Warehouse allocation

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1 Problem description

There are N warehouses on different locations, each warehouse w has a set-up price s_w and a capacity cap_w. Also, there are M customers and each customer c damands d_c goods. There is defined delivery cost t_{cw} between each pair of customer and warehouse.

The goal is to assign one warehouse to each customer, while satisfying their demands and minimizing the overall cost.

$$\begin{aligned} \text{minimize} \quad & f = \sum_{w=1}^{N} (I(|a_w| > 0) \cdot s_w + \sum_{c \in a_w} t_{cw}) \\ \text{subject to} \quad & \sum_{c \in a_w} d_c \leq cap_w && \forall w = 1, \ldots, N \\ & \sum_{w=1}^{N} I(c \in a_w) = 1 && \forall c = 1, \ldots, M \end{aligned} \tag{1}$$

problem	optimum value
wl_16_1	976738.625
wl_25_2	796648.438
wl_50_1	793439.562
wl_100_4	17765201.949
wl_200_1	2686.479
wl_500_1	2608.148
wl_1000_1	5283.757
wl_2000_1	10069.803

Table 1: Problem instances

2 Representation and fitness function

Candidate representation

Customers are represented as numbers $c = 1, 2, \ldots, M$ and warehouses as numbers $w = 1, 2, \ldots, N$. Each candidate solution is represented as an integer vector of length M. On each position c is a number of warehouse w which was assigned to customer c.

1	2	$\cdots$	$M-1$	M
w_1	w_2	$\cdots$	w_{M-1}	w_M

Each candidate solution also holds excesses of individual capacities as a vector of length N, also as fitness function and constraint violation sum.

Fitness function

Fitness function is split into two parts: overall cost and constraint violations. The overall cost is computed according to problem fitness function as specified in previous section. Constraint violations are computed as absolute value of difference between capacity and accumulated demand after assiging the warehouses to customers. It is useful this way, because it allows to use two different comparison operators.

First operator compares two candidates by their constraint violations and prefers the less violating. If both candidates are feasible, only then they are compared by their fitness e.g. overall cost. This operator is used mostly in finding and comparing *bsf* candidates.

Second operator uses weighted sum of these two properties. It is usually managed by multipling constraing violations with some large number (1000 in my case) and adding the result with fitness. This operator showed a bit better results in evolution operators as it can keep some infeasible but otherwise really fit candidates in the population.

3 Algorithms and experiments

All algorithms can be terminated either by number of calls of function *Candidate.evaluate()*, or by number of unimproving iterations / generations. The submitted version uses the first one and the limit number is set by global object *state.set_limit(n)*. Note, that the summary will print out slightly larger number of evaluations than the limit, but it is only caused by checking the condition after evaluating the whole population for more simplicity. The *bsf* solution is not influenced by these evaluations over the limit.

To change the termination condition to unimproving generations, it suffices to remove lines containing *state.enough()*. Then, the *state.set_limit(n)* corresponds to iterations in local search and to generations in evolution algorithm and specialized algorithm.

3.1 Local search

First used algorithm is simple local search with first-improving strategy. Solver is implemented in *src/local_search/local_search.cpp* and is run by binary *out/ls* made from main file *src/solver/ls.cpp*.

3.1.1 Description

Initialization

The initial candidate solution is created greedily by assigning the warehouse with lowest transport cost for each customer. This initialization showed much better solutions than random initialization, especially for smaller instances. Here, the search space isn't as large and the result of this greedy construction is already pretty good, only a bit invalid.

Operators

Two perturbation operators were used to modify the candidate solution.

First operator (*heuristics::improve_violating*) was used only when the candidate solution was invalid. It iterates over all assignments and when it finds a warehouse whose capacity was depleted, it changes the assignment to a random warehouse. Then it evaluates the solution and checks if it is better (less invalid or more fit). If it is, this candidate is accepted as improved, and the iteration continues until next constraint violation occurs.

Second operator (*Candidate.mutate(n)*) was used when the candidate solution was already feasible. It simply selects n random customers and changes their assigned warehouses to random ones. My experiments were run with $n = 1$.

3.1.2 Experiments

Each instance of problem was run 11 times (so there is a median) for increasing number of evaluations. Each batch with the same number of evaluations has highlighted it's median.

From the results it can be seen, that this type of local search is extremely fast and good on simpler instances and even with quite low number of evaluations it gets really close to global optimum. However, increasing the evaluations above certain number doesn't have any effect on quality of the solution. The algorithm probably gets stuck in some local optimum and the simple mutation of one assignment is not able to shift it somewhere else. Big advantage for these smaller instances is the greedy initialization, but this can also cause problem with convergence to global optimum as it can be located really far from this starting point and the algorithm pushes it another way.

