An Adaptive Iterated Local Search for the Mixed Capacitated General Routing Problem

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Outline

- Background and Motivation
- The Mixed Capacitated General Routing Problem (MCGRP)
- Literature
- Adaptive Iterated Local Search
- Results
- Summary, Conclusion, Further Work

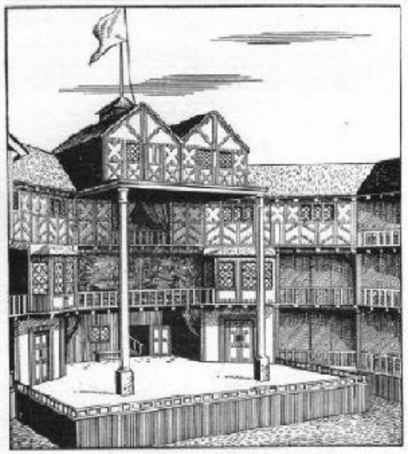
The Daily Shake

Elizabethan Words Inc. | 1/31/1593 | Edition 1, Volume 1

Bubonic Plague ravaging London, Globe Theatre closed

(1593)

It's been nearly 200 years since the Black Death spread to Europe. Now the Globe theatre, along with many other theatres and public areas, has been closed in attempt to stop the recent outbreaks which have been occurring since 1563. These closings are causing widespread fear throughout the masses, as well as a lack of pay for actors and theatre management workers. It is unknown as to when the Globe will re-open, with death rates terrifyingly high



The Stage of the Globe (drawn from the model made by Dr. J. C. Adams)

Early man of "Action"

William Shakespeare

1564 - 1616

William Shakespeare was baptized on April 25, 1564. He was the son of John and Mary Shakespeare.He was born third out of eight children. Most of his early life is suspected to have been spent in grammar schools, where he learned to read and write.At age 18 he married 26 year old Anne Hathaway on November 27, 1582. It is suspected that the wedding was rushed because six months later his first daughter, Susanna, was born on May 26, 1583. Two years later the twins, Hamnet and Judith, were born on February 2, 1585. Then in 1596, his son Hamnet died, at age 11, of unknown causes.

William Shakespeare spent most of his career life as a poet, actor, and playwright. He is the writer of many of the world's most famous plays such as Romeo & Juliet, Macbeth, and A Midsummer Nights Dream. His early works were comedies, up until about 1600. Then it turned to tragedies. This could have been a reaction to the early death of his son. Along with being a playwright, he was a skilled poet. He has 154 famous sonnets, named their number in chronological order, such as "Sonnet 29."

William Shakespeare died of unknown causes on April 23, 1616. He was buried April 25, 1616 in the Holy Trinity Church. His remains reside there still today as requested in his last will and testament. The words on his tombstone are:

"Good friend for Jesus forbear
To dig the dust enclosed here!
Blest be the man that spares these stones,
And curst be he that moves my bones."

