Solving the Traveling Salesman Problem with Ant Colony Optimisation

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Optimisation for Artificial Intelligence - Final Project

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Problem Statement

- **Traveling Salesman Problem (TSP):**
  - Find the shortest Hamiltonian circuit in a weighted, complete graph.

  - NP-hard combinatorial optimisation problem.
- **Hamiltonian Circuit:**
  - Path visiting each node once, with the same start and end.
- **Goal:** Minimize the total weight of the path.

Benchmark Datasets

- **Source**: TSPLIB Dataset Repository.
- Worked with graphs of size: 22, 48, 72, 127, 202.

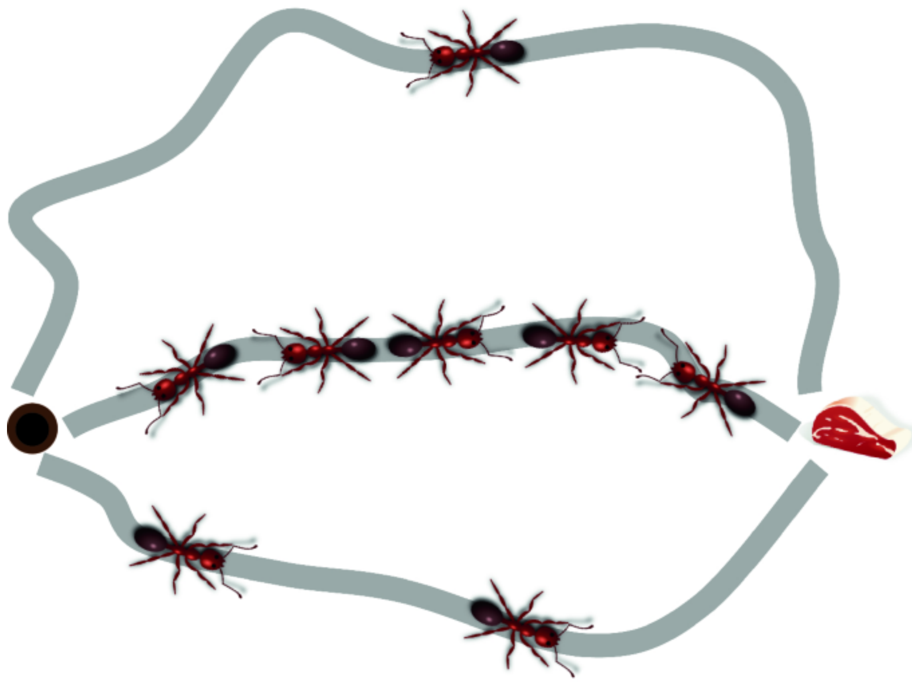

Figure 1: bg vertical w:500 right:50%

Ant Colony Optimisation (ACO) Basics

- **Multiple agents** (ants) independently explore paths.
- **Movement** is based on heuristic information (inverse of edge weight) and by pheromone trails left by ants of previous iterations.
- **Pheromone** is updated at each iteration: uniform evaporation and increasing pheromone in edges of good/common solutions.
- **Exploration:** probabilistic movement ensures diverse solutions.
- **Exploitation:** heuristic edge costs and pheromone informations improve efficiency.

Implemented Algorithm – Design

- `networkx` for graph representation and management.
- **Implemented Classes:**
  - `TSP`: Manages algorithm parameters and updates the pheromone matrix.
  - `Path`: Generates solutions and stores graph and pheromone matrix in class attributes shared by all `path` instances for efficient storing and access.

Algorithm Refinements

- **Gradual Updates of the Coefficients:**
  - Decreasing `alpha` (pheromone weight) and increasing `beta` (heuristic weight) after a fixed amount of steps for better learning.
- **Pheromone Matrix** initialised as 1/`heuristic cost` to favourite an initial smooth update.

- **Handling Numerical Issues:**
  - Ensure comparability (same order of magnitude) between pheromone and heuristic scales: the pheromone and heuristic probabilites of moevement are computed independently and then are joined together weighting by `alpha`and `beta`.
  - When the beta parameter becomes too big, take back the parameters to the configuration of the best path found.
  - Lower bound to the pheromone matrix: some edges are almost never visited and their pheromone tends exponentially to 0.

Parallel Considerations

- **Independence of Agents:**
  - Each agent (ant) works independently, making parallel processing feasible.
- **Possible Parallel Strategy:**
  - Agents access shared graph/pheromone matrix and communicate generated paths to the master process.

  - Suitable for large graphs, where generating a path may be time consuming.

Classical Optimisation Algorithms

In a comparison between 2 Mixed-Integer Linear Programming programs (Hexaly vs Gurobi) made by Hexaly, they claim these results:

Problem Size	Hexaly 13.0	Gurobi 11.0
1 – 100	0.0	0.0
101 – 1000	0.2	28.4

The gaps represent the average percentage gap to the optimal solution within 1 minute of running time, leveraging a AMD Ryzen 7 7700 processor (8 cores, 3.8GHz, 8MB cache) and 32GB RAM.

Conclusion

- The implemented ACO algorithm effectively solves TSP in a reasonable amount of time.
- Achieves sufficiently good solutions (small percentage gap) but struggles to find the global optimum.
- Local (Lamarckian) optimisation techniques improve solution quality.
- Potential for parallel scalability in large-scale problems.