EVOLUTIONARY COMPUTATION ALGORITHM

WEEK #2

MENGSAY’S NOTES

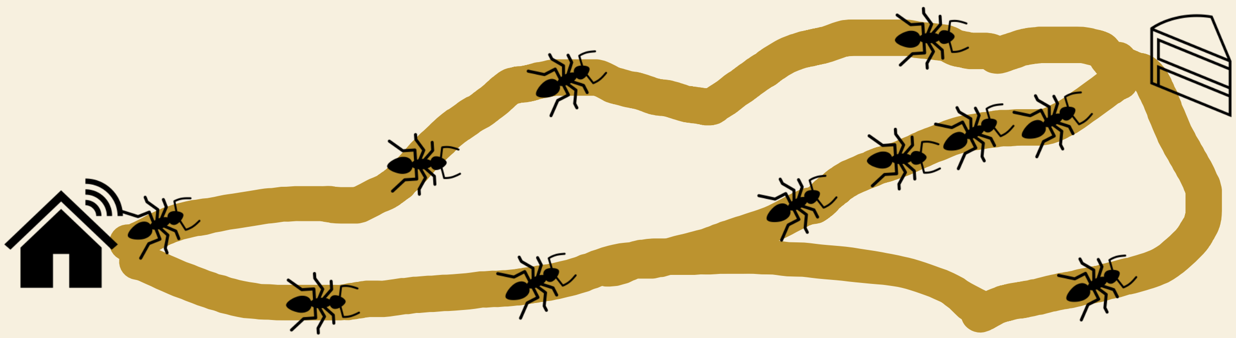
CONTENT

ANT COLONY OPTIMIZATION

CONCEPT AND EXAMPLE WITH TSP

FORAGING BEHAVIOR OF ANTS

- When ants find foods, they carry the food to their nest while attaching a chemical called Trail Pheromone to the ground.
- Ants tend to follow trail pheromone when leading to a feeding site or looking for a new feeding site.



FORAGING BEHAVIOR OF ANTS

- Trail pheromone is volatile substances and evaporate over time
- By comparing the amount of pheromone remaining, they determine the long and short route from nest to feeding site.
  - Long route : less pheromone
  - Short route: more pheromone
- By choosing route with more pheromone, it ends up in result of More ants using the shorter route and Less ants (or zero) using longer route. This lead to a solution to Shortest Path Problem or TSP.

