Project: Solving the Vehicle Routing Problem with Time Windows (VRPTW)

Course Project – Decision Aid methodologies in transportation

Introduction

The Vehicle Routing Problem with Time Windows (VRPTW) is a fundamental and widely studied problem in logistics and transportation optimization. In VRPTW, a fleet of vehicles must serve a set of customers with known demands, each within a specific time window. The goal is to minimize the total distance traveled or total cost, subject to capacity and scheduling constraints.

This project gives students hands-on experience in both exact optimization and heuristic methods by working on benchmark instances from Marius Solomon, a seminal dataset in the VRP literature. Students will model the problem using three different Mixed-Integer Linear Programming (MILP) formulations and compare their performance, then implement a metaheuristic to tackle larger-scale instances.

Data: Solomon Benchmark Instances

The Solomon instances are available online and can be accessed here:

- **URL**: http://web.cba.neu.edu/~msolomon/problems.htm
- Or URL: https://www.sintef.no/projectweb/top/vrptw/100-customers/
- Instances are categorized into different types (R1, R2, C1, C2, RC1, RC2), representing different customer distributions (random, clustered, or mixed).
- For the project, we will use only the random and clustered instances R1 and C1 (r1.., c1...).
- Files are provided in .txt format and include coordinates, demand, service times, and time window data.

You are expected to write a parser or use an existing one to convert the data into a format suitable for your solver and metaheuristic algorithm.

Project Structure

Part 1: Exact Solution Using MILP

You must implement different MILP formulations for the VRPTW, as presented in class. These may include:

1. **2-index directed formulation with Miller Tucker Zemilin (MTZ) subtour elimination constraints.**
2. **3-index formulation with Miller Tucker Zemilin (MTZ) subtour elimination constraints.**

Use a commercial solver such as **Gurobi** to solve the Solomon instances with:

- **25 customers**
- **50 customers**
- **100 customers**

For each instance size:

- Report the **computation time**
- Report the **optimality gap** (if available)
- Comment on the **strengths and weaknesses** of each model, especially as instance size increases.

You may set a time limit (e.g., 60 minutes per instance) to allow comparison when optimality cannot be reached.

Part 2: Metaheuristic Implementation

Choose and implement one metaheuristic to solve VRPTW instances with **100 customers**. Possible approaches include:

- ALNS
- Simulated Annealing
- Variable Neighborhood Search
- LNS.
- Column Generation.

- Other (you can choose other algorithms if you want, e.g., taboo search)

In your report, you must:

- **Describe the metaheuristic** in detail, including parameters and adaptation to VRPTW
- **Justify your design choices**
- Report results on **100-customer Solomon instances**, including:
  - Best solution found (total cost)
  - Computation time
  - Optimality gap based on the lower bound of the MILP.
- Compare your results with the exact methods and discuss scalability

Evaluation Criteria

- **Correctness** and completeness of MILP implementations (25%)
- **Quality of metaheuristic results** (solution quality and efficiency) (40%)
- **Clarity and structure of the report**, including data analysis and visualization (20%)
- **Critical discussion and comparison of approaches** (15%)

Submission Guidelines

- Submit a written report (PDF) containing all results, explanations, and visualizations
- Include well-commented code in a separate folder
- Deadline: April 29th 2025 at 23h59