SOLVING VEHICLE ROUTING PROBLEMS VIA SINGLE GENERIC TRANSFORMATION APPROACH

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Abstract: *We present a simple data structure capable to solve a broad class of vehicle routing problems. Our modeling approach involves vehicle capacity constraints and extends to the tactical location decisions of location routing problems. The unique data structure accompanied by a single generic transformation allows an effective search of the solution space. We provide simulated annealing results for standard benchmarks that confirm the quality of the proposed algorithm.*

Keywords*: Vehicle routing, Location routing, Simulated annealing.*

1. INTRODUCTION

Heuristic approaches prevail as the solution approaches for various vehicle routing problems (see e.g. [7]). Although invented to be simple, fast and generic it is often the case that applying heuristic to a specific vehicle routing problem required new data structures and iteration steps design, or at least some significant adjustments.

On the other hand, supply chain practice required optimization of the entire logistics value chain, and thus led to a new group of problems that combines facility location problems with vehicle routing problems. These problems, known as location routing problems, according to [3], needed redesign of the neighborhood search techniques of the solution spaces.

In this paper, we present a simple data structure accompanied by a single generic transformation which leads to an effective search of the solution space. The power of the transformation is that most of the classical transformations like insertion, swap, 2–opt, and some others, can be seen as its special cases. Our modeling approach involves vehicle capacity constraints and extends to the tactical location decisions of location routing problems.

The paper is organized in 5 sections. The introduction is followed by data structure presentation and transformation description in Section 2. In Section 3, we show how vehicle routing problems can be modeled with the new data structure, and in Section 4 we present some results on capacitated location routing problems. In the last section we provide some final remarks.

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2. ROUTES AND TRANSFORMATIONS IN CIRCULAR BUFFER

Every vehicle routing problem has a depot, a vehicle and a customer. We add a depot, a vehicle and/or a customer as markers to the positions of a circular list.

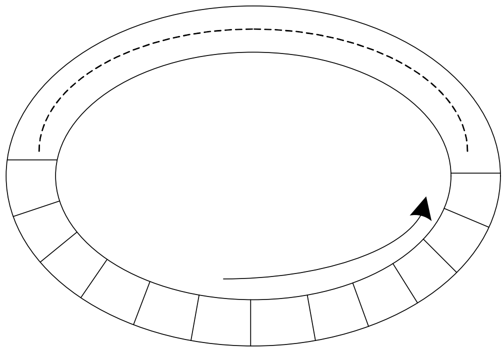

Figure 1. Circular list.

If a position in the list is marked as a depot D, then all positions before the next depot position, where the counter clockwise direction is assumed, are associated with the depot D. If a position is associated with a vehicle V, all positions before the next vehicle position, where the counter clockwise direction is assumed, belong to the vehicle V, i.e. all customers on those positions should be served by vehicle V (Figure 2).

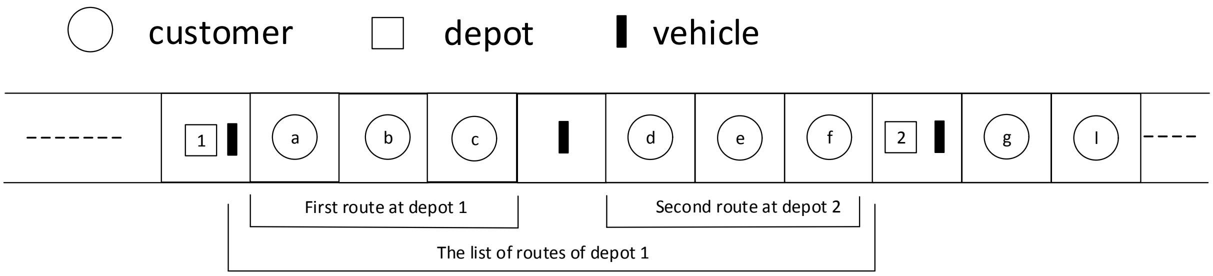

Figure 2. Positions and markers in a list.

Note that depot positions contain vehicle markers, which we interpret as the first routes starts.

We next define a generic transformation. The power of this transformation is that most of the classical transformations like insertion, swap, 2–opt and some others, can be seen as its special cases. In order to perform transformation one should choose 2 'outer' positions, A and B in the list, and two 'inner' positions C and D (Figure 3). The first step in the transformation is to invert the sub-list between A and B. In the second step, we invert the sub-list between C and D.