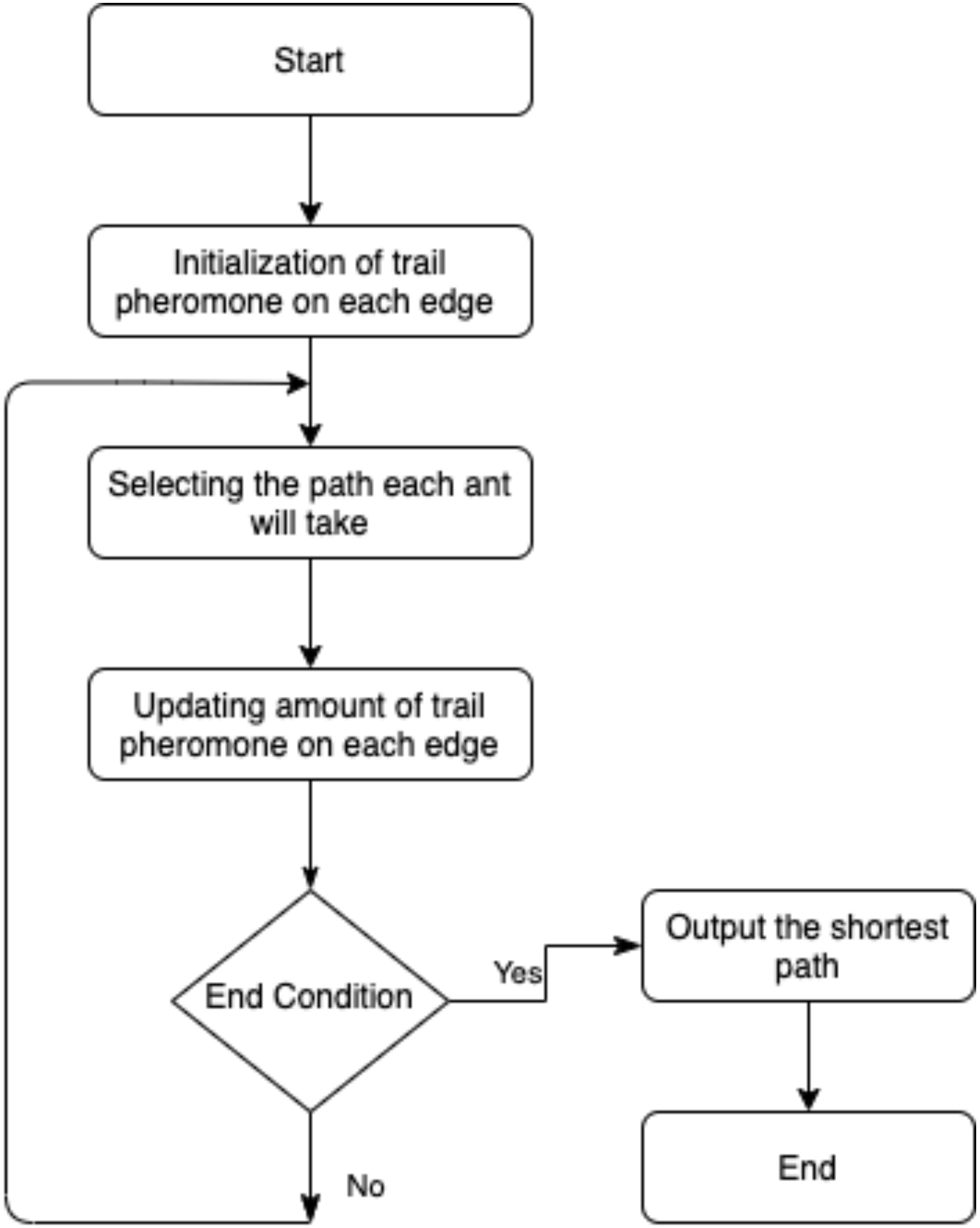
BASIC CONCEPT OF ACO

- Ant Colony Optimization: ACO
- By Marco Dorigo, 1992
- Getting hint from ants' foraging behavior to solve shortest path problem
- Mainly focus on:
  - Ants attache trail pheromone while moving
  - Pathways with more pheromone amount are likely to be selected by ants
  - Trail pheromones evaporate with the passage of time

BASIC CONCEPT OF ACO

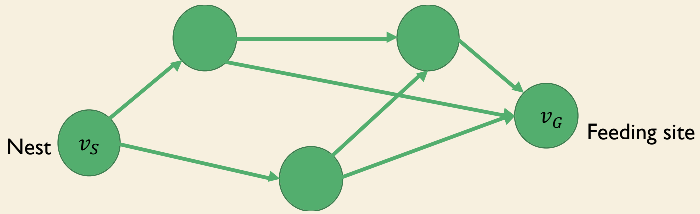
- Assumptions:
  - All ants leave the nest at once to go to the feeding site
  - The difference in pheromone evaporation at each location due to the difference in elapsed time is not considered.
  - The total amount of trail pheromone secreted by one ant in one action is assumed to be constant
  - The pheromone on the pathway is updated after all the ants have finished their moving.
  - Moving from the feeding site to the nest is not considered

ALGORITHM



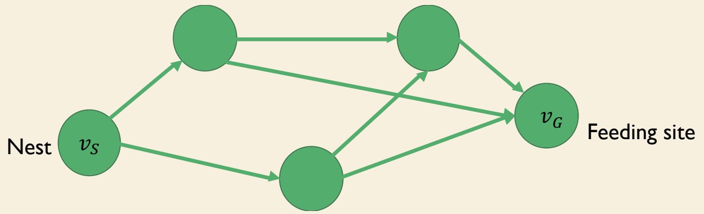
Start
Initialization of trail pheromone on each edge
Selecting the path each ant will take
Updating amount of trail pheromone on each edge
End Condition
Yes
No
Output the shortest path
End

PATH SELECTION



- Consider nest, feeding site, transit points as nodes of a graph with edges labeled by distance values.
- The path taken by each ant is determined by selecting adjacent nodes one by one, from the nest node to the feeding site node.
- We assume that each edge is given heuristic information that influences the ease with which an ant chooses a path to take.
- For example, if a shorter edge is more likely to be selected, the inverse of the distance between the two points is used as heuristic information.

PATH SELECTION



- Let v_s be the nest node. From edges connecting to v_s, select one edge whose another node is v_j. Here, edge with more trail pheromone and large value of heuristic information is likely to be selected.
- Next, from node v_j, again, select edge which have not been visited and connecting to v_j. Then move to another-side node of the selected edge.
- Repeat this process until feeding site node v_G is visited.

