

What makes the dynamic capacitated arc routing problem hard to solve

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Algorithm 1: VND-CARP

```
1 Generate tour by Frederickson heuristic.
2 Apply SHORTEN and CUT to obtain an initial solution.
3 while True do
4   Set  $i = D/Q$ ,  $s_{best} = s$ ;
5   while True do
6     Set number of neighbours:  $c = 1$ .
7     Set best value of a neighbour:  $f_{best} = f(s)$ .
8     while  $c \leq M_i$  do
9       Select  $i$  routes in  $s$ , merge them into a giant tour.
10      Apply SWITCH and then CUT on this tour.
11      Apply SHORTEN on each new tour.
12      New resulting solution:  $s'$ ;
13      if  $f(s') < f_{best}$  then
14        Set  $best_s = s'$ ;
15        Set  $f_{best} = f(s')$ ;
16       $c = c + 1$ ;
17      if  $f_{best} < f(s)$  then
18        Set  $s = best_s$ ;
19      else
20         $i = i - 1$ 
21        if  $i \geq 1$  then
22          break;
23    if  $f(s) \geq f(s_{best})$  then
24      break;
```

Algorithm 2: ILMA

```
1 Initialization:  $nc - 3$  chromosomes;
2 Add one chromosome by Path_Scanning;
3 Add one chromosome by Augmnt-Merge;
4 Add one chromosome by Ulusoy's split;
5 while Stop criterion is not met do
6   Select two chromosomes  $P_1$  and  $P_2$  by binary tournament selection;
7   Apply ordered crossover operator to  $P_1$  and  $P_2$  to generate  $O_x$ ;
8   Set  $O = O_x$ ;
9   if  $rand() < P_{ls}$  then
10    apply local search to  $O_x$  to generate  $O_m$ ;
11    if  $O_m$  is not existed in pop then
12       $O = O_m$ ;
13   Evaluate  $O$  to get  $f(O)$ ;
14   if  $f(O) == f(P_1)$  then
15     Replace  $P_1$  by  $O$ ;
16   else if  $f(O) == f(P_2)$  then
17     Replace  $P_2$  by  $O$ ;
18   else if  $f(O) == f(P)$  &&  $P! = P_1$  &&  $P! = P_2$  then
19     Discard  $O$ ;
20   else if  $f(O)$  is not used in current pop then
21     Randomly choose a  $P$  from  $[nc/2, nc]$ ;
22     Replace  $P$  with  $O$ ;
23   Resort Population;
24   if Replacement criteria are met then
25     replace  $nrep$  chromosomes with randomly generated chromosomes;
```

Algorithm 3: The pseudo code of Simulation System

Input: Executable solution s , Time of change: t , Previous graph G

```
1 Set Events probability:  $\{p_1, p_2, p_3, p_4, p_5\}$ ;  
2 Set probability for broke down roads recovering:  $p_{bdr}$ ;  
3 Set probability for congest roads recovering and becoming better:  $p_{crr}, p_{crbb}$ ;  
4 Determine the stopping point for each vehicles according to  $s, t, G$ ;  
5 Update graph, and remove all served tasks.  
6 Randomly select  $p_1 \times 100\%$  vehicles to break down (Event 1).  
7 Update the graph.  
8 **** Cost Impact ****/  
9 for each edge  $e_i$  do  
10   if  $e_i.change == 0$  then  
11      $r_2 = rand(), r_3 = rand()$   
12     if  $r_2 < p_2$  and  $r_3 < p_3$  then  
13       Event 2 happens:  $e_i.cost = Inf, e_i.change == 2$  ;  
14     if  $r_2 < p_2$  and  $r_3 > p_3$  then  
15       Event 3 happens: Increase cost of  $e_i, e_i.change == 3$  ;  
16   else if  $e_i.change == 2$  and  $rand() < p_{recover}$  then  
17     Recover edge  $e_i, e_i.change == 0$  ;  
18   else if  $e_i.change == 3$  then  
19     if  $rand() < p_{congestion.recover}$  then  
20       Recover edge  $e_i, e_i.change == 0$  ;  
21     else if  $rand() < p_{congestion.better}$  then  
22       Decrease cost of  $e_i$   
23     else  
24       Increase cost of  $e_i$   
25   else  
26     continue;  
27 **** Demand Impact ****/  
28 for each edge  $e_i$  do  
29   if  $e_i.change = 1$  then  
30     continue;  
31   else  
32      $r_4 = rand(), r_5 = rand()$ ;  
33     if  $Edge.demand > 0$  and  $r_4 < p_4$  then  
34       Event 4 happens:  $e_i.change = 4$ ;  
35     if  $Edge.demand == 0$  and  $r_5 < p_5$  then  
36       Event 5 happens:  $e_i.change = 5$ ;
```

