A generic yet effective memetic algorithm for rich routing problems

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1 Algorithm outline

To solve optimization problems in practice, the two-phase strategy of first building an initial solution with a powerful construction heuristic and then improving that solution with a local-search based procedure is widely adopted. In an attempt to improve solution quality, this two-phase strategy is often iterated a number of times (in a so-called multi-start or multi-pass heuristic), if calculation time permits.

Another widely adopted solution strategy is that of evolutionary algorithms. In these, solutions are encoded as chromosomes, and then crossover and mutation are used to create new solutions from existing ones. The idea is to build a population of diverse high-quality solutions by (i) combining the good characteristics of different solutions into a single solution through crossover, (ii) letting good quality solutions have a higher probability of being selected for crossover, and (iii) creating the possibility for individual improvement through mutation.

In so-called hybrid evolutionary algorithms or memetic algorithms, a combination of these two approaches is used. The evolutionary algorithm framework is adopted, but when a new solution is generated, a local-search based improvement heuristic is applied to it. The idea is to intensify the solution process by using the local search component that finds local optima and at the same time diversify the solution process by using the crossover and mutation operators that lead the search into new regions in the solution space.

Although memetic algortihms have often been used to address VRPs and VRPTWs, applications to other routing problems such as period routing and inventory routing are less common. This paper presents a generic memetic algorithm for cyclic inventory routing and also applies it to a variety of capacitated and periodic vehicle routing problems. The novelty of the algorithm lies in the fact that it only uses basic building blocks and does not use complicated chromosome encodings or crossover and mutation operators that would require a lot of problem-specific parameter tuning. The outline of the algorithm is as follows. First, a greedy construction heuristic and three well-known local search (LS) operators are used to generate a pool of high quality solutions. An evolutionary algorithm (EA) then manages solution quality and diversity in the pool by using disruptive crossover and mutation operators that destroy solutions partially and then rebuild them using the same three local search operators. The versatility and performance of the approach is illustrated on a set of benchmark problems on the cyclic inventory routing problem (CIRP), the periodic vehicle routing problem (PVRP) and the classical capacitated vehicle routing problem (CVRP).

The construction heuristic that was adopted is the randomized Clarke-and-Wright savings approach, well-known from standard vehicle routing problems. The local search operators in the algorithm are the relocate, swap and 2-opt moves. These are all well-known from standard vehicle routing, but they have also been extended for the PVRP and the CIRP. For computational efficiency, the local search operators have been implemented using Static Move Descriptors (SMDs).

Both the crossover and mutation operators work in a ruin-and-recreate manner. During crossover, the common parts of parent solutions are kept and the remainder of the solution is scrapped. The mutation operator also destroys part of the solution, working along the lines of guided local search, since those parts of the solution that seem least promising are scrapped. In both crossover and mutation, the resulting solutions are reoptimized after scrapping, using the same (re-)construction and local search operators.

The next important issue is the population management. Since all of the solutions in the population have been optimized using local search operators, these are all local optima, and the intensification part of the search process is already very strong. Therefore, the population management aspect can be used to take care of the diversification part of the search process. This is done by explicitly measuring the diversity among the individuals in the population, and then selecting individuals for crossover based on their diversity instead of their (scaled) objective values. This idea is similar to what happens in scatter search procedures and some multi-objective genetic algorithms.

2 Computational experiments

Some limited computational results are presented here. More results and a more elaborate discussion of these results will be available in the full paper.

The MA is applied to the cyclic inventory routing problem benchmark instances of Raa and Aghezzaf (2009). It turns out that the EA considerably outperforms the multi-start heuristic presented there for almost all instances (see Table 1).

The same benchmark instances were also solved with a multistart two-phase heuristic that uses the same construction and improvement heuristics as those adopted for the MA, and that is run with computation times as long as those of the EA. The results, also in Table 1, show that the MA is always better, which proves the value of the proposed crossover and mutation operators, or in other words, it proves that the population management guiding the same set of local search operators helps achieve better results.

Table 1. CIRP computational results.

CCAP	HC	NR	[?]	EA-LS	Improvement	Multistart	EA-LS	Improvement
No	80c	[30, 70]	1297.03	1247.97	3.78%	1248.06	1247.97	0.01%
No	80c	[80, 120]	2822.56	2622.96	7.07%	2642.95	2622.96	0.76%
No	8c	[30, 70]	714.77	716.65	−0.26%	716.73	716.65	0.01%
No	8c	[80, 120]	1562.11	1553.53	0.55%	1559.49	1553.53	0.38%
Yes	80c	[30, 70]	1632.45	1564.37	4.17%	1567.55	1564.37	0.20%
Yes	80c	[80, 120]	3335.86	3079.35	7.69%	3121.19	3079.35	1.34%
Yes	8c	[30, 70]	1324.01	1267.93	4.24%	1270.58	1267.93	0.21%
Yes	8c	[80, 120]	2633.03	2430.30	7.70%	2484.64	2430.30	2.19%

3 Conclusion

This paper presents a memetic algorithm for rich routing problems. The algorithm combines highly disruptive crossover and mutation operators with standard local search (LS) operators. Preliminary results on benchmark instances of CIRP, PVRP and CVRP show the versatility and effectiveness of the proposed MA.