Newspaper carrier routing

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A: PASSPORT - Session1
File Edit Transfer Options Session Macro Help
=>PF2=TILBAKE,PF5=ENDRE,PF6=SLETT,PF10=BLANKER,PF11=RUTEKONS,PF12=TILLEGGSOPP
A F T E N P O S T E N    DISTRIBUSJONSSYSTEM   KOSTNADS- OG TIDSBEREGNING
Rute: 21509 Utg.: M Ukedag: 0 Pr. dato: 221105              Betjenes med: G
 Ant.l0nn:  265 -Ant. abo og andre,      0  -Ant. pressede  Sone: 3  O/U: U
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 Avstandsl0nn:   3,3 km a kr.   52,80                             = kr    174,24
 Vintertillegg:  5 mnd. a kr.  291,00 :12                         = kr    121,25
 Sum l0nn                                                  *MIN*  = kr   6892,17
  26,00 % tillegg for feriepenger og arb.avgift                   = kr   1791,96
 Sykkelgodtgj.                                                    = kr      0,00
 Transp.godtgj.     3,3 km x 26,00 dager x kr.:    0,00           = kr      0,00
 Transp.strekn.     0,0 km x 26,00 dager x kr.:    0,00           = kr      0,00
 Sum l0nn, sos.kostn. og transp.godtgj.                    *MIN*  = kr   8684,13
 Kostnad pr. abonnement pr. mÅned                                 = kr     32,77
1. Klargj0ring f0r start          =       15 min | Dekn.%:   44,69
2. Avstand    3,3 km       a  12,00 =   39,60 min | Beregnet tid  128,13 min.
3.    0 oppg. uten n0kkel a   0,35 =    0,00 min | Reell    tid  128,13 min.
4.   53 oppg. med n0kkel  a   0,50 =   26,50 min | Beregn. dagl0nn  248,87 kr
5.  206 etasjer           a   0,35 =   72,10 min | Reell   dagl0nn  260,42 kr
6.     0 lev. i enebolig  a   0,15 =    0,00 min | Beregn. timel0nn  116,54 kr
7.   63 lev. i rekkehus   a   0,20 =   12,60 min | Reell   timel0nn  121,95 kr
8.    4 lev. i FK (ute)   a   0,15 =    0,60 min | Timetillegg o/18 ....... kr
9.    0 fellesleveringer  a   0,00 =    0,00 min | Antall husstander    593
Totalt                           =  166,40 min |
TB                          A2--Session1   R 4   C 1          3:22p 22/11/05
```

Arc or Node Routing?

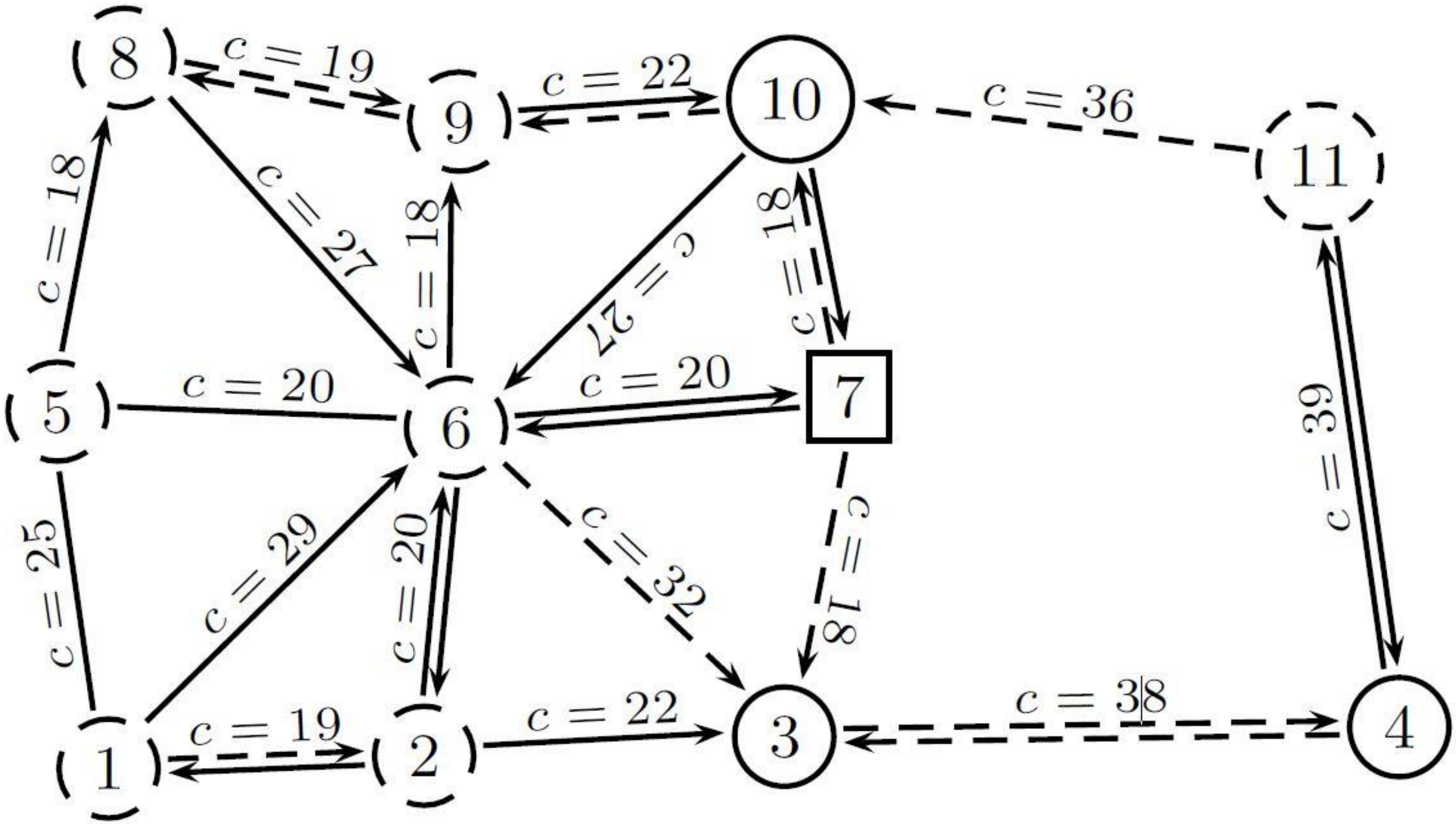
- Point-based demand
  - doormat
  - mailbox
  - node routing
  - large number
- Abstraction
  - aggregate demand along street segments
  - all street segments with demand must be serviced
  - arc routing
  - too crude
- Qualified aggregation
- Node/arc routing

The Mixed Capacitated General Routing Problem (MCGRP)

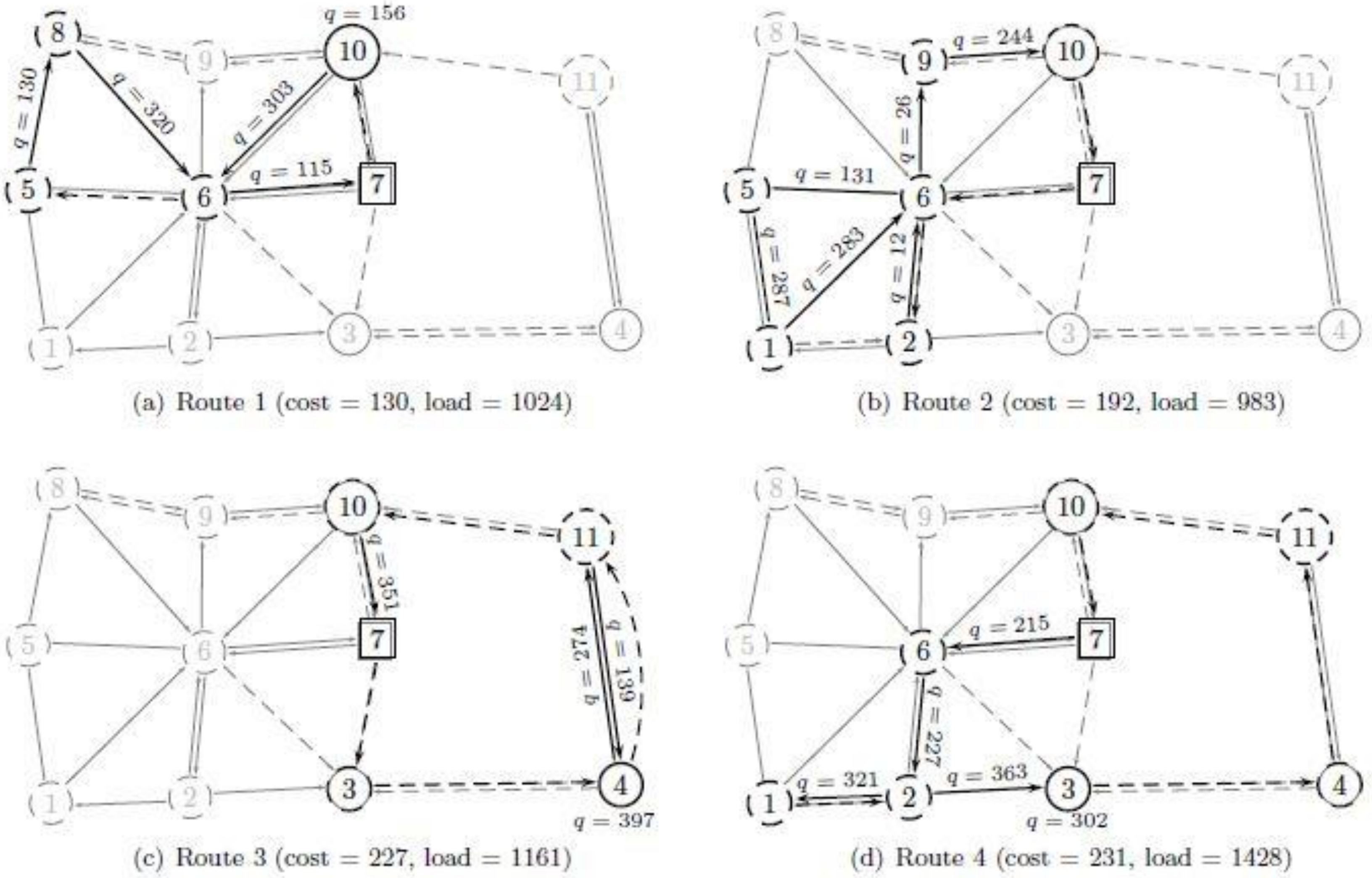
- A.k.a.
  - the Capacitated General Routing Problem (on mixed graphs) CGRP(-m)
  - the Node, Edge, and Arc Routing Problem (NEARP)
- Mixed weighted (multi)graph $\boldsymbol{G=(V,E,A)}$, depot $d \in \boldsymbol{V}$
- Travel cost $c_{i,j}$ for each link
- Customers $\boldsymbol{V_R,E_R,A_R}$, demand $q_{i,j,}$ service cost $s_{i,j}$
- Homogeneous (fixed) fleet of vehicles ***K,*** each with capacity Q
- Find minimum cost plan such that each customer is serviced exactly once by a vehicle starting and ending at the depot, respecting the vehicle capacity
- Generalization of CVRP, CARP, GRP, …
- Removes node/arc routing dichotomy
- Transformations to CARP / GVRP / … possible

Example - CBMix23

Q=1437, $c_{ij}=c_{ji}$, $s_{ij}=q_{ij}$, $|N_r|=3$, $|E_r|=2$, $|A_r|=15$, $\tau=20$