Output: The new graph G_1

Algorithm 4: Build auxiliary graph for DCARP

Input: Individual : $I = \{t_1, t_2, \dots, t_N\}$

- 1 Stop points for outside vehicles: $V = \{v_1, v_2, \dots, v_K\}$
- 2 Remain capacity for outside vehicles: $CP = \{cp_1, cp_2, \dots, cp_K\}$
- 3 Generate $N + 1$ Nodes (Index from 0 to N) for the auxiliary graph G^* .
- 4 **for** each outside vehicle k **do**
- 5 **for** each node pair: $Node_i$ and $Node_j$ **do**
- 6 Use vehicle k to serve $\{t_{i+1}, t_{i+2}, \dots, t_j\}$;
- 7 Sub-route: $r_{ijk} = \{v_k \rightarrow t_{i+1} \rightarrow t_{i+2} \rightarrow \dots \rightarrow t_j \rightarrow depot\}$;
- 8 Calculate the total demand d_{ijk} of r_{ijk} ;
- 9 **if** $d_{ijk} > cp_k$ **then**
- 10 \hookrightarrow *continue*;
- 11 **else**
- 12 Calculate the cost of r_{ijk} : c_{ijk} ;
- 13 Assign an edge e_{ijk} between $Node_i$ and $Node_j$ with weight equal to c_{ijk} ;

Output: An auxiliary graph G^*

Algorithm 5: A* based optimal split scheme

Input: Individual : $I = \{t_1, t_2, \dots, t_N\}$

- 1 Build an auxiliary graph G^* for DCARP;
- 2 $expandNode = Node_0$; $openNodeSet = \{\}$; $pathSet = \{\}$;
- 3 **while** *True* **do**
- 4 **if** $expandNode == target$ **then**
- 5 Shortest path P : path correspond to $expandNode$;
- 6 Minimal cost C : $f_{expandNode}$ correspond to $expandNode$;
- 7 **break**;
- 8 Select $rootPath$ (i.e. path from $Node_0$ to $expandNode$) from $pathSet$;
- 9 **for each** *successor* of $expandNode$ **do**
- 10 $newPath = rootPath + expandNode \rightarrow successor$;
- 11 Remove all edges correspond to vehicles being used in $newPath$ for $successor$;
- 12 Calculate the h_{succ} and g_{succ} ;
- 13 Set $f_{succ} = h_{succ} + g_{succ}$;
- 14 **if** $successor == target$ **then**
- 15 Repair f_{succ} ;
- 16 Add the $successor$ into $openNodeSet$;
- 17 Add the path correspond to $successor$ into $pathSet$;
- 18 Remove the $expandNode$ from $openNodeSet$, and the $rootPath$ from $pathSet$;
- 19 Select the node in $openNodeSet$ with minimal f as $expandNode$;
- 20 The shortest path from $Node_0$ to $target$ in G^* : $P = \{p_1, p_2, \dots, p_M\}$;
- 21 Each p_m represents an edge e_{ijk} , which denotes a sub-route r_{ijk} ;
- 22 Obtain the solution S by splitting the I by P .

