Diversity Guided Unified Evolutionary Framework for MDPCVRP

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1. Problem Definition: The Vehicle Routing Problem is a combinatorial optimization problem seeking to serve a set of customers with known demands and service frequency with minimum-cost routes originating and terminating at several depots on different periods. Here minimum cost refers to the minimization of the total route distances and number of vehicles.

2. Objective: Devising an algorithm for finding a minimum cost solution with a minimum computational effort

3. Solution Representation: Solutions are represented with 3 different chromosomes *(Figs. 1-3).*

	C0	C1	C2	C3	C4	C5	C6	C7	C8	C9
P0	1	1	0	1	0	1	0	1	1	0
P1	1	0	1	1	0	1	1	1	0	1
P2	0	0	0	0	1	1	0	0	1	1

Fig. 1: *Period assignment Chromosome*
- Assigns customers to periods.

P0	7	8	2	1	9	3	0	4	6	5
P1	4	0	5	3	8	1	2	9	7	6
P2	4	8	3	1	9	6	2	7	0	5

Fig. 2: *Permutation Map Chromosome*
- contains permutation of clients for different periods

	Cut 0	Cut 1	Cut 2
P0	2	4	7
P1	2	3	6
P2	1	4	8

Fig. 3: *Route partition chromosome*
– Segments permutations into routes

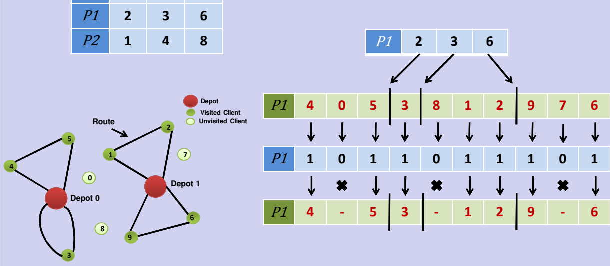


Fig. 4: Extraction of routes for a specific period (P1) from the solution representation for a small instance of MDPVRP.

5. Crossover Operator:

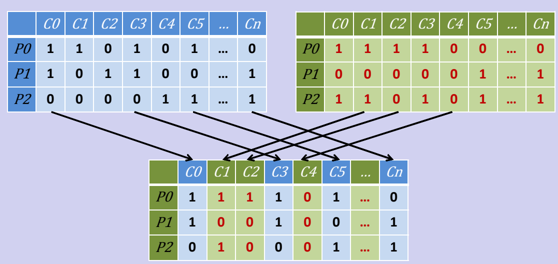


Fig. 5: *Uniform Crossover* for Period Assignment chromosome

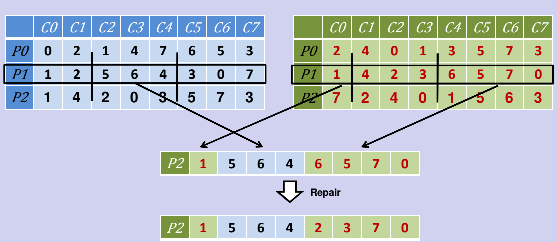


Fig. 6: *Variant of Partially Mapped Crossover(VPMX)* for Permutation map chromosome