A CBMix23 (Q=1437) solution, 4 routes with total travel cost 780



(a) Route 1 (cost = 130, load = 1024)

(b) Route 2 (cost = 192, load = 983)

(c) Route 3 (cost = 227, load = 1161)

(d) Route 4 (cost = 231, load = 1428)

Literature (1)

- Pandit & Muralidharan (1995):
  A capacitated general routing problem on mixed networks. Computers & Operations Research, 22:465–478, 1995.
- First definition of the MCGRP (heterogeneous fleet and maximum duration constraint, named the *Capacitated General Routing Problem* (CGRP)
- Route-first-cluster-second heuristic
- Test instances
  - inspired from curb-side waste collection in residential areas
  - random instances from the Capacitated Chinese Postman Problem literature

Literature (2)

- Gutiérrez et al. (2002): The capacitated general routing problem on mixed graphs. Revista Investigacion Operacional, 23:15–26, 2002.
- Studied the homogeneous fixed fleet version of the CGRP
- Called it the *Capacitated General Routing Problem on Mixed Graphs (CGRP-m)*
- Proposed a $O(n^3)$ heuristic
- Comparative study
  - 28 homogeneous fixed fleet instances, $k=2,3,4$; $6<\tau<21$
  - Average 10% better than Pandit and Muralidharan (1995)

Literature (3)

- Prins & Bouchenoua (2005): A memetic algorithm solving the VRP, the CARP and general routing problems with nodes, edges and arcs.
  In *Recent Advances in Memetic Algorithms*, vol 166, pp 65–85. Springer.
- Introduced the Node, Edge, and Arc Routing Problem (NEARP) name
- Proposed a memetic algorithm
- Defined the CBMix MCGRP benchmark with 23 grid based instances
- Experiments on CBMix, standard CARP and CVRP instances

Literature (4)

- Kokubugata, Moriyama, and Kawashima (2007):
  A practical solution using simulated annealing for general routing problems with nodes, edges, and arcs.
  In *Engineering Stochastic Local Search Algorithms. Designing, Implementing and Analyzing Effective Heuristics*, vol. 4638, pp136–149. Springer.
- Developed a simulated annealing algorithm for MCGRP
- Provided several new best known solutions for CBMix

Literature (5)

- Bach, Hasle, Wøhlk (2013):
  A lower bound for the node, edge, and arc routing problem.
  Computers & Operations Research, 40(4):943–952, 2013.
- The first lower bounding procedure for the MCGRP
- BHW benchmark – 20 instances based on well known CARP instances (gdb, val, egl)
- DI-NEARP benchmark – 24 instances from real-world newspaper distribution cases in Norway
- Numerical results on CBMix, BHW, DI-NEARP

Literature (6)

- Hasle, Kloster, Smedsrud, and Gaze (2012): Experiments on the node, edge, and arc routing problem. Technical Report A23265, SINTEF, 2012.
- Spider industrial VRP solver
- Experiments on CBMix, BHW, and DI-NEARP benchmarks
- Several best new upper bounds

- Web page for MCGRP http://www.sintef.no/nearp

Literature (7)

- Bosco, Laganà, Musmanno, and Vocaturo (2013): Modeling and solving the mixed capacitated general routing problem. Optimization Letters, 7(7):1451–1469
- Proposed the first IP formulation for the MCGRP
- Extended valid inequalities for the CARP to the MCGRP
- Developed a B&C algorithm
- Two new benchmarks, totalling 342 instances:
