Ant Colony Meta-heuristic

- **Procedure** AntMetaHeuristic
  - Set parameters, initial pheromone levels
  - **While** (termination condition not met) do
    - Construct Ants’ Solutions
    - Evaluate Solutions
    - Update Pheromones (according to soln goodness)
  - **End**
- **End**
Ant Colony System

- An iterative optimization method, extension of the AntMetaheuristic.
- Was shown to be competitive with state-of-the-art algorithms in solving the TSP.
- When making a choice ants consider:
  - Static (heuristic) distance information
  - Dynamic (pheromone level) experience
Heuristic Computation

- Ants make decisions maximizing
  Heuristic = pheromone * (1 / distance)

Nearness(Blagoevgrad, Sofia) = 1 / 100 = 0.01
Nearness(Blagoevgrad, Varna) = 1/500 = 0.002

Suppose pheromone on both edges is 0.5
Heuristic(Sofia) = 0.5 * 0.01 = 0.005
Heuristic(Varna) = 0.5 * 0.002 = 0.001

Heuristic(Sofia) > Heuristic(Varna)
Solution Construction

Ant is at city \( r \).
The probability of choosing next city to be \( s \) depends on:

1. The heuristic value (nearness * pheromone)
2. The value of a random number \( q \sim (0,1) \) and a threshold \( q_0 = 0.9 \)

If \( q < q_0 \)
   \( r = \text{max heuristic city (exploitation)} \)

Else
   \( r = \text{random proportional choice from non-visited cities (exploration)} \)
## Exploration Mode City Choice

<table>
<thead>
<tr>
<th></th>
<th>Pheromone</th>
<th>Distance</th>
<th>Nearness</th>
<th>Heuristic</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sofia</td>
<td>0.1</td>
<td>100</td>
<td>0.01</td>
<td>0.001</td>
<td>31.25%</td>
</tr>
<tr>
<td>Varna</td>
<td>0.1</td>
<td>500</td>
<td>0.002</td>
<td>0.0002</td>
<td>6.25%</td>
</tr>
<tr>
<td>Bansko</td>
<td>0.1</td>
<td>50</td>
<td>0.02</td>
<td>0.002</td>
<td>62.5%</td>
</tr>
</tbody>
</table>

1. Calculate **Heuristic** for all cities
2. Normalize **Heuristic** values
3. Generate a number (0,360) and select the corresponding city

![Pie Chart]

- **Sofia** 31%
- **Bansko** 63%
- **Varna** 6%
Pheromone Update Rules

- Elitist approach – only the best tour so far is used to globally update pheromone
  - Favors exploitation of the best tour so far

- Local pheromone update – weakens the pheromone trail of an edge, once an ant has traversed it
  - Prevents pheromone trail value explosion
  - Favors exploration and prevents premature convergence
Recap

- Traveling Salesman Problem (TSP)
- Ant Colonies in Nature and Optimization
- Ant Colony Meta-Heuristic Overview
- Ant Colony System
- Test Results
- Applications
- Summary
Initial and Final Tours – gr120

Initial Tour

Final Tour – 200 iterations, 40 ants
Test Results

Different number of ants - TSPLIB gr120

![Graph showing Deviation from Optimal Tour Length - TSPLIB gr120](image-url)
Test Results

- Different number of ants - TSPLIB pr1002

![Graph showing deviation from optimal tour length with different numbers of ants.](image)