On more difficult and large instances it performs poorly. It possibly searches the space too slowly and it would be better with some more aggressive perturbation. On the other hand, it almost always finds feasible solution, even though it is quite far from global optimum.

evaluations	generations	time	violations	objective	ratio with optimum
1000	982	3ms	0	1269490.0	1.29972
1000	985	4ms	0	1126970.0	1.15381
1000	980	3ms	0	1356970.0	1.38928
1000	988	3ms	0	1185400.0	1.21363
1000	990	3ms	0	1238880.0	1.26839
1000	984	3ms	0	1167110.0	1.19491
1000	967	3ms	0	1237270.0	1.26674
1000	970	2ms	0	1158580.0	1.18617
1000	981	2ms	0	1099360.0	1.12554
1000	985	2ms	0	1251900.0	1.28171
1000	984	2ms	0	1620870.0	1.65947
5000	4988	14ms	0	1138740.0	1.16585
5000	4981	14ms	0	1252160.0	1.28198
5000	4980	14ms	0	1154300.0	1.18179
5000	4985	14ms	0	1075590.0	1.10121
5002	2451	16ms	8	1307050.0	1.33818
5000	4978	14ms	0	1041990.0	1.06681
5000	4976	14ms	0	1030990.0	1.05555
5000	4980	14ms	0	1123180.0	1.14993
5000	4989	14ms	0	1184410.0	1.21262
5000	4985	14ms	0	1061620.0	1.0869
5000	4982	9ms	0	1135120.0	1.16215
10000	9980	27ms	0	1199140.0	1.2277
10000	9985	27ms	0	1115900.0	1.14247
10000	9981	26ms	0	1140900.0	1.16807
10000	9987	27ms	0	1051590.0	1.07663
10000	9986	28ms	0	1165960.0	1.19372
10000	9985	28ms	0	1030990.0	1.05555
10000	9980	27ms	0	1138840.0	1.16596
10000	9967	28ms	0	1016450.0	1.04066
10000	9988	27ms	0	1016780.0	1.041
10000	9985	28ms	0	1097470.0	1.12361
10000	9982	19ms	0	1212000.0	1.24087
50000	49984	96ms	0	1068770.0	1.09422
50000	49976	96ms	0	1205760.0	1.23447
50000	49979	97ms	0	1507780.0	1.54369
50002	20624	113ms	8	1300430.0	1.3314
50000	49989	97ms	0	1035490.0	1.06015
50000	49982	98ms	0	1017100.0	1.04132
50000	49986	96ms	0	1014980.0	1.03915
50000	49988	99ms	0	1202290.0	1.23092
50000	49991	98ms	0	1182330.0	1.21049
50000	49982	98ms	0	1016450.0	1.04066
50000	49986	92ms	0	1114320.0	1.14086
100000	99988	212ms	0	1082350.0	1.10813
100000	99990	213ms	0	1165960.0	1.19372
100000	99985	211ms	0	1081610.0	1.10737
100000	99979	211ms	0	1187270.0	1.21554
100000	99976	211ms	0	1036240.0	1.06092
100000	99979	210ms	0	1088230.0	1.11415
100000	99989	214ms	0	1035080.0	1.05973
100000	99986	213ms	0	1011450.0	1.03554
100000	99978	212ms	0	1146540.0	1.17385
100000	99983	211ms	0	1142530.0	1.16974
100000	99989	198ms	0	1035080.0	1.05973
500000	499986	1105ms	0	1138840.0	1.16596
500000	499987	1113ms	0	1035490.0	1.06015
500000	499986	1085ms	0	1030990.0	1.05555
500000	205676	1260ms	8	1180340.0	1.20845
500000	499983	1098ms	0	1138840.0	1.16596
500000	499981	1081ms	0	1114430.0	1.14097
500000	499985	1080ms	0	1120060.0	1.14674
500000	499963	1086ms	0	1104430.0	1.13074
500000	499976	1091ms	0	1115900.0	1.14247
500000	499984	1099ms	0	1008970.0	1.033
500000	499982	1022ms	0	1123360.0	1.15011
1000000	999981	2248ms	0	1034980.0	1.05962
1000000	999973	2211ms	0	1009180.0	1.03321
1000000	999990	2223ms	0	1164930.0	1.19267
1000000	999985	2219ms	0	1071690.0	1.09721
1000000	999983	2206ms	0	1010080.0	1.03413
1000000	999982	2224ms	0	1084360.0	1.11018
1000000	999978	2218ms	0	1190290.0	1.21864
1000000	999987	2219ms	0	1146560.0	1.17386
1000000	999985	2216ms	0	1435100.0	1.46927
1000000	999981	2227ms	0	1138740.0	1.16585
1000000	999983	2119ms	0	1116910.0	1.14351
5000000	4999978	11261ms	0	1016200.0	1.0404
5000000	4999986	11221ms	0	1016140.0	1.04034
5000000	4999987	11227ms	0	1167990.0	1.19581
5000000	4999941	11227ms	0	1016450.0	1.04066
5000000	4999983	11169ms	0	1058560.0	1.08377
5000000	4999975	11211ms	0	1166370.0	1.19414
5000000	4999973	11164ms	0	993907.0	1.01758
5000000	4999980	11184ms	0	1091950.0	1.11795
5000000	4999982	11205ms	0	1120210.0	1.14689
5000000	4999986	11237ms	0	1035490.0	1.06015
5000000	4999986	10902ms	0	1166370.0	1.19414

