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# Comparative Study of Order Crossover Variants in Memetic Algorithms for Solving the CVRP

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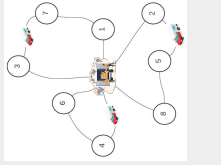
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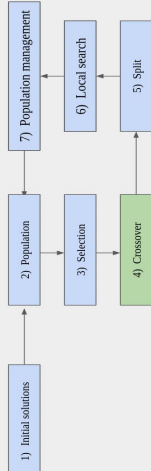
Introduction



- Vehicle Routing Problem with limited capacity (CVRP): Finding the most efficient routes for a fleet of vehicles with limited capacity.
- Importance in logistics and operations research: Minimizing costs while delivering goods to customers.
- Focus on operational efficiency and logistics costs.
- Finding optimal solutions is challenging due to the complex nature of the problem.
- Necessitates innovative methods for finding near-optimal solutions.

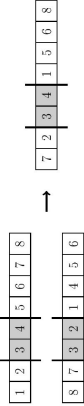
Resolution method

We used the open source code of Vidal (2022), which implements a memetic algorithm to solve the CVRP.

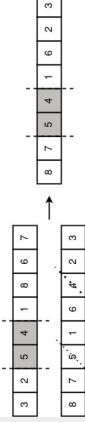


Our approach was to test different configurations of crossover operators to identify the best performing one. This allowed us to evaluate the impact of each operator on the quality of the solution and the convergence of the algorithm.

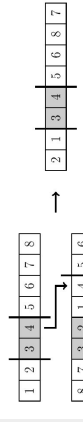
Order Crossover (OX):



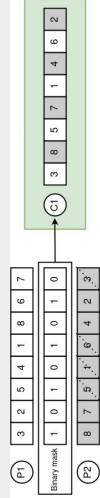
Linear Order Crossover (LOX):



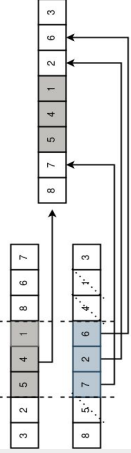
Adjusted Order Crossover (AOX):



Uniform Order Crossover (UOX):



Partially mapped cross (PMX):



Results

The table 1 gives for each instance the best known score in the literature (BKS), the best and the average of the results obtained over 10 runs started with a search budget of one hour, as well as the average time in seconds needed to obtain these results by the five order crossover variants: OX, LOX, AOX, UOX and PMX.

Instance	BKS		OX		LOX		AOX		UOX		PMX	
	best	time	best	time	best	time	best	time	best	time	best	time
X-001-025	2791	2791	2791	2791	2791	2791	2791	2791	2791	2791	2791	2791
X-001-031	2791	2791	2791	2791	2791	2791	2791	2791	2791	2791	2791	2791
X-001-035	1871	1871	1871	1871	1871	1871	1871	1871	1871	1871	1871	1871
X-001-040	1871	1871	1871	1871	1871	1871	1871	1871	1871	1871	1871	1871
X-001-045	1871	1871	1871	1871	1871	1871	1871	1871	1871	1871	1871	1871
X-001-050	5539	5539	5539	5539	5539	5539	5539	5539	5539	5539	5539	5539
X-001-055	5539	5539	5539	5539	5539	5539	5539	5539	5539	5539	5539	5539
X-001-060	2900	2900	2900	2900	2900	2900	2900	2900	2900	2900	2900	2900
X-001-065	2900	2900	2900	2900	2900	2900	2900	2900	2900	2900	2900	2900
X-001-070	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
X-001-075	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
X-001-080	4219	4219	4219	4219	4219	4219	4219	4219	4219	4219	4219	4219
X-001-085	4219	4219	4219	4219	4219	4219	4219	4219	4219	4219	4219	4219
X-001-090	2322	2322	2322	2322	2322	2322	2322	2322	2322	2322	2322	2322
X-001-095	2322	2322	2322	2322	2322	2322	2322	2322	2322	2322	2322	2322
X-001-100	1418	1418	1418	1418	1418	1418	1418	1418	1418	1418	1418	1418
X-001-105	1418	1418	1418	1418	1418	1418	1418	1418	1418	1418	1418	1418
X-001-110	4007	4007	4007	4007	4007	4007	4007	4007	4007	4007	4007	4007
X-001-115	4007	4007	4007	4007	4007	4007	4007	4007	4007	4007	4007	4007
X-001-120	4792	4792	4792	4792	4792	4792	4792	4792	4792	4792	4792	4792
X-001-125	4792	4792	4792	4792	4792	4792	4792	4792	4792	4792	4792	4792
X-001-130	2145	2145	2145	2145	2145	2145	2145	2145	2145	2145	2145	2145
X-001-135	2145	2145	2145	2145	2145	2145	2145	2145	2145	2145	2145	2145
X-001-140	4226	4226	4226	4226	4226	4226	4226	4226	4226	4226	4226	4226
X-001-145	4226	4226	4226	4226	4226	4226	4226	4226	4226	4226	4226	4226
# best average	1871	1871	1871	1871	1871	1871	1871	1871	1871	1871	1871	1871
# best average	1871	1871	1871	1871	1871	1871	1871	1871	1871	1871	1871	1871

Table 1: Comparison of different order crossover variants. **Best results are in bold.**

Specific power per variant :

**OX (Ordinary Crossover):** Better overall performance with solutions close to BKS on several instances. Best computation time for the majority of instances. Performs well in cases where other variants do not produce optimal solutions.

**AOX (Adaptive Ordinal Crossover):** Very good behaviour, close to OX in many instances. Performs well in terms of solution quality and average results.

**UOX (Uniform Order Crossover):** Less efficient than OX and AOX. More variability in results, with performance varying from instance to instance.

**PMX (Partially Mapped Crossover):** Variable performance; better than OX and AOX in some specific cases. High diversification capacity, which helps with instances such as X\_n106\_k14.

**LOX (Linear Order Crossover):** Worst performance of the variants tested.

Less efficient in producing optimal solutions and with lower average results than the other variants.

Overall comparison:

- OX and AOX outperform the UOX and PMX variants overall in many cases.
- The results suggest that informed crossover strategies (OX and AOX) are superior to more random strategies (UOX and PMX).
- PMX shows its strengths in specific cases where diversity is crucial.
- LOX is the least competitive in terms of solution quality.

Conclusion

Objective of the paper

- Optimizing the CVRP using a memetic algorithm (MA).
- Combining the global search capabilities of evolutionary algorithms with the local refinement of heuristic methods.

Hybrid approach of memetic algorithms

- Ability to produce high-quality solutions in a reasonable time.
- Effectiveness in solving complex optimization problems like the CVRP.

Analysis of results

- Performance of crossover variants influenced by the characteristics of each problem instance.
- Informed approaches can significantly improve solution quality in specific contexts.
- Crossover variants beyond the traditional ordered crossover (OX) can improve search space exploration.

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