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Optimization Algorithms for the Vehicle Routing Problem

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Abstract
In this research we studied and implemented several algorithms for the TSP and VRP such as the 2-approximation based on the minimum spanning tree (MST) algorithm, the 1.5-approximation based on the Christofides algorithm, and also a local search single-swap heuristic. As intermediate steps, we solved the MST problem using the Kruskal algorithm, and the minimum matching using a single-swap algorithm. We also implemented a java graph package with several operations and a package to visualize the solutions. The objective was to execute instances with 28 thousand vertices, but the largest instance we could execute had 6417 vertices. At end, we study heuristics and algorithms for VRP. We implemented Clarke & Wright's Savings Algorithm.

Key words:
VRP, Logistics, Optimization.

Introduction

The Traveling Salesman Problem (TSP) is one of the most studied problems of combinatorial optimization. A generalization of TSP is the Vehicle Routing Problem (VRP). This problem creates k cycles that cover all delivery points (customers) with a special vertex in common (depot). The VRP has additional requirements according to the situation.

The Vehicle Routing Problem (VRP) models various situations, such as routing of vehicles to answer calls, definition of routes for postmen, definition of routes for garbage collection, definition of bus an vans routes, among many others. The problem is NP-Hard, which implies that there are no efficient algorithms to solve it unless P = NP.
This project aimed to study optimization techniques and design algorithms for VRP and TSP. The project was developed in the Java language with Netbeans IDE.

Results and Discussion

The Christofides algorithm uses the minimum spanning tree algorithm and the minimum matching algorithm as subroutines. We implemented the Kruskal algorithm and a *Draw* class to visualize solutions. The first algorithm for minimum matching consisted in generating thousands to millions of random matchings and selecting the best one. The Eulerian path is a step in the Christofides algorithm. We note that the Eulerian path in question is made in a multi-graph. We reinforce the 1.5 approach with a single-swap technique to improve the route from the algorithm. For VRP, we implemented Savings Heuristic, which is one of the most well-known approaches to solving the problem. More specifically, we use Clarke & Wright's Savings Algorithm.
Image 1 contains the route from the TSP with 6417 locations in the Southeast region obtained by the 1.5 approximation followed by the single-swap approach. Table 1 contains details on the execution of the algorithm in several instances.

Image 1. Result obtained after execution of Christofides algorithm followed by single-swap.

Table 1. Regions of Brazil with processing time and memory usage for Christofides algorithm followed by single-swap.

Instance	Vertices number	Time (min)	Memory (GB)
Midwest	2786	11	1,2
South	2953	10	0,9
North	4132	27	1,5
Southeast	6417	108	2,3

Conclusions

The experiments to TSP with the regions of Brazil showed that as the number of vertices increases, execution time and memory usage increase considerably, as expected. From these values it is possible to have an idea of the necessary hardware resources to replicate the experiments.

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