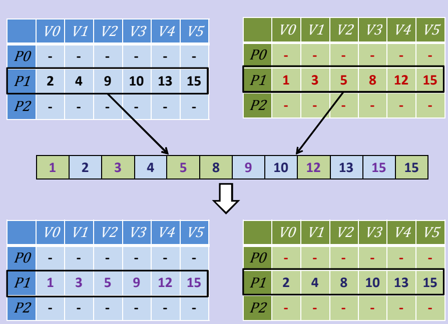


Fig. 7: *Sorted Crisscross Crossover(SCX)* for Route partition chromosome

4. Proposed Algorithm - DGUEF:

- Initialize population, X with M random solutions
- **for** generation ← 0 to G_{max}
  - Offspring Population, $Y \leftarrow \emptyset$
  - **while** offspring population size ≤ M
    - Select Parent, A_1 with Roulette Wheel Selection
    - Select Parent, A_2 with Fitness Uniform Selection Scheme
    - $[O_1, O_2]$ ← Crossover (A_1, A_2)
    - Apply Mutation Scheme on O_1 and O_2
    - Insert O_1 and O_2 into Y
  - Select, L ← Set of candidates for local improvement from parent + offspring population $(X \cup Y)$
  - Run Simulated Annealing as local improvement procedure for each l in L
  - **Replace genotype duplicates** with randomly generated solutions
  - Population, X ← Survivor Selection Scheme (parent + offspring population)

Crossover Scheme: Three different crossover schemes are employed for the three chromosomes *(Figs. 5-7).*
Mutation Scheme: Each mutation operator has a probability of application associated with it. These probabilities are changed periodically based on their performance. Initially all mutation operators have same probability *(Figs. 8-10).*
Local Improvement Candidate Selection Scheme: $K/2$ best individual are always chosen for local improvement, another $(M/3 - K/2)$ individuals are chosen with *FUSS*, where $K = k\%$ *of* M.
Survivor Selection Scheme : Best K individuals are always selected for the next generation. The rest $(M - K)$ individuals are selected uniformly over fitness from the remaining $(2M - K)$ individuals.

6. Mutation Operators:

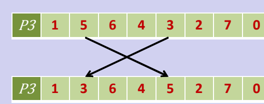


Fig. 8: *Transpositional Mutation* operator for Period assignment and Permutation map chromosome

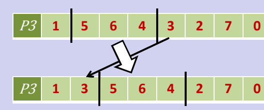


Fig. 9: *Insertion Mutation* operator for Permutation Map chromosome

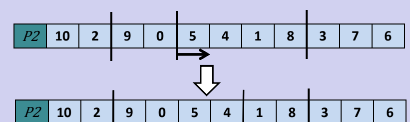
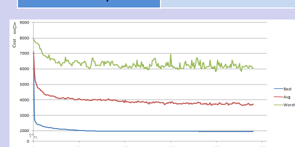


Fig. 10: *Random Walk Mutation* Operator for Route partition Chromosome

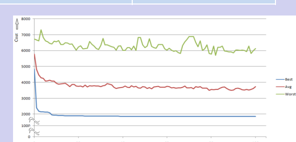
7. Results: The proposed algorithm was run on some instances of the available datasets and compared with the existing benchmarks. The performance is quite satisfactory *(Table 1, Fig. 11).*

Table 1: Comparison between our results and existing benchmarks for some selected instances

Problem Instance	Min (10 runs)	Average (10 runs)	Best Known Solution
MDPVRP – pr01	1958.094	1986.4	2019
PVRP – p14	954.8071	954.8071	954.8071
PVRP – p15	1862.63	1862.63	1862.63



(a): MDPVRP – pr01



(b): PVRP – p15

Fig. 11: Evolution of population for instances MDPVRP-pr01(a) [2] and PVRP-p15(b) [1]

8. Conclusion: The *MDPVRP*, *PVRP*, *MDVRP* and *CVRP* classes of VRP problems are of high dimensions. Our proposed algorithm uses crossover and mutation operators quite effectively to explore and exploit the search space to find the global optima avoiding local optimas by maintaining diversity and local improvement procedure in a *unified framework*. In future, we intend to increase convergence rate while maintaining diversity and decrease the computation resource consumed for larger datasets with higher dimensions.

References:
[1] J. F. Cordeau, M. Gendreau, and G. Laporte. A tabu search heuristic for periodic and multi-depot vehicle routing problem. Networks, 30:105-119, 1997
[2] Vidal, Thibaut, et al. "A hybrid genetic algorithm for multi-depot and periodic vehicle routing problems." *Operations Research* 60.3 (2012): 611-624.

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