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Application of ant colony algorithm for vehicle routing problems

Abstract: In recent years, mathematical methods based on the natural mechanisms of making decisions are extensively appliedin optimization problems.Repeated studies have shown that the most of the processes occurring in the nature are organized very efficiently. In particular, a number of scientific observations were held, which objects were the ant colonies. During the observation, it was found that the length of the path, laid from the anthill to a food source by ants, was close to the optimum value. Moreover, when the environment changes ant colony quickly adapts and finds new shortcuts.In order to improve the efficiency and quality of vehicle routing problem solution new approaches and algorithms are offered. Swarm intelligence algorithms refer to such a type of methods. Developed modifications of the algorithms will improve the quality of the solutions. Quality of the solutions of vehicle routing problems has direct affect on the pricing of the product. The paper provides an overview of numerical methods for solving vehicle problems and the algorithm of ant colonies is considered in details as an example.

Key words: vehicle routing problems, swarm intelligence, ant colony optimization algorithms.

Introduction

Ant is not quick-witted. Single ant is unable to take the slightest decision. The fact that it is extremely primitive: all its actions are reduced to elementary reactions to the environment and its congeners. Ant is not able to analyze, draw conclusions and look for solutions.

These facts, however, disagree with the success of ant as the species. They exist on the planet over 100 million years, building huge anthills, providing them with all necessary and even leading real wars. In comparison with the utter helplessness of individuals, the achievements of ants seem to be unthinkable.

Ants are able to achieve such success because of their sociality. They live only in groups - colonies. All ants of the colony form so-called swarm intelligence. The individuals that make up the colony should not be intelligent: they should only engage in certain, very simple rules, and then the entire colony will be effective.

In recent years, mathematical methods based on the natural mechanisms of making decisionsobtainmore and more applications in optimization problems.

Repeated studies have shown that the most of the processes occurring in the nature are organized very efficiently. In particular, a number of scientific observations were held, which objects were the ant colonies. During the observation, it was found that the length of the path, laid from the anthill to a food source by ants, was close to the optimum value. Moreover, when the environment changes ant colony quickly adapts and finds new shortcuts.

The results of these studies inspired by an Italian mathematician Marco Dorigo to create an approach known as "Ant Algorithm", which has gained widespread use in optimization problems. This algorithm was considered in the works of Kazharov A.A., Kureichik V.M [1], Novikov A.K. [2].

Setting a vehicle routing problem

Capacitated Vehicle Routing Problem (CVRP) isa combinatorial optimization problem in which the set of routes to distant points of several customers should be determined for parks of the vehicles located in one or more depots, herewith the total weight of all orders on each route must not exceed the carrying capacity of the vehicle carrying freight.

The main purpose of the researchis the minimization of the vehicle park and the total distance traversed by all types of transport. Graphical illustration of the problem is shown in Figure.

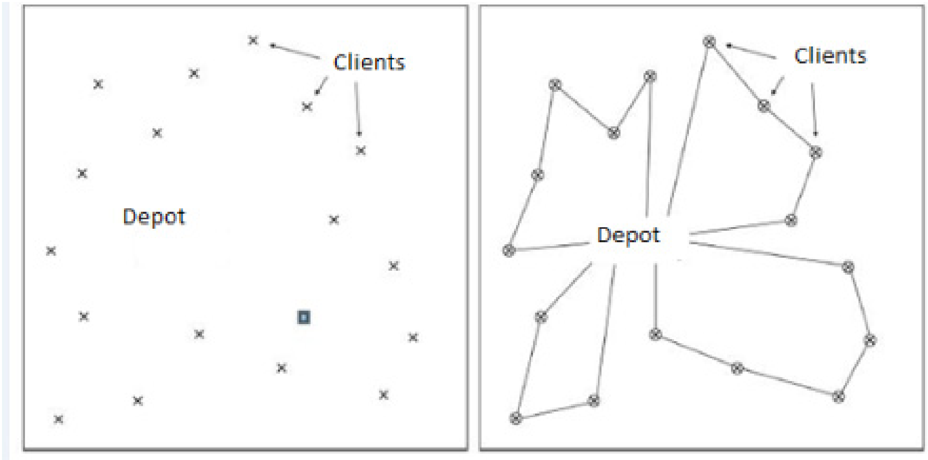

Figure – Graphical illustration of a routing problem

This problem can be represented as a graph *G(V, E)*, where:

$V = \{v_0, v_1, ..., v_n\}$ is a vertex set (v_0 isa depot, $v_{1.n}$is a customer);

E a plurality of ribs $\{(v_i, v_j) \mid i \neq j\}$;

C non- negative matrix of distances(path cost) c_{ij}between consumers;

q_i the volume of cargo shipped the *i*-th customer;

m the number of vehicles;

W capacity constraint of one vehicle;

R_i the route of *i*-th vehicle (*i*=1...m);

(R_i) the route cost R_i;

There are following restrictions on the problem:

- each route begins and ends at the depot;
- each node is part of the route only once;
- each node is visited by only one car;
- the total weight of the order for all the vertices in the route does not exceed W.

The solution of the problem will be a partition of the whole V set of vertices on the routes and the order of traversal on that route.