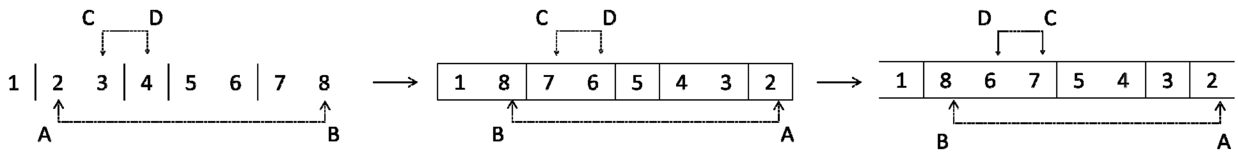

Figure 3. Generic transformation.

It can be easily observed that makes traditional insertion transformation if A coincides with C and D and B are consecutive positions. If A and C on one side and D and B on the other side are both pairs of consecutive positions, the transformation is simply the traditional swap transformation.

3. MODELING ROUTING PROBLEMS

In this section we show how several known vehicle routing problems can be modeled via our approach. We use capacitated location routing problem (CLRP), considered in [] as our reference problem. As all routing problems, it contains customers, vehicles and depots. Each customer ordered a certain quantity of a product that needs to be delivered. The main goal is to make a routing plan such that the overall warehousing and transportation costs are minimized.

More formally, we consider that the set of locations of customers and depots, accompanied with the cost matrix containing all pair-wise traveling cost is given. Each depot has its opening cost of opening and the capacity, while customer has its demand. The fleet of vehicles is homogeneous, hence each vehicle has the usage price and the capacity. The total cost of a capacitated location routing plan is the sum of the costs for opening depots, using vehicles and total traveling cost. The ultimate goal is to make a plan such that all capacity constraints are satisfied, while the total costs are minimized.

We can model CLRP using a framework presented in the previous section. If D is the number of depots, C the number customers and V the number of vehicles ($V \geq D$), we create a circular list with $V+C$ positions, where D positions are marked with both depot and vehicle markers, V-D with only vehicle markers and C positions with customer markers. The scenarios of closed depots or not activated vehicles are given in the Figure 4.

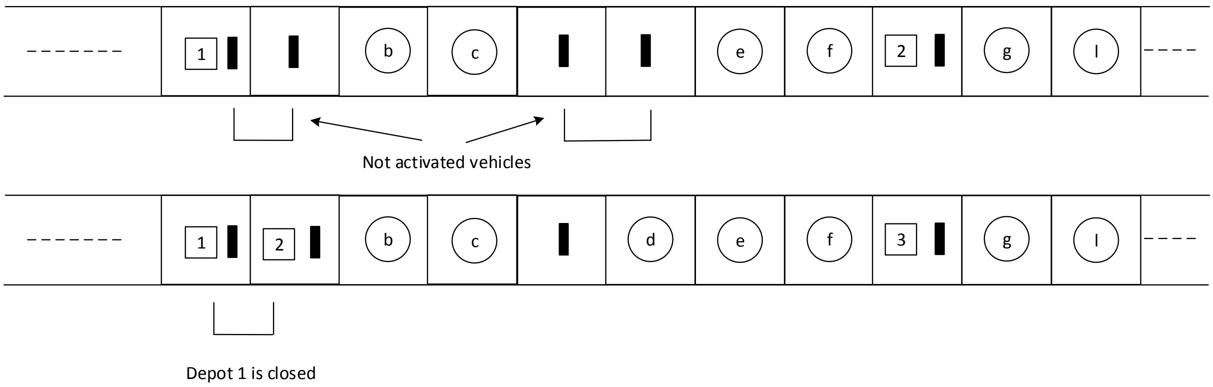

Figure 4. Scenarios with empty vehicles and closed depot.

Finally, various routing problems can be considered as special cases of CLRP, and their modeling is boils down to simplification of the circular buffer. For example, multi-depot VRP problems are obtained when depot opening costs are set to zero, and vehicle usage costs set according to multi-criteria priorities. On the other hand, one can consider adding time constraints, without adding complexity in the given structure, and thus capture vehicle routing problems with time window or working time constrains.