PATH SELECTION

- At t-th iteration, the probability that an ant A_k at node v_i will move v_j is defined by $p_{ij}^k(t)$

$$p_{ij}^k(t) = \begin{cases} \dfrac{\psi_{ij}(t)^\alpha h_{ij}^\beta}{\sum_{v_m \in \Omega_{ik}} \psi_{im}(t)^\alpha h_{im}^\beta} & v_j \in \Omega_{ik} \\ 0, & \text{otherwise} \end{cases}$$

- $\psi_{ij}(t)$ is amount of pheromone on edge (v_i, v_j)
- h_{ij} is heuristic information of edge (v_i, v_j)
- Ω_{ik} is set of edges that ant A_k has not visited and connecting to node v_i
- α, β are degree of consideration between pheromone and heuristic information

PHEROMONE SECRETION AND UPDATE

- At t-th iteration, the amount of pheromone secreted by ant A_k on edge (v_i, v_j) is $\Delta\psi_{ij}^k(t)$

$$\Delta\psi_{ij}^k(t) = \begin{cases} \dfrac{Q}{l_k(t)} & (v_i, v_j) \in E_k(t) \\ 0 & \text{otherwise} \end{cases}$$

$E_k(t)$ is set of edges ant A_k used

Q is the total amount of pheromone each ant used in one iteration

$l_k(t)$ is distance of path ant A_k moved.

- At $t + 1$-th iteration, the amount of pheromone is updated

$$\psi_{ij}(t+1) = \rho\psi_{ij}(t) + \sum_{k=1}^{N} \Delta\psi_{ij}^k(t)$$

N is number of ants, ρ is the evaporation ratio

ARTIFICIAL BEE COLONY ALGORITHM

CONCEPT AND EXAMPLE WITH REGRESSION PROBLEM

FORAGING BEHAVIOR OF HONEYBEES

- One queen bee, many worker bees, and a few male bees live in a single hive, sharing the workload.
- Mature worker bees are responsible for tasks related to food(nectar and pollen) collection.
- In addition to collecting nectar, the outside workers are responsible for staying in the hive and exploring new food sources.

FORAGING BEHAVIOR OF HONEYBEES

- The nectar-collecting bees repeat the process of searching near the target food source, collecting nectar, and bringing it back to the hive.
- When they return to the hive, they communicate information about the quality and direction of the food source from which he collected nectar, and the distance to the food source, to the waiting bees in a waggle dance.

FORAGING BEHAVIOR OF HONEYBEES

- Based on the information obtained, the waiting bees determine their target food source, change their role to that of nectar collector, and go out to collect nectar.
- Conversely, bees that have run out of nectar from their target food source will stay in the hive.

BASIC CONCEPT OF ABC

- Artificial Bee Colony algorithm: ABC
- By Dervis Karaboga, 2005
- Mainly focus on
  – It has three roles: collecting nectar, waiting in the hive, and exploring new food sources.
  – Explore and collect nectar near the target food source.
  – Information about the food source is passed on to the waiting bees.
  – Once the bees receive the information about the food source, they will go to the food source they have been told about.
  – If the bees repeatedly collect nectar from the same food source, they will have collected all the nectar they can.

BASIC CONCEPT OF ABC

- When modeling the collection behavior of honeybees, the three roles of honeybees are employed bee, onlooker bee, and scout bee, respectively.
- Assumptions:
  - Employed bees have one food source as their target, and they go to that food source to collect nectar.
  - When the nectar of the target food source is exhausted, the employed bees use the new food source found by the scout bees as the target food source.

