CI & A

NATURE INSPIRED CALCULUS

ANT COLONY OPTIMIZATION

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Biological inspiration

Observing an ant colony, it appears that each of them seems to move at random, without purpose. However, suddenly, increasingly larger groups of ants focuse on common directions. This behavior seems to indicate the formation of a **collective intelligence** that is based on the behavior of each individual.

ANT COLONY OPTIMIZATION

Principles

Ants are guided by pheromone trails with different densities.

Exemplu

Let us consider the case of two groups of ants with the same number of members (e.g. 3 ants per group). The two groups have to travel between points A and B, where A is the shelter or place of food storage, and B - the source of food.

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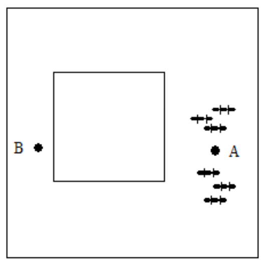

Example

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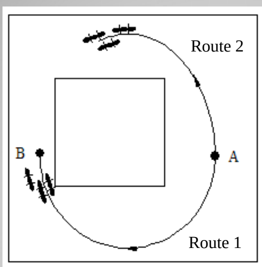

Example

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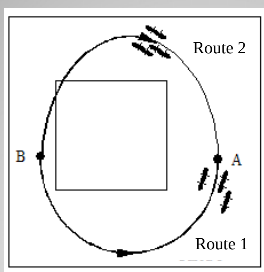

Example

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Implementation

Copying this natural behavior in an artificial algorithm is usually different depending on the type of optimization problem that aims to be resolved. The implementation of ACO algorithm introduces a number of changes to the natural model, changes which usually have a simplifying nature.

Example → **The traveling salesman problem**

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The traveling salesman problem

A salesman must visit a number of customers who live in a certain number of cities.

A feasible solution describes the order in which the traveling salesman should visit the cities so that the total length of the route is minimal.

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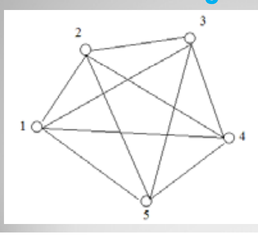
The traveling salesman problem



The solution approach uses a complete graph representation with *N* nodes (cities visited by the salesman) and all branches that can be defined between these nodes.

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The traveling salesman problem

(the algorithm is attached on a printed file)

1. A pheromone concentration τ_{ij} is associated to each branch (*i, j*) in the complete graph. Concentration τ_{ij} will be used to select the path followed by the ant colony, which will be referred to as agents. Initially, concentrations τ_{ij} are set to low positive values (for example, c = 0.01).

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The traveling salesman problem

2. The *NA* agents are evenly distributed (if possible) between nodes in the graph. If the number of nodes and the number of agents are chosen so that $NA = m \cdot N$ (where *m* is an integer), then $m = NA / N$ agents will be distributed in each node. The node where agent *k* is located at a given time is denoted by $City_k$.

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The traveling salesman problem

3. Since constraints exist that each agent must pass through each city without forming cycles (a city is visited once), the path of each agent is stored into a *tabu list*, which contains $N + 1$ elements describing the sequence in which cities are visited. For example, if the five cities are visited by an agent in the order 3, 1, 4, 5 and 2, the associated taboo list should be (3,1,4,5,2,3).

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The traveling salesman problem

4. **Initialization**: Because the problem aims to determine a minimum value, the minimum path length is initialized with a high value, symbolically denoted LMin = ∞. After distributing agents in the nodes of the graph, the taboo list associated to each agent is initialized in the first position with the number of the city where the agent was distributed.

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The traveling salesman problem

5. **Move agents to complete TABOO lists**: for each agent *k*, the current city is considered $i = City_k$ and the destination city j^* is chosen not to appear in the taboo list of agent *k*. City j^* is chosen based on probabilities calculated using pheromone concentration on branches (*i, j*) and the visibility of nodes *j* as "seen" from node *i*, estimated by the inverse of distances between nodes, d_{ij}.

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The traveling salesman problem

Probability to move agent *k* from city *i* to city *j*:

$$P_{ij} = \begin{cases} \dfrac{(\tau_{ij})^{\alpha} \cdot (1/d_{ij})^{\beta}}{\sum_{p \notin Tabu_k} (\tau_{ip})^{\alpha} \cdot (1/d_{ip})^{\beta}} & j \notin Tabu_k \\ 0 & j \in Tabu_k \end{cases}$$

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The traveling salesman problem

6. **Completion of TABOO lists**: after completing *N* steps, when all agents have passed through all nodes in the graph, the path of each agent closes by returning to the home node. Next, calculate the lengths of paths for all agents and store the value of the minimum length. This point in time mark the end of a step / iteration of the algorithm.

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The traveling salesman problem

7. **Update pheromone concentration**: Before moving to the next step, proceed to update pheromone concentrations on each branch of the graph. The amount of pheromone on the graph branches is changed only once, at the end of each cycle / iteration. The amount of pheromone added to each branch is inversely proportional to the length of the entire route traveled by that agent.

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The traveling salesman problem

Updating pheromone concentrations:

$$\tau_{ij} = \rho \cdot \tau_{ij} + \Delta\tau_{ij}$$

Adjustment of pheromone concentrations:

$$\Delta\tau_{ij} = \sum_{k=1}^{NA} \Delta\tau_{ij}^k$$

Individual adjustments:

$$\Delta\tau_{ij}^k = \begin{cases} \dfrac{Q}{L_k} & i, j \in Tabu_k \text{ and } i = Tabu_k(p);\ j = Tabu_k(p+1) \\ 0 & \text{elsewhere} \end{cases}$$

ANT COLONY OPTIMIZATION

Characteristics

- is a natural inspired algorithm
- is a parallel and distributed algorithm
- is a cooperative algorithm
- is a versatile algorithm
- is a robust algorithm