  - mggdb derived from the gdb undirected CARP instances (138)
  - mgval, derived from the mval mixed CARP instances (204)
  - 6 sets corresponding to different values of β: # required links whose demand is shifted to adjacent vertices.
- Computational experiments
  - mggdb and mgval instances with less than 8 vehicles
  - 4 smallest-size CBMix instances, providing two optimal solutions

Literature (8)

- Gaze, Hasle, Mannino (2013): Column generation for the mixed capacitated general routing problem. WARP1
- Gaze (2013): Exact optimization methods for the mixed capacitated general routing problem. Master's thesis, Norwegian University of Science and Technology, 2013.
- Extends the column generation approach by Letchford and Oukil (2009) to the MCGRP and uses it to solve the root node of a Branch-and-Price tree
- Experiments on mcgrp and small subset of mgval

Literature (9)

- Bach, Lysgaard, Wøhlk (2014): A Branch-and-Cut-and-Price Algorithm for the Mixed Capacitated General Routing Problem. In Routing and Scheduling Problems – Optimization using Exact and Heuristic Methods. Ph.D. dissertation, School of Business and Social Sciences, Aarhus University, Denmark.
- Developed a B&C&P for the MCGRP
- Experiments on CBMix, BHW, mggdb, mgval (one subset)
  - CBMix: improve the best known upper bound for 2 instances and the best known lower bound for 21 instances
  - BHW: prove optimality for 2 new instances
  - mggdb: prove optimality for 31 new instances

Literature (10)

- Bode, Irnich, Laganà, Vocaturo (2014): Two-Phase Branch-and-Cut for the Mixed Capacitated General Routing Problem. Technical Report LM-2014-02, University of Mainz
- Presents new two-index mathematical model for the MCGRP
- Proposes a two-phase B&C algorithm that uses an aggregate formulation to develop an effective lower bounding procedure
- Computational experiments for half of the mggdb and mgval instances (β = 0.25, 0.30, 0.35)
  - 62 out of 69 mggdb instances solved to optimality
  - to 62 out of 102 mgval instances solved to optimality

Adaptive Iterative Local Search (AILS)

- Good balance between intensification and diversification
- Avoid non-productive search efforts

- Iterated Local Search
  - Simulated search over local optima
  - Trajectory based intensification
  - Perturbation
- ALNS + conditional deep intensification with pure LS
- No progress: major disruption ("kick") + LS

AILS – Initial solution and ALNS details

- Initial solution – Augment-merge + bin packing
- Destructors
  - Random
  - Node
  - Edge
  - Arc
  - Worst
  - Related
  - Tree
- Constructors
  - Random
  - Greedy
  - Regret
- Merits based on Destructor / Constructor pairs

AILS – Local Search details

- 5 operators
- LS_Full
  - Swap
  - Or-opt, max segment length 3
  - 2-opt
  - 3-opt, max segment length 3
  - Flip
- LS1
- LS2

- Aggressive move strategy
  - Union of neighborhoods
  - All moves with positive savings considered

Algorithm tuning

- Selection of 17 hard CBMix, BHW, DI-NEARP instances
- Two destructor configurations
- No further intensification
- No kick diversification
- No quality discrimination
- No reset of roulette wheel scores

- Parameter tuning

Algorithm 2 Adaptive Iterative Local Search (* Final Detailed Implementation *)