Table 2: local search: wl_16_1

evaluations	generations	time	violations	objective	ratio with optimum
1000	998	2ms	0	814938.0	1.02296
1000	998	2ms	0	818368.0	1.02726
1000	998	2ms	0	823696.0	1.03395
1000	998	2ms	0	818559.0	1.0275
1000	998	1ms	0	819949.0	1.02925
1000	998	1ms	0	814296.0	1.02215
1000	998	1ms	0	821488.0	1.03118
1000	998	1ms	0	820441.0	1.02987
1000	998	1ms	0	817235.0	1.02584
1000	998	1ms	0	816081.0	1.02439
1000	998	2ms	0	820342.0	1.02974
5000	4998	15ms	0	812441.0	1.01982
5000	4998	16ms	0	815128.0	1.0232
5000	4998	15ms	0	814938.0	1.02296
5000	4998	16ms	0	813276.0	1.02087
5000	4998	15ms	0	814938.0	1.02296
5000	4998	16ms	0	813276.0	1.02087
5000	4998	16ms	0	814335.0	1.0222
5000	4998	15ms	0	814938.0	1.02296
5000	4998	16ms	0	813276.0	1.02087
5000	4998	16ms	0	812903.0	1.0204
5000	4998	10ms	0	813276.0	1.02087
10000	9998	30ms	0	810780.0	1.01774
10000	9998	30ms	0	814938.0	1.02296
10000	9998	30ms	0	813276.0	1.02087
10000	9998	30ms	0	810780.0	1.01774
10000	9998	30ms	0	812441.0	1.01982
10000	9998	30ms	0	812441.0	1.01982
10000	9998	30ms	0	814938.0	1.02296
10000	9998	30ms	0	813276.0	1.02087
10000	9998	30ms	0	814938.0	1.02296
10000	9998	30ms	0	813276.0	1.02087
10000	9998	20ms	0	814938.0	1.02296
50000	49998	106ms	0	810780.0	1.01774
50000	49998	107ms	0	814938.0	1.02296
50000	49998	105ms	0	814938.0	1.02296
50000	49998	105ms	0	814938.0	1.02296
50000	49998	105ms	0	814938.0	1.02296
50000	49998	105ms	0	814938.0	1.02296
50000	49998	105ms	0	814938.0	1.02296
50000	49998	106ms	0	813276.0	1.02087
50000	49998	108ms	0	813276.0	1.02087
50000	49998	105ms	0	814938.0	1.02296
50000	49998	102ms	0	812441.0	1.01982
100000	99998	232ms	0	813276.0	1.02087
100000	99998	234ms	0	813276.0	1.02087
100000	99998	232ms	0	814938.0	1.02296
100000	99998	233ms	0	813276.0	1.02087
100000	99998	231ms	0	812441.0	1.01982
100000	99998	245ms	0	814938.0	1.02296
100000	99998	233ms	0	810780.0	1.01774
100000	99998	232ms	0	814938.0	1.02296
100000	99998	233ms	0	813276.0	1.02087
100000	99998	233ms	0	813276.0	1.02087
100000	99998	217ms	0	814938.0	1.02296
500000	499998	1184ms	0	814938.0	1.02296
500000	499998	1183ms	0	814938.0	1.02296
500000	499998	1188ms	0	814938.0	1.02296
500000	499998	1236ms	0	813276.0	1.02087
500000	499998	1192ms	0	813276.0	1.02087
500000	499998	1191ms	0	813276.0	1.02087
500000	499998	1185ms	0	814938.0	1.02296
500000	499998	1206ms	0	813276.0	1.02087
500000	499998	1190ms	0	812441.0	1.01982
500000	499998	1184ms	0	814938.0	1.02296
500000	499998	1137ms	0	810780.0	1.01774
1000000	999998	2437ms	0	812441.0	1.01982
1000000	999998	2429ms	0	814938.0	1.02296
1000000	999998	2430ms	0	810780.0	1.01774
1000000	999998	2435ms	0	810780.0	1.01774
1000000	999998	2437ms	0	810780.0	1.01774
1000000	999998	2424ms	0	814938.0	1.02296
1000000	999998	2429ms	0	814938.0	1.02296
1000000	999998	2427ms	0	814938.0	1.02296
1000000	999998	2445ms	0	813276.0	1.02087
1000000	999998	2444ms	0	813276.0	1.02087
1000000	999998	2321ms	0	813276.0	1.02087
5000000	4999998	12259ms	0	814938.0	1.02296
5000000	4999998	12251ms	0	814938.0	1.02296
5000000	4999998	12330ms	0	813276.0	1.02087
5000000	4999998	12260ms	0	814938.0	1.02296
5000000	4999998	12220ms	0	814938.0	1.02296
5000000	4999998	12292ms	0	810780.0	1.01774
5000000	4999998	12287ms	0	813276.0	1.02087
5000000	4999998	12314ms	0	813276.0	1.02087
5000000	4999998	12267ms	0	814938.0	1.02296
5000000	4999998	12343ms	0	810780.0	1.01774
5000000	4999998	11975ms	0	813276.0	1.02087

