Parallelized Large Neighborhood Search Approach for very-large CVRP

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Method Description

OGA Team proposes a hybrid approach to solve the *Capacitated Vehicle Routing Problem* (CVRP), designed to balance solution quality with computational efficiency. The method combines a fast initial construction with advanced neighborhood search techniques and local intensification strategies.

The process begins with a constructive heuristic inspired by the Clarke & Wright Savings algorithm (see [1]), which generates feasible initial solutions by combining customers in a way that reduces total route cost. Variations of the savings method are applied, such as proximity-based filters, to produce a diverse set of initial solutions that will feed the subsequent search phase.

Once initial solutions are available, a Large Neighborhood Search (LNS, see [2]) is applied. This metaheuristic alternates between different destruction and repair operators. Destruction operators include random customer removal, cost-biased removal, proximity-based removal, and cluster or route removal. Repair operators insert the removed customers back into the solution using strategies such as sequential insertion, incremental cost-based insertion, and multi-criteria insertion considering distance and vehicle load. By alternating operators in a controlled manner, the LNS can explore very large neighborhoods while maintaining feasibility.

After the LNS phase, the solutions are refined using Variable Neighborhood Descent (VND, see [3]). This local search method applies standard CVRP moves such as 2-opt, Or-opt, swap, relocate, and k-edge exchanges, further improving solution quality.

To ensure temporal feasibility and reduce computational effort, all neighborhood searches are restricted to the k-nearest customers during relevant operations. Limiting the search space in this way significantly reduces execution time while preserving the quality of solutions, particularly in instances where geographic proximity strongly influences route efficiency.

Finally, the method incorporates parallelization and inter-process communication. Multiple processes explore different solution paths simultaneously and exchange the best solutions found, enhancing diversification and preventing premature convergence. This approach takes full advantage of multi-core hardware, improving overall computational efficiency and solution quality.

Input: CVRP instance, time limit T_max, number of processes P, k-nearest parameter k, destruction operators ΩD, repair operators ΩR, VND neighborhoods ΩV
Output: Best solution found S_best

```
Initialize S_best ← ∅
S0 ← ConstructInitialSolution (Clarke–Wright variants)
Run in parallel P workers
for each worker p do
    S ← Copy(S0)
    S ← VND(S, ΩV, k)
    while time < T_max do
        Select destruction operator D ∈ ΩD
        Select repair operator R ∈ ΩR
        S' ← R(D(S))               // LNS step
        S' ← VND(S', ΩV, k)        // local intensification
        if Accept(S', S) then
            S ← S'
        end if
        if z(S) < z(S_best) then
            Share S with other workers
            Update S_best
        end if
    end while
end for
return S_best
```

In summary, the proposed method integrates heuristic construction, large neighborhood exploration, local search intensification, and parallel computing to provide a robust and efficient solution to the CVRP. By combining these techniques, the method achieves a strong balance between exploration and exploitation while ensuring that computational constraints are met.

References

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