CVRPLIB BKS challenge : The MAMUT approach

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1 Introduction

The Traveling Salesman Problem (TSP) is a common example of a routing problem, where the objective is to find the shortest possible Hamiltonian cycle that visits every node exactly once. Routing Problems, and particularly Vehicle Routing Problems (VRP), extend this framework with additional constraints, such as time windows (TSPTW), where nodes must be visited within specific intervals, or vehicle capacity limits (CVRP), which involve optimizing routes for a fleet with restricted carrying capacities.

As VRP increases in complexity, exact algorithms become computationally infeasible for large-scale instances. This has led to the widespread use of heuristics and metaheuristics to find near-optimal solutions within reasonable time frames. Heuristics, such as the nearest neighbor or Clarke-Wright savings algorithm [1], provide fast but approximate solutions by adhering to problem-specific rules. Metaheuristics offer a more flexible and powerful approach by balancing exploration and exploitation of the solution space. These methods enable escape from local optima and moving closer to global optimality, which makes them particularly valuable for tackling real-world VRP with complex constraints.

In addition, the integration of machine learning and data-driven methods is becoming increasingly prevalent in solving VRP. These approaches leverage historical data to predict demand, travel times and paths, or dynamic constraints, which can then inform and guide optimization algorithms.

2 The CVRPLIB BKS challenge

From this perspective, the CVRPLIB BKS challenge aims to gather contributions from the scientific community to improve the best-known solutions (BKS) for a new set of very large benchmark instances (1000 to 10000 customers) for the Capacitated Vehicle Routing Problem (CVRP) by combining traditional metaheuristics methods and novel data-driven approaches.

The foundational set of Best Known Solutions (BKS) for the CVRPLIB challenge will be established through the rigorous deployment of a suite of state-of-the-art metaheuristics. This baseline will be constructed using recognized algorithms such as KGLS_XXL[2], SISRs[3], FILO[4] (including its successor FILO2[5]), AILS-II[6], and HGS-CVRP[7] enhanced with decomposition[8] strategies.

To ensure the highest possible quality of these initial benchmarks, each method is allocated a substantial computational budget of approximately five CPU-days per problem instance. This effort will be distributed across multiple independent executions, utilizing diverse random seeds and parameter configurations to maximize search space exploration.

Our approach at MAMUT consists on 3 key componants built on top of the classical HGS-CVRP[7] algorithm :

- centroid-based clustering operator with adaptive K-means grouping and lightweight sub-HGS solves (run in parallel, with recursion guards and time scaling) that polish subsets of routes before global LS smoothing
- hybrid population seeding policy mixing random tours, randomized savings heuristics, and sweep-based tours to boost initial diversity and quality
- enriched local search featuring adaptive neighbor budgets, slack-aware filtering, destroy/repair kicks, Or-opt (up to length 4), restricted cross-exchange, and shallow ejection chains, all driven by route priorities and convergence safeguards

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