ANALYSIS AND SYNTHESIS OF ALGORITHMS

Routing Algorithm for Ocean Shipping and Urban Deliverie

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Introduction

Travelling Salesperson Problem

In this project we analyse the Travelling Salesperson Problem (TSP) and design heuristics to solve it, using several datasets from the context of ocean shipping and urban deliveries.

Load and parse the provided dataset files

Graph Class

The loadGraphWithFile, loadNodeCoordinates, and loadGraphWithCoordinates functions work together to load and analyze data from the provided datasets. The haversine function is used to calculate distances between nodes based on their geographic regions. These functions ensure that the graph is correctly loaded and ready to be used in implemented TSP algorithms.

Backtracking Algorithm

The Backtracking algorithm implemented in the Graph class explores all possible paths to find the Hamiltonian cycle with the lowest cost. The TSPUtil function does the recursive work of marking nodes, updating paths, and backtracking when necessary, while the TSP function initializes the process and returns the final result. Although finding the optimal solution is guaranteed, its factorial complexity makes it impractical for large graphs, highlighting the need for heuristics such as the triangular approximation for larger-scale problems.

Triangular Approximation Heuristic

The heuristic starts at the starting node and, at each step, visits the closest node that has not yet been visited, until all nodes have been visited. Then, it returns to the starting node to complete the cycle. This approach is more efficient than backtracking, with a time complexity of O(V^2), where V is the number of vertices. It is especially useful for medium to large sized graphs, where the backtracking algorithm would be impractical due to its exponential complexity. Which is often sufficient for practical applications such as urban deliveries.

Heuristics - Small Dataset

Triangular Approximation Heuristic

```
| TRIANGULAR APPROXIMATION HEURISTIC |

Data Load Time: 530 us
Algorithm Time: 0 ms

Approximate Path:
   Cost: 2600
   Path: 0 -> 3 -> 2 -> 1 -> 4 -> 0
```

BackTracking Algorithm

```
| BACKTRACKING ALGORITHM |

Data Load Time: 1270 us
Algorithm Time: 0 ms

Optimal Path:
   Cost: 2600
   Path: 0 -> 3 -> 2 -> 1 -> 4 -> 0
```

Comparison of results shows that, for small graphs, the Backtracking algorithm can be used to obtain the optimal solution. However, as the size of the graph increases, the triangular approximation heuristic becomes a practical and efficient alternative, although it sacrifices some optimality to gain in efficiency. In real-world applications, such as urban deliveries, where calculation speed may be more critical than absolute accuracy, the triangular approximation heuristic is often preferred.

Heuristics - Medium and Large Graphs

Triangular Approximation Heuristic

```
  | TRIANGULAR APPROXIMATION HEURISTIC |

  Data Load Time: 1458 us
  Algorithm Time: 0 ms

  Approximate Path:
     Cost: 309680
     Path: 0 -> 1 -> 2 -> 16 -> 3 -> 19 -> 10 -> 18 -> 21 -> 13 -> 14 -> 11 -> 7 -> 17 -> 24 -> 8 -> 4 -> 22 -> 12 -> 2
3 -> 9 -> 15 -> 5 -> 6 -> 20 -> 0
```

For medium and large graphs, the Triangular Approximation Heuristic is the practical choice due to its efficiency. Although it sacrifices the optimality guaranteed by the Backtracking algorithm, it offers a fast and reasonably good solution, making it ideal for real applications, such as urban deliveries, where response time is critical.

Conclusion

The implementation of the Backtracking algorithms and the Triangular Approximation Heuristic provided a clear understanding of the trade-offs between efficiency and optimality in the context of TSP. While Backtracking is theoretical and guarantees optimal solutions, heuristics have proven to be practical and effective for real applications in urban deliveries. This project demonstrates the importance of choosing the right algorithm for the right problem, considering the specific limitations and needs of the application context.

The End !

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