```
function AILS(Instance)
    comment: Initialize global variables
    IterationCounter := 0;
    IterPerStage := N_ITER_PER_STAGE
    KickCountdown := N_ITER_BEFORE_KICK
    RESET_ROULETTE_PROBABILITIES()
    comment: Construct first solution and take to deep local optimum
    x_init :=CONSTRUCT_INITIAL_SOLUTION(Instance)
    x_incumbent :=LS_FULL(x_init)
    x_LocalIncumbent := x_incumbent
    comment: Main body: iterative phase
    repeat
        x_current := x_BestThisStage := x_LocalIncumbent
        comment: Execute a batch of iterations
        for i := 0 to IterPerStage do
            IterationCounter := IterationCounter + 1
            NewBest := COMBINED_ALNS_AND_LS
            if NewBest then
                IterPerStage := N_ITER_PER_STAGE -1
                KickCountdown := N_ITER_BEFORE_KICK
                break
            end if
        end for
        comment: Increase number of iterations
        IterPerStage := IterPerStage + 1
    until TIMEOUT()
    return x_incumbent
end function
```

Algorithm 3 Combined ALNS and LS

```
function COMBINED_ALNS_AND_LS
    comment: Check for stagnation
    if KickCountdown > 0 then
        comment: Reset roulette probabilities regularly
        if (IterationCounter modulo PI_RESET) = 0 then RESET_ROULETTE_PROBABILITIES()
        k :=RANDOM(1, k_max)
        x_current :=ROULETTE_DESTROY_AND_REPAIR(k)
        if z(x_current) ≥ QUALITY_FACTOR · z(x_BestThisStage) return FALSE
        comment: Cost acceptable, intensify with LS1 or LS2 based on 70% probability
        x_current := if RANDOM(0,100)≤ 70 then LS1(x_current) else LS2(x_current)
        KickCountdown := KickCountdown − 1
        if z(x_current) < z(x_BestThisStage) then
            x_BestThisStage := x_current
            comment: Give higher probability to selected Destructor/Constructor pair
            UPDATE_ROULETTE_PROBABILITIES()
            comment: Return true if an update has been performed
            return UPDATE_INCUMBENTS(x_current)
        end if
        return FALSE
    else
        comment: Nothing has happened for a while, make a major, random destroy and repair
        k :=RANDOM(τ/2, τ)
        x_LocalIncumbent :=RANDOM_DESTROY_AND_REPAIR(k)
        x_current := x_LocalIncumbent :=LS_FULL(x_LocalIncumbent)
        UPDATE_INCUMBENTS(x_current)
        comment: Return true to exit the for loop of AILS
        return TRUE
    end if
end function
```

Computational Experiments MCGRP(1)

- C++ under Linux Ubuntu 12.04.1 LTS 64-bit
- Intel Xeon E5530 @2.4 GHz
- CBMix (23)
  - 11-150 nodes
  - 29-332 edges/arcs
  - $20 \leq \tau \leq 212$
- BHW (20)
  - 11-72 nodes
  - 22-380 edges/arcs
