FACULDADE DE ENGENHARIA
DA UNIVERSIDADE DO PORTO

G16_03

Ocean Shipping & Urban Deliveries

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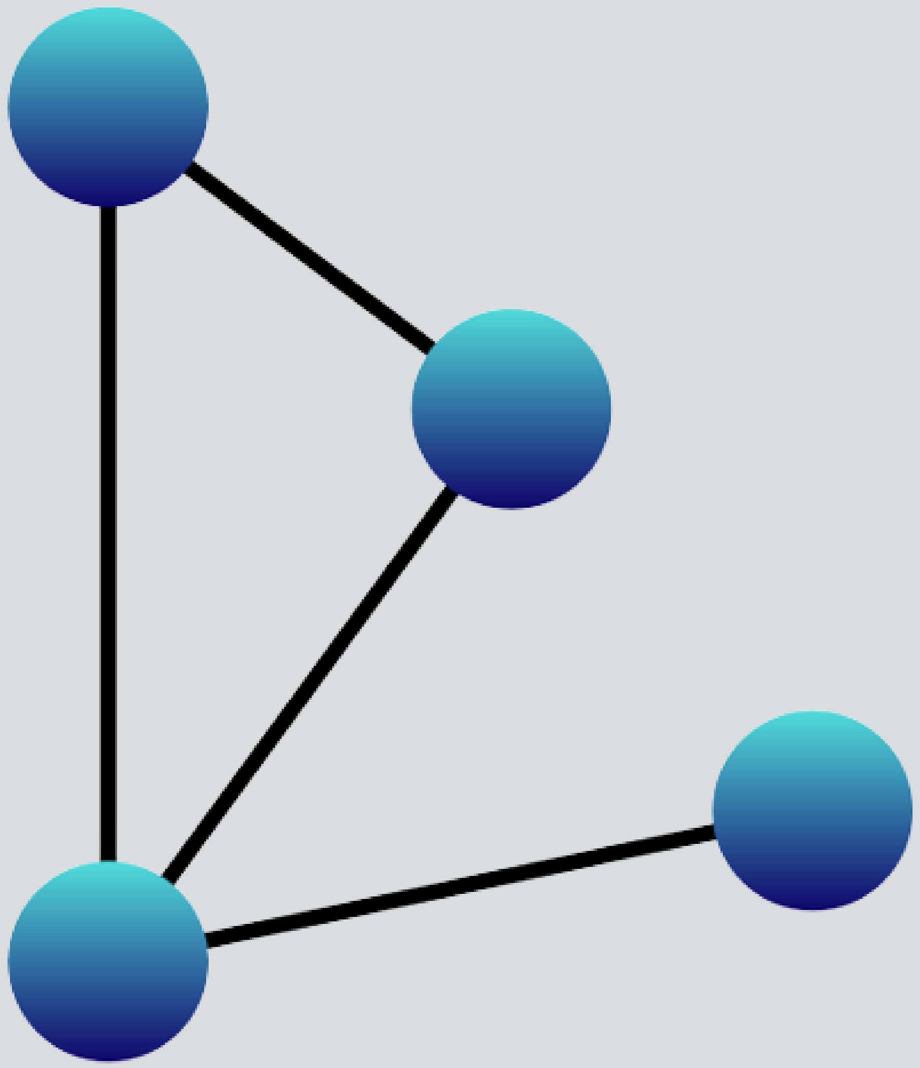
Problem Description

Finding effective routes for cars in shipment and delivery scenarios is the main goal of this project. The issue is known as the Traveling Salesperson Problem (TSP), and there are no effective solutions. To address this, we must create heuristic-based approximation techniques.

The purpose is to develop and test viable heuristics for various graph sizes and kinds. In order to measure heuristic performance, we will also construct a backtracking algorithm for optimal solutions in short graphs.