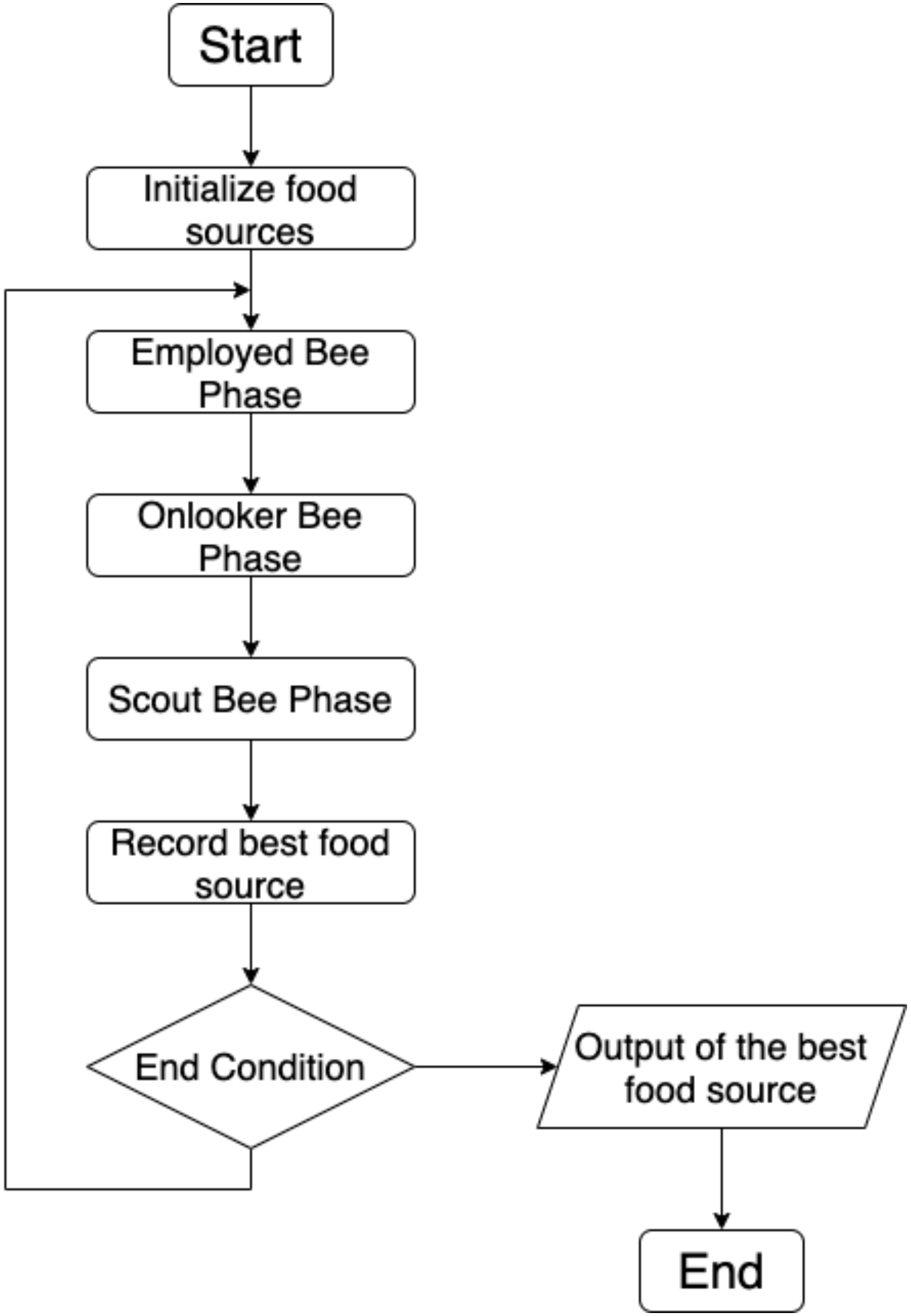
BASIC CONCEPT OF ABC

- Assumptions:
  - The onlooker bees determine the target food source based on the information from the employed bees and go to collect nectar.
  - Even if the onlooker bees decide on a target food source, once they have collected nectar and returned home, they will redecide on the target food source again.
  - Examine one food source near the food source you are headed to, and if it is better than the target, change the target.

BASIC CONCEPT OF ABC

- Assumptions:
  - All the nectar in the food source will be harvested by a specified number of times.
  - Employed bees, Onlooker bees, and Scout bees work in that order.

ALGORITHM



Start
Initialize food sources
Employed Bee Phase
Onlooker Bee Phase
Scout Bee Phase
Record best food source
End Condition
Output of the best food source
End

EMPLOYED BEE PHASE

- First, determine the food source from which the employed bees will collect nectar.
- Instead of searching the vicinity, you will create one new food source near the target food source.
- If the new food source is better, replace the target food source with the new food source and collect honey from the new food source.

EMPLOYED BEE PHASE

- When the target food source for the employed bee B_i is $\overrightarrow{x_i}$, the k-th component of x_i is changed to make the food source $\overrightarrow{y_i}$ near the target food source.
- To change the component, we use the k-th component of x_l, the food source targeted by another employed bee B_l. k and l are randomly chosen numbers.
- j-th component of $\overrightarrow{y_i}$ is defined by

$$y_j^i = \begin{cases} x_j^i + rand[-1,1] \times \left(x_j^i - x_j^l\right), & j = k \\ x_j^i, & \text{otherwise} \end{cases}$$

$rand[-1,1]$: random real numbers between -1, 1

ONLOOKER BEE PHASE

- First, the onlooker bee decides which employed bee to follow.
- Since the onlooker bee gets information about the food source from the dance of the employed bee and determines the target food source, the onlooker bee is determined based on the evaluation of the target food source of the employed bee.

ONLOOKER BEE PHASE

- Probability that employed bee B_k is chosen to target food source F_k is $\Pr(B_k)$

$$\Pr(B_k) = \frac{value(F_k)}{\sum_i value(F_i)}$$

Here, $value(F_i)$ is evaluation of food source F_i

SCOUT BEE PHASE

- Among the food sources targeted by the employed bees, the food source whose nectar collection frequency reaches the specified upper limit C is replaced by a new food source.
- The new food source $\overrightarrow{x_i}$ is generated by the following equation

$$\overrightarrow{x_i} = \begin{pmatrix} x_1^i \\ \vdots \\ x_d^i \end{pmatrix}$$

$$x_j^i = x\_min_j + \left(x\_max_j - x\_min_j\right) \times rand[0,1]$$

$rand[-1,1]$: random real numbers between 0, 1