

Route-Centroid Partitioning with AILS-II Global Search and Parallel HGS Intensification for Large-Scale CVRP

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Abstract

This report describes a CVRP solver developed for the CVRPLIB BKS challenge, targeting improvements over published best-known solutions on large-scale instances. The proposed approach combines Hybrid Genetic Search (HGS) with the Adaptive Iterated Local Search (AILS-II) to exploit complementary strengths in diversification and intensification within a scalable computational pipeline.

1 Motivation

Hybrid Genetic Search (Vidal, 2022; Vidal et al., 2012) is a state-of-the-art CVRP heuristic that combines population-based recombination with intensive local search. It performs particularly well when enough runtime is available to balance diversification and intensification. However, on very large-scale instances, achieving top performance can require a substantial computational budget. AILS-II (Máximo et al., 2024) is an adaptive iterated local search that alternates perturbation and local improvement to rapidly obtain high-quality feasible solutions, making it especially effective under tight time budgets and a natural candidate for producing warm-start solutions for HGS. Motivated by these complementary strengths, we use AILS-II to quickly generate strong incumbents and decompose them into smaller, structured subproblems on which HGS can intensify efficiently in parallel, while periodic global refinement allows improvements across subproblem boundaries.

2 Method

The proposed solver follows a multi-cycle hybrid scheme that combines AILS-II for global exploration and warm-starting, and parallel HGS runs for local intensification. At each cycle, AILS-II produces an incumbent solution $S = \{R_1, \dots, R_K\}$, where each route R_k is a set of served customers. For each route R_k , we compute a geometric representative given by the centroid of its customers:

$$c_k = \frac{1}{|R_k|} \sum_{i \in R_k} x_i,$$

where $x_i \in \mathbb{R}^2$ denotes the coordinates of customer i . The set of centroids $\{c_1, \dots, c_K\}$ is then partitioned into P clusters, yielding P route-based subproblems. More precisely, each route R_k is assigned to one cluster $p \in \{1, \dots, P\}$, and subproblem p is formed by the union of the customers belonging to the routes assigned to that cluster. In this way, the decomposition preserves the route structure of the incumbent while grouping geographically close routes into parallel subproblems for intensification. We then run HGS on P sub-problems parallel for intensification.

To reduce artifacts caused by hard boundaries, we generate several alternative partitions in each cycle, so that routes or customers near partition borders can be optimized under different groupings and neighborhood contexts. After each parallel HGS round, the improved routes are merged into an updated incumbent solution, from which a new partition is computed for the next round. Finally, we apply a global AILS-II pass on the full instance to enable cross-group moves that are not visible within the restricted subproblems. This loop is repeated for several cycles, and we return the best solution obtained.

Algorithm 1 Multi-cycle hybrid AILS-II-HGS method with route-centroid partitioning

Require: Instance, cost function f , number of clusters P , number of cycles T , number of alternative partitions M

Ensure: Best solution S^*

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1:  $S \leftarrow$  solution returned by AILS-II on the full instance
2:  $S^* \leftarrow S$ 
3: for  $t = 1, \dots, T$  do
4:   Decompose  $S$  into routes  $S = \{R_1, \dots, R_K\}$ 
5:   for  $k = 1, \dots, K$  do
6:     Compute the centroid of route  $R_k$ :  $c_k = \frac{1}{|R_k|} \sum_{i \in R_k} x_i$ 
7:   end for
8:   for  $m = 1, \dots, M$  do
9:     Partition the centroids  $\{c_1, \dots, c_K\}$  into  $P$  clusters
10:    Construct  $P$  route-based subproblems
11:    for all subproblems  $p = 1, \dots, P$  in parallel do
12:      Run HGS on subproblem  $p$ 
13:    end for
14:    Merge the improved subproblem solutions into  $S$ 
15:  end for
16:  Apply AILS-II to the full instance using  $S$  as warm start
17:  if  $f(S) < f(S^*)$  then
18:     $S^* \leftarrow S$ 
19:  end if
20: end for
21: return  $S^*$ 
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Hardware and computing time used. The experiments were conducted on a machine equipped with an Intel Xeon Platinum 8480+ CPU with 32 cores and 251 GiB of RAM. The total computing time used for the competition runs was approximately 239 hours.

References

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