Basic concepts of the ant algorithm

The basic idea of the ant algorithm is to model the behavior of ant colony in the search path to a food source. Despite the fact that a single ant (system agent) is rather primitive, and alone ant is not able to make optimal decisions, the behavior of the colony in its entirety is reasonable. The intelligence of such kind of system grounded by low-level interaction between agents that occurs via a chemical substance - pheromone laid by ant on its way. Choosing the direction of movement, each agent of the system is based on the experience of previous generations (the amount of pheromone deferred by the colony previously). Thus, the most ants preferred this route, the greater will be delayed pheromone on it, and therefore, the probability, that the next ant will move in this direction, increases. However, this positive feedback can quickly lead to the fact that this route will be the only one, and all the ants will move only in one way. Therefore, in the process of evaporation of pheromone a negative feedback loop is introduced, which ensures us to study new routes.

The behavior of the ants and their properties on choosing the path are described:

1) The ants have their own "memory", which is presented as a list of vertices in which the ant has already been.

2) The ants have a "vision". The quantity, which is inversely proportional to the length of a rib, is accepted as the vision of the ant: $\eta_{ij} = 1/D_{ij}$.

3) The ant is able to pick up the trail of pheromone, which will determine the desire of the ant to pass the rib. Pheromone level at time *t* on the rib D_{ij} will meet $\tau_{ij}(t)$.

4) The transition probability of an ant from vertex *i* to vertex *j* will be determined by the following equation:

$$\begin{cases} P_{ij,k}(t) = \dfrac{[\tau_{ij}(t)]^{\alpha} \cdot \dfrac{1}{[D_{ij}(t)]^{\beta}}}{\sum\limits_{l \in J_{i,k}} [\tau_{il}(t)]^{\alpha} \cdot [\eta_{il}(t)]^{\beta}}, j \in J_{i,k} \\ P_{ij,k}(t) = 0, j \notin J_{i,k}, \end{cases} \qquad (1)$$

where:

α isan empirical coefficient of "the greed" of the algorithm;

β is empirical coefficient of "the herd" of the algorithm;

$J_{i,k}$ is a list of vertices, that have not yet been visited by the ant.

5) On the path each ant lays pheromone, the amount of which is determined by the following formula:

$$\Delta\tau_{ij}(t) = \begin{cases} \frac{Q}{L_{k(t)}}, (i,j) \in T_k(t) \\ 0, (i,j) \notin T_k(t) \end{cases}, \qquad (2)$$

where Q is a parameter having a value of the order of the optimal path, $L_k(t)$ is the length of the route $T_k(t)$.

6) Evaporation of pheromone is determined by the following expression:

$$\tau_{ij}(t+1) = (1-p) * \tau_{ij}(t) + \sum_{k=1}^{m} \Delta\tau_{ij,k}(t), \qquad (3)$$

where m is the number of ants, p is evaporation coefficient $(0 \le p \le 1)$.

7) The maximum weight of the load, which is able to move each ant on one path does not exceed the value of W.

Description of the ant algorithm for the CVRP problem

The set of vertices $V = \{v_0, v_1, ..., v_n\}$, to which the position and weight of the goods to be delivered to each of the vertices are given, goes as input data for this problem.

At the preparatory stage, there is a need to calculate the distance matrix D between all nodes, set the initial amount of pheromone on all arcs, as well as to determine the coefficients α, β, Q, p. The correct choice of these factors has a significant impact on the resulting optimal response of the algorithm.

Then, the loop is initialized on all the ants. Each ant starts to move from the top to the top. To select the next vertex transition probability is estimated to each of the vertices, that has not yet visited by ant. Probability values depend on the value inversely proportional to the length of the arc connecting the current and selected top, as well as the amount of pheromone on a given arc. Probability is calculated according to the rule (1). Then, a random number is generated and the next vertex is selected depending on what probabilistic range it fells to.

If load capacity of ant W has reached the maximum possible load capacity W_{max}, he has to return to the starting vertex (depot), and then continue to bypass the remaining vertices. This process is completed as soon as the list of $J_{i,k}$ not visited by ant vertices becomes empty.

After traversing all the vertices a number of pheromone on route traversed by ant is updated by the formula (2) and evaporation of the pheromone on all the vertices is updated according to the formula (3).

In the next step the length of route L traversed by k-th ant is compared with the best long routes on the current L *. If the value is less than the current best, then we update the information on the best route.

The algorithm ends when all the ants take over all vertices. A lot of routes T^* and the total length of L^* are the answer to the problem.

Conclusion

The Ant Algorithms are well suited for use in conjunction with the local search procedures, allowing to find starting points for them quickly.

An important feature of the Algorithm is that due to the negative feedback, even after a large number of iterations, the set of solutions are investigated at the same time, which lets minimize the delay time in the local extremes.

Solution of vehicle problems of routing by using classical method allows to get the result of absolute certainty. However, in the real problems the dimension of input data is high. In this case, the time spent on the search for solutions by using classical method becomes unacceptable. In such cases, the application of The Ant Algorithm, which allows to find a solution that is close in size to the optimum in a short time, is extremely effective.

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