  - $20 \leq \tau \leq 410$
- DI-NEARP (24)
  - 560-1120 nodes
  - 815-1450 edges
  - $240 \leq \tau \leq 833$

Computational Experiments MCGRP(2)

- mggdb (6 sets of 23 instances=138)
  - 3-10 vehicles
  - $18 \leq \tau \leq 48$
- mgval (6 sets of 34 instances=204)
  - 2-10 vehicles
  - $38 \leq \tau \leq 129$

Summary of experimental results (1)

- CBMix (200s and 3600s time limit)
  - Best known upper bounds for 22 of 23, even with 200s limit. 3600s: 1.8% lower than SA. 2 optimal solutions.
  - Prins & Bouchenoua 2005, MA
  - Kokubugata et al. (2007), SA
  - SINTEF Spider (2012), ILS/VND
  - Bach, Lysgaard, Wøhlk (2014), B&C&P
- BHW (3600s)
  - Best known upper bounds for all 20 instances
  - 4 optimal solutions, 1 only closed by AILS
  - SINTEF Spider (2012), ILS/VND
  - Bach, Lysgaard, Wøhlk (2014), B&C&P
- DI-NEARP instances (3600s)
  - Best known upper bounds for all 24 instances
  - SINTEF Spider (2012), ILS/VND

Summary of experimental results (2)

- mggdb (138, 107 known optimal solutions)
  - AILS finds all
  - 12 first known upper bounds
  - 17 ties
  - 2 inferior
- mgval (204, 103 known optimal solutions)
  - AILS finds all
  - 61 improved upper bounds (27)
  - 35 ties
  - 5 inferior

- Bach, Lysgaard, Wøhlk (2014), B&C&P
- Bode, Irnich, Laganà, Vocaturo (2014), B&C

Table 19: Average percentage above the BKS for top-performing CARP algorithms in the literature.

Algorithm	Problem set gdb	val	egl	C	D	E	F
GLS	0.000	0.032	–	0.047	0.011	0.098	0.000
MA	0.025	0.132	0.805	–	–	–	–
BACO	0.154	0.351	2.348	–	–	–	–
VNS	–	0.056	0.538	–	–	–	–
TSA	0.070	0.100	0.725	0.054	0.164	0.168	0.249
Ant-CARP	0.102	0.083	0.558	0.210	0.083	0.360	0.199
MA	0.285	–	–	–	–	–	–
AILS	0.000	0.053	0.330	0.018	0.000	0.228	0.000

- GLS: Beullens et al. (2003)
- MA: Lacomme et al. (2004a)
- BACO: Lacomme et al. (2004b)
- VNS: Polacek et al. (2008)
- TSA: Brandão and Eglese (2008)
- Ant-CARP: Santos et al (2010)
- MA: Prins & Bouchenoua (2005)

Table 20: Average percentage above the BKS for top-performing CVRP algorithms in the literature.

Algorithm	Problem set: Christofides et al. (1969, 1979)	Taillard (1993)	Golden et al. (1998)	Li et al. (2005)
GRASP	0.071	–	0.525	–
MB	0.027	0.236	0.263	0.202
MA-CVRP	0.030	0.096	0.210	–
PARALLEL	0.085	0.131	0.411	0.299
MA	0.389	–	–	–
AILS	0.073	0.180	1.063	0.489

- GRASP: Prins (2009)
- MB: Mester and Bräysy (2007)
- MA-CVRP: Nagata and Bräysy (2009)
- PARALLEL: Gröer et al. (2011)

Table 4: Computational results on the CBMix instances.

			MA		SA		Spider (sec_{tot}=7200)		AILS (sec_{tot}=200)		AILS (sec_{tot}=3600)	
Instance	τ	LB	z	sec_{tot}	$avg\ z$	sec_{tot}	z	sec_{inc}	z	sec_{inc}	z	sec_{inc}