4. CALCULATION RESULTS FOR CLRP

We give some test results on standard benchmark problems for CLRP in this section. In Table 1 our algorithm that uses presented framework and relies on simulated annealing approach is named SIMPGEN (from simple and generic). The algorithms GRASP. MAPM, LGRST and SALRP, together with the results in the corresponding column are the results from [6], [2], [5], and [9] respectively.

The benchmark problems are described in [1], [6], and [8]. In Table 1, the columns 'Problem', 'Cust', 'Dep', 'BKS' contain the names of instances, the number of customers, the number of depots and the best know solution result, respectively. For each of the 5 algorithms the total cost, the gap towards the best known solution and the CPU times are given. The comparison of the CPU times is not relevant since tests for different algorithms were performed on different machines.

Table 1. Comparison results for CLRP

Algorithms				GRASP			MAPM			LRGTS			SALRP			SIMPGEN		
Problem	Cust	Dep	BKS	Cost	Gap	CPU	Cost	Gap	CPU	Cost	Gap	CPU	Cost	Gap	CPU	Cost	Gap	CPU
Christ50	50	5	565.60	599.1	5.92%	2.3	565.6	0.00%	3.8	586.4	3.68%	2.4	565.6	0.00%	52.8	565.60	0.00%	43.062
Christ75	75	10	844.40	861.6	2.04%	9.8	866.1	2.57%	9.4	863.5	2.26%	10.1	844.4	0.00%	126.8	848.85	0.53%	129.81
Christ100	100	10	833.40	861.6	3.38%	25.5	850.1	2.00%	44.5	842.9	1.14%	28.2	833.4	0.00%	330.8	833.43	0.00%	238.61
Das88	88	8	355.78	356.9	0.31%	17.3	355.8	0.00%	34.2	368.7	3.63%	17.5	355.8	0.00%	226.9	355.78	0.00%	157.33
Das150	150	10	43919.90	44625	1.61%	156	44011.7	0.21%	255.0	44386.3	1.06%	119.2	43919.9	0.00%	577.0	43919.90	0.00%	328.28
Gaspelle	21	5	424.90	429.6	1.11%	0.2	424.9	0.00%	0.3	424.9	0.00%	0.2	424.9	0.00%	18.3	424.90	0.00%	9.609
Gaspelle2	22	5	585.10	585.1	0.00%	0.2	611.8	4.56%	0.3	587.4	0.39%	0.2	585.1	0.00%	16.6	585.11	0.00%	5.703
Gaspelle3	29	5	512.10	515.1	0.59%	0.4	512.1	0.00%	0.8	512.1	0.00%	0.4	512.1	0.00%	23.9	512.10	0.00%	11.078
Gaspelle4	32	5	562.20	571.9	1.73%	0.6	571.9	1.73%	0.8	584.6	3.98%	0.6	562.2	0.00%	27.0	562.22	0.00%	3.579
Gaspelle5	32	5	504.30	504.3	0.00%	0.5	534.7	6.03%	1.0	504.8	0.10%	0.5	504.3	0.00%	25.1	504.33	0.01%	4.546
Gaspelle6	36	5	460.37	460.4	0.01%	0.8	485.4	5.44%	1.4	476.5	3.50%	0.7	460.4	0.01%	31.7	460.37	0.00%	61.218
Min27	27	5	3062.00	3062	0.00%	0.4	3062.0	0.00%	1.0	3065.2	0.10%	0.3	3062.0	0.00%	23.3	3062.02	0.00%	1.297
Min134	134	8	5709.00	5965.1	4.49%	49.6	5950.1	4.22%	110.5	5809.0	1.75%	48.3	5709.0	0.00%	522.4	5709.00	0.00%	346.36
Average	61.23	6.62	4487.62	4569.07	1.63%	20.28	4523.25	2.06%	35.62	4539.41	1.66%	17.58	4487.62	0.00%	154.05	4487.97	0.04%	103.11

3. CONCLUSION

We presented a framework for modeling various vehicle routing problems. It uses positions in a circular list and accompanied with generic transformation offers powerful tool for searching the solution spaces of considered problems. We tested it on CLRP benchmark problems and obtained promising results that are comparable to other approaches.

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