inspired by adaptation of a natural system. The medium used by ants to communicate information regarding shortest paths to food, consist of pheromone trails. ACO has been initiated by Dorigo [1] which has been successfully applied to several NP-hard combinatorial optimization problems such as traveling salesman [2], quadratic assignment problem [3], job-shop scheduling [4], vehicle routing [5], telecommunication networks [6], etc.

The quadratic assignment problem (QAP) is a combinatorial optimization problem has been introduced by Koopmans and Beckman in 1957 [7]. The QAP is a NP-hard (nondeterministic polynomial time complete) optimization problem [8]; even finding a solution within a factor of $(1 + e)$ of the optimal one remains NP-hard [9]. This paper presents a new method for the QAP, this method is a hybridization of the ant colony optimization with a local search method based on simulated annealing (SA). The algorithm is analyzed by using several standard instances. The paper is organized as follows: In Section 2, ACO is described generally.

After QAP is defined in Section 3, our ACO based algorithm for the QAP will be detailed in Section 4. Finally, results of experiments are given and are compared with other metaheuristics.

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2. Ant colony optimization

ACO is based on the natural foraging system found in an ant colony. Ants are used very simple communication mechanism to find the shortest path between any two points. This mechanism is guided by pheromone trail that is left on the ground. The role of this trail is to guide the other ants towards the target point. The idea is that if at a given point an ant has to choose among different paths, those which were heavily chosen by preceding ants (that is, those with a high trail level) are chosen with higher probability. Furthermore high trail levels are synonymous with short paths. As illustrated in Fig. 1, if the path is cut off by an obstacle, there is an equal probability for every ant to choose the left or right path. As the right 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 prefer the right path because of the higher pheromone trail.

ACO algorithms for combinatorial problems follow a specific ant algorithm outlined in Fig. 2.

After the initialization of the pheromone trails and some parameters, iterations are continued. In the each iteration, firstly, each ant construct feasible solution, then the solution is improved by applying local search, and finally pheromone trails are updated. This process is iterated until a stopping criterion.

3. Applying the ACO to the QAP

A large number of metaheuristic methods like simulated annealing (SA), tabu search (TS), genetic algorithm, have been used to solve the QAP.

The QAP represents an important class of NP-hard combinatorial optimization problems. In this section, first, QAP will be defined, then a new method (AntSimulated) will be presented that is a hybridization of the ACO with a local search method based on SA.

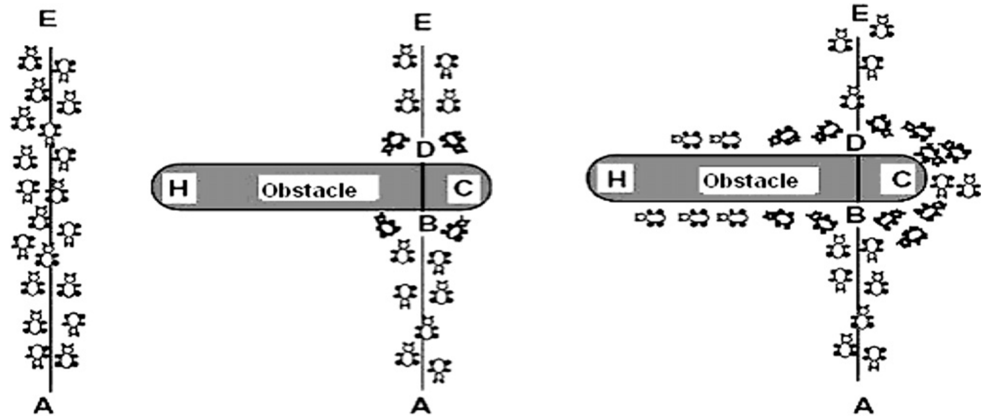

Fig. 1. How real ants find a shortest path.

Initialization
- Set parameters,
- Initialize pheromone trails

Iteration
Repeat (For each ant)
- Construct solution,
- Apply local search,
- Update trails,

Until stopping criteria

Fig. 2. General algorithmic schema for ACO algorithms.