CBMix1	48	2409	2632	108.3	2617.1	15.1	2589	1231.0	**2585**	26.4	**2585**	26.4
CBMix2	185	9742	12336	1078.5	12322.4	661.4	12222	4156.0	11876	192.4	**11749**	1869.2
CBMix3	79	3014	3702	157.0	3695.2	56.0	3767	6612.0	3619	195.8	**3614**	418.3
CBMix4	98	5302	7583	548.1	7728.5	76.1	7802	6744.0	7550	68.4	**7483**	3384.7
CBMix5	65	3789	4562	100.0	4685.3	41.5	4688	1349.0	4508	118.6	**4459**	593.1
CBMix6	108	5201	7087	204.5	7101.4	98.0	7139	6687.0	7043	106.3	**6969**	1619.0
CBMix7	168	7296	9974	662.6	9704.8	351.7	9767	3205.0	9444	139.7	**9428**	2516.7
CBMix8	177	7956	10714	767.6	10710.2	263.8	10689	1413.0	10405	156.1	**10338**	2143.9
CBMix9	50	3460	4041	140.8	4132.4	12.5	4147	5517.0	4002	53.3	**3991**	430.7
CBMix10	107	6432	7755	843.2	7763.2	108.3	7931	4665.0	7538	150.9	**7525**	1399.5
CBMix11	82	3031	4503	414.7	4599.6	49.8	4525	536.0	4494	75.3	**4484**	543.8
CBMix12	53	3138	3235	71.3	3235	21.4	3235	14.0	***3138**	178.9	***3138**	178.9
CBMix13	141	6524	9339	550.6	9270.6	312.8	9332	1427.0	9079	168.4	**9037**	2840.4
CBMix14	93	5731	8615	357.2	8769.3	65.3	8638	6404.0	8511	26.3	**8473**	608.7
CBMix15	91	6318	8359	390.2	8385.3	97.3	8443	3553.0	8269	59.0	**8221**	2962.2
CBMix16	169	7416	9389	536.1	9024.3	445.5	9022	6754.0	8743	185.5	**8742**	844.6
CBMix17	63	3654	4165	116.1	4107.6	43.0	4235	1271.0	**4034**	62.2	**4034**	62.2
CBMix18	127	6089	7411	475.7	7214.6	278.4	7346	1994.0	7130	150.8	**7052**	2556.7
CBMix19	212	11143	17036	1273.4	16677.5	469.8	16692	5688.0	16322	189.6	**16155**	451.8
CBMix20	73	3452	4918	164.6	4902.9	50.7	4859	3501.0	4806	126.7	**4738**	577.9
CBMix21	180	12474	18509	1370.6	18318.3	530.4	18809	5322.0	18060	140.8	**17875**	1012.9
CBMix22	42	1825	**1941**	65.8	1970.5	9.5	**1941**	492.0	**1941**	8.8	**1941**	8.8
CBMix23	20	780	***780**	20.4	***780**	2.7	***780**	0.3	***780**	0.0	***780**	0.0
Sum/Average	2431	126176	167806	452.9	166936.0	176.6	167818	3414.6	163877	112.2	**162811**	1176.1

Table 5: Computational results on the BHW instances.

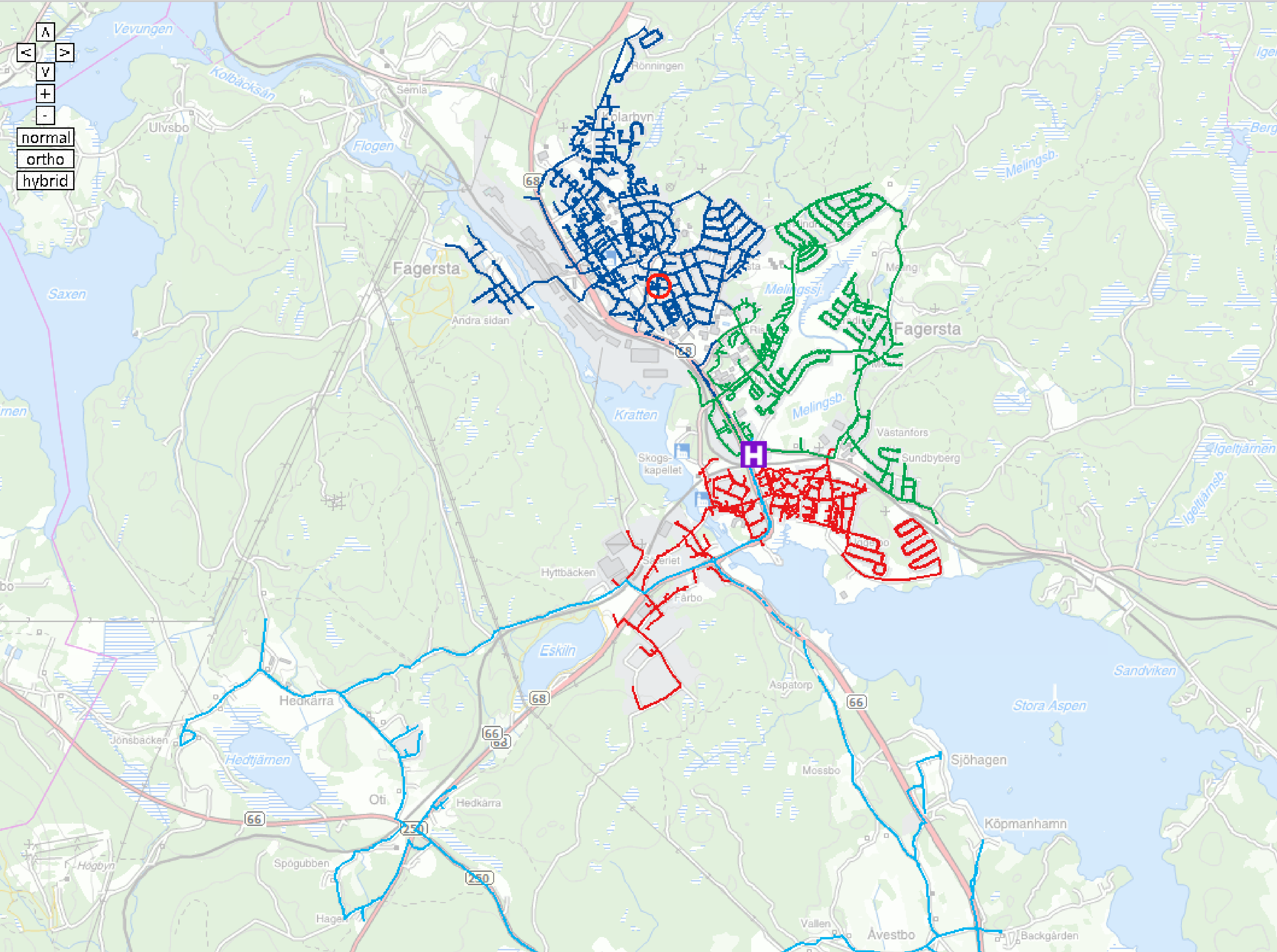
Instance	τ	LB	Spider (sec_{tot}=7200) z	Spider (sec_{tot}=7200) sec_{inc}	AILS (sec_{tot}=3600) z	AILS (sec_{tot}=3600) sec_{inc}
BHW1	29	324	**337**	6.0	**337**	0.2
BHW2	29	470	***470**	36.0	***470**	0.1
BHW3	20	326	**415**	18.0	**415**	23.2
BHW4	50	240	***240**	1.0	***240**	0.0
BHW5	162	502	506	610.0	***502**	119.2
BHW6	110	388	***388**	58.0	***388**	10.7
BHW7	229	930	1104	6324.0	**1070**	2895.1
BHW8	117	644	672	1801.0	**668**	1273.2
BHW9	178	791	920	2431.0	**875**	212.3
BHW10	142	6810	8596	6205.0	**8524**	152.9
BHW11	71	3986	5023	3012.0	**4914**	2139.6
BHW12	115	6346	11042	6059.0	**10887**	19.0
BHW13	175	8746	14510	5723.0	**14346**	2962.6