Output: Solution $S = \{r_1, r_2, \dots, r_M\}$, Minimal cost: C

Algorithm 6: Greedy split scheme

Input: Individual : $I = \{t_1, t_2, \dots, t_N\}$

1 Build an auxiliary graph G^* for DCARP;

2 **for** each edge e_{ijk} in G^* **do**

3 Calculate the UDC: UDC_{ijk} ;

4 $expandNode = Node_0$; $newPath = Node_0$

5 **while** True **do**

6 **if** $expandNode == target$ **then**

7 Greedy path: $newPath, P = \{p_1, p_2, \dots, p_M\}$;

8 Calculate the greedy cost of greedy path: C ;

9 **break**;

10 $rootPath \leftarrow newPath$;

11 Select the $Node_X$ with minimal UDC from all *successors* for $expandNode$;

12 $newPath = rootPath + expandNode \rightarrow Node_X$;

13 Remove all edges correspond to vehicles being used in $newPath$;

14 $expandNode \leftarrow Node_X$;

15 Each p_m represents an edge e_{ijk} , which denotes a sub-route r_{ijk} ;

16 Obtain the solution S by splitting the I by P .

Output: Solution $S = \{r_1, r_2, \dots, r_m\}$, Greedy cost: C

Algorithm 7: The hybrid local search framework

Input: The update Map (update graph data)

Dynamic State:

- 1). Stop locations of outside vehicles;
- 2). Remaining capacities of outside vehicles;
- 3). Remaining tasks.

```
1 Initialize the solution archive  $SA \leftarrow \emptyset$ ;  
2 Re-construct the solution  $S_0$  with explicit routes;  
3 Add initial solution into archive  $SA = SA \cup S_0$ ;  
4 Set global best solution  $S_{gb} = S_0$  for each solution  $S_i$  in  $SA$  do  
5   Local best solution  $S_{lb} = S_i$ ;  
6   while true do  
7     // The following loop (line7-line10) run in parallel  
8     for each neighborhood move  $Move_j$  do  
9       Solution  $S_{mj} = Move_j(S_{lb})$   
10      if improved AND archive is not full then  
11        Add  $S_{mi}$  into archive:  $SA = SA \cup S_{mi}$ ;  
12      Update best solution  $S_{lb}$  from  $S_{mj}$ ;  
13      if No improved move OR exceed time limitation then  
14        break;  
15  if  $S_{lb}.cost < S_{gb}.cost$  then  
16     $S_{gb} \leftarrow S_{lb}$ ;  
17  if exceed time limitation then  
18    break;
```

Output: The global best solution S_{gb}

Algorithm 8: Pseudo code of the instance generator.

Input: Static instance, initial solution;

The full capacity of vehicles: Q ;

A configuration of dynamic event: C_{Event} ;

Configurations of state factors: C_{OV} , C_{RQ} ;

Output: A DCARP instance

```
1 if  $C_{Event} == ND$  then
2   if  $ND-N == few$  then
3      $p = 20\%$ 
4   else
5      $p = 80\%$ 
6   Uniformly random select  $p$  of tasks in the remaining tasks and save them into a set
      $Set_{ND}$ .
7   if  $ND-V == small$  then
8      $dm = \frac{Q}{|Set_{ND}|}$ 
9   else
10     $dm = \frac{4Q}{|Set_{ND}|}$ 
11   Add demand  $dm$  to each task in  $Set_{ND}$ .
12 if  $C_{Event} == NT$  then
13   Save all available edges (not task) in a list  $List_{NT}$ ;
14   if  $NT-P == close$  then
15     Sort  $List_{NT}$  in ascending order according to the max distance of two nodes to the
       depot.
16   else
17     Sort  $List_{NT}$  in descending order according to the max distance of two nodes to the
       depot.
18   if  $NT-N == few$  then
19      $p = 20\%$ 
20   else
21      $p = 80\%$ 
22   Select the front  $p$  of edges from  $List_{NT}$  as the new tasks and save into  $Set_{NT}$ .
23   if  $NT-V == small$  then
24      $dm = \frac{Q}{|Set_{ND}|}$ 
25   else
26      $dm = \frac{4Q}{|Set_{ND}|}$ 
27   Add demand  $dm$  to each task in  $Set_{NT}$ .
```