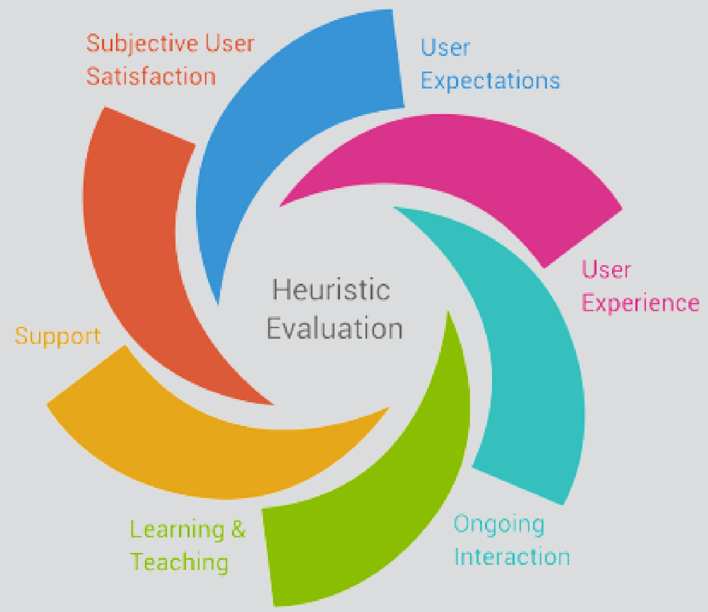
GRAPH STRUCTURE

A biderectional graph with points as vertices and each edge having a weight as a distance between the two points.



ALGORITHMS AND HEURISTICS

In plan to solve the issue of the Traveling Salesperson Problem (TSP) and not having effecitve solutions, we must create heuristic-based approximation techniques. Such as an backtracking algortihm in order to measure heuristic perfomance.



Backtracking Algorithm

- The backtracking algorithm is a problem-solving technique used to systematically explore all possible solutions to a problem. It involves making choices, exploring their consequences, and undoing choices that lead to dead ends. The algorithm is recursive in nature and is commonly used for solving combinatorial and optimization problems. It starts with an initial solution and incrementally builds upon it, backtracking whenever a choice leads to an invalid or unsatisfactory solution. The process continues until a valid solution is found or all possible combinations have been explored. Backtracking is an efficient approach for solving problems that can be divided into subproblems and have a well-defined set of constraints.

Triangular Aproximation

- Is a simple method for estimating an unknown value. It involves creating a triangle-shaped distribution using three parameters: the minimum, maximum, and most likely values. This heuristic is used when data is limited, providing a rough estimate and helping decision-makers make informed judgments. It is a practical approach to handling uncertainty in decision-making.

- This heuristic is adequate to all graphs, but in specific to the real graphs.
- This is considered as an a efficient heuristic due to its simplicity, intuitive nature, quick estimation capabilities, and ability to work with limited data.
- The results of backtracking and triangular aproximation are very similar, the case that´s different it´s the shipping, because it´s the not fully connected one.

```cpp
double Graph::triangularApproximation() {
    // Create the MST using Prim's algorithm
    std::vector<int> par(vertexSet.size(), -1);
    findMinimumSpanningTree(par);

    // Perform DFS traversal to obtain the order of visited cities
    std::vector<bool> visited(vertexSet.size(), false);
    std::vector<int> route;
    std::stack<int> vertexStack;
    dfs(0, par, visited, vertexStack, route);

    // Print the order of visited points
    std::cout << "Order of visited points: ";
    for (int i = 0; i < route.size(); ++i) {
        std::cout << route[i];
        if (i != route.size() - 1)
            std::cout << " -> ";
    }
    std::cout << " -> 0" << std::endl;

    double totalDistance = calculateTotalDistance(route);

    return totalDistance;
}
```

Other Heuristics

We implemented two heuristics: Tabu Search and Simulated Annealing (Both using Nearest Neighbour as initial solution). These techniques not only provide alternative approaches to solving the TSP but also enhance the efficiency and effectiveness of our solutions.

Simulated Annealing algorithm uses a temperature parameter that controls the acceptance of worse solutions during the search process. At higher temperatures, the algorithm is more likely to accept worse solutions, allowing for more exploration of the search space. As the temperature decreases, the algorithm becomes more selective and tends to accept only better solutions, focusing on exploitation.

In Tabu Search, we start with an initial solution and improve it, by searching it's neighbours. In order to generate other neighbours, we used an auxiliar function that has 4 options to mutate the current solution: swap elements, insert element in different place, reverse or shuffle the order of a random "piece" of solution. We also use a tabu list, preventing the current solution to converge to the same solutions, and instead explore other solutions. The stopping criteria is the number of max iterations, or the number of max iterations without a better solution.

Concluding, having a initial solution based on Nearest Neighbor instead of a random solution helps the algorithm to converge faster do the optimal solution. In addition, Tabu search is generally considered better than simulated annealing due to its ability to efficiently explore and exploit the solution space.

Conclusions

In conclusion, the Traveling Salesman Problem (TSP) is a complex and widely studied optimization problem with numerous practical applications. While finding the optimal solution for large instances remains challenging, various algorithms and heuristics have been developed to provide efficient approximations. By continually advancing our understanding and leveraging computational power, we are making significant progress in solving TSP and similar combinatorial optimization problems. As we explore new techniques and innovations, we inch closer to achieving optimal solutions and enhancing real-world logistics, routing, and network planning.