BHW14	221	17762	25194	4584.0	**24833**	2812.6
BHW15	128	12193	15564	6728.0	**15354**	2223.0
BHW16	410	26014	44527	5747.0	**43948**	3352.9
BHW17	240	15396	26768	6823.0	**26235**	3548.7
BHW18	194	11202	15833	5532.0	**15170**	1551.1
BHW19	107	7080	9480	3605.0	**9388**	677.2
BHW20	293	10730	16625	6769.0	**16291**	1748.1
Sum/Average	3020	130880	198214	3603.6	**194855**	1286.1

Table 6: Computational results on the DI-NEARP instances.

Instance	τ	LB	Spider (sec_{tot}=7200) z	Spider sec_{inc}	AILS (sec_{tot}=3600) z	AILS sec_{inc}
DI-NEARP-n240-Q2k	240	16376	24371	4569.0	**23807**	3003.0
DI-NEARP-n240-Q4k	240	14362	18352	4495.0	**18197**	2374.2
DI-NEARP-n240-Q8k	240	13442	15937	6421.0	**15884**	2001.8
DI-NEARP-n240-Q16k	240	13116	14953	5274.0	**14717**	1058.4
DI-NEARP-n422-Q2k	422	11623	19133	6629.0	**18943**	2486.2
DI-NEARP-n422-Q4k	422	11284	15987	4524.0	**15869**	940.0
DI-NEARP-n422-Q8k	422	11220	14627	2925.0	**14442**	813.7
DI-NEARP-n422-Q16k	422	11198	14357	4661.0	**14339**	240.5
DI-NEARP-n442-Q2k	442	35068	52062	7091.0	**51052**	1303.4
DI-NEARP-n442-Q4k	442	33585	45906	6308.0	**44952**	3339.7
DI-NEARP-n442-Q8k	442	32985	45395	5964.0	**43264**	1029.5
DI-NEARP-n442-Q16k	442	32713	42797	6480.0	**42683**	1452.8
DI-NEARP-n477-Q2k	477	19722	23124	5996.0	**22896**	3218.8
DI-NEARP-n477-Q4k	477	18031	20198	7006.0	**20035**	1923.5
DI-NEARP-n477-Q8k	477	17193	18561	2999.0	**18490**	1546.5
DI-NEARP-n477-Q16k	477	16873	18105	4079.0	**18040**	2410.3
DI-NEARP-n699-Q2k	699	34101	59817	6993.0	**58948**	1776.7
DI-NEARP-n699-Q4k	699	26891	40473	7178.0	**40124**	2101.8
DI-NEARP-n699-Q8k	699	23302	30992	6095.0	**30799**	2871.4
DI-NEARP-n699-Q16k	699	21967	27028	3173.0	**26999**	3370.4
DI-NEARP-n833-Q2k	833	32435	56877	7135.0	**56102**	3556.7
DI-NEARP-n833-Q4k	833	29381	42407	6861.0	**41192**	3383.6
DI-NEARP-n833-Q8k	833	28453	35267	6940.0	**34812**	2688.3
DI-NEARP-n833-Q16k	833	28233	33013	4046.0	**32567**	3407.6
Sum/Average	12452	533554	729739	5576.8	**719153**	2179.1

Summary and Conclusions

- MCGRP relevant and important
- Not much studied
- AILS efficient, also for special cases


normal
ortho
hybrid
Vevungen
Kolbäcksån
Semla
Rönningen
Kolarbyn
Ulvsbo
Flogen
Saxen
Fagersta
Andra sidan
Melingsb.
Melingssj.
Fagersta
Melingsb.
Kratten
Västanfors
Sundbyberg
Skogs-
kapellet
Hyttbäcken
Färbo
Igeltjärnen
Igeltjärnsb.
Eskiln
Hedkärra
Jönsbacken
Hedtjärnen
Oti
Hedkärra
Aspatorp
Sandviken
Stora Aspen
Sjöhagen
Mossbo
Köpmanhamn
Spögubben
Högbyn
Hagen
Vallen
Åvestbo
Backgården
68
66
250

The Taming of the Shrew: An Adaptive Iterated Local Search for the Mixed Capacitated General Routing Problem

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