Table 3: local search: wl_25_2

evaluations	generations	time	violations	objective	ratio with optimum
1000	998	2ms	0	856230.0	1.07914
1000	998	2ms	0	855539.0	1.07826
1000	998	2ms	0	867868.0	1.0938
1000	998	2ms	0	848080.0	1.06887
1000	998	2ms	0	852520.0	1.07446
1000	998	2ms	0	849197.0	1.07027
1000	998	2ms	0	857586.0	1.08084
1000	998	2ms	0	848972.0	1.06999
1000	998	2ms	0	858389.0	1.08186
1000	998	2ms	0	862924.0	1.08757
1000	998	2ms	0	874751.0	1.10248
5000	4998	19ms	0	823947.0	1.03845
5000	4998	19ms	0	834184.0	1.05135
5000	4998	19ms	0	823315.0	1.03765
5000	4998	19ms	0	813630.0	1.02545
5000	4998	19ms	0	826272.0	1.04138
5000	4998	19ms	0	827811.0	1.04332
5000	4998	19ms	0	818262.0	1.03128
5000	4998	19ms	0	836577.0	1.05437
5000	4998	19ms	0	829060.0	1.04489
5000	4998	19ms	0	837321.0	1.05531
5000	4998	12ms	0	829673.0	1.04567
10000	9998	37ms	0	818283.0	1.03131
10000	9998	37ms	0	819628.0	1.03301
10000	9998	37ms	0	810015.0	1.02089
10000	9998	37ms	0	827617.0	1.04308
10000	9998	37ms	0	817478.0	1.0303
10000	9998	37ms	0	815994.0	1.02842
10000	9998	37ms	0	814854.0	1.02699
10000	9998	37ms	0	817361.0	1.03015
10000	9998	37ms	0	827873.0	1.0434
10000	9998	37ms	0	813980.0	1.02589
10000	9998	25ms	0	824499.0	1.03915
50000	49998	130ms	0	815927.0	1.02834
50000	49998	129ms	0	823873.0	1.03836
50000	49998	129ms	0	819040.0	1.03226
50000	49998	130ms	0	825340.0	1.04021
50000	49998	130ms	0	827671.0	1.04314
50000	49998	130ms	0	832705.0	1.04949
50000	49998	133ms	0	817847.0	1.03076
50000	49998	129ms	0	812181.0	1.02362
50000	49998	131ms	0	818747.0	1.03189
50000	49998	130ms	0	813502.0	1.02529
50000	49998	125ms	0	813100.0	1.02478
100000	99998	283ms	0	817134.0	1.02986
100000	99998	284ms	0	829193.0	1.04506
100000	99998	292ms	0	832060.0	1.04867
100000	99998	289ms	0	817917.0	1.03085
100000	99998	294ms	0	810324.0	1.02128
100000	99998	292ms	0	826568.0	1.04175
100000	99998	282ms	0	818671.0	1.0318
100000	99998	283ms	0	816200.0	1.02869
100000	99998	282ms	0	823099.0	1.03738
100000	99998	280ms	0	818209.0	1.03122
100000	99998	260ms	0	818799.0	1.03196
500000	499998	1437ms	0	807209.0	1.01735
500000	499998	1456ms	0	828036.0	1.0436
500000	499998	1448ms	0	815656.0	1.028
500000	499998	1466ms	0	826356.0	1.04149
500000	499998	1470ms	0	820571.0	1.03419
500000	499998	1454ms	0	820031.0	1.03351
500000	499998	1447ms	0	823032.0	1.0373
500000	499998	1438ms	0	815984.0	1.02841
500000	499998	1461ms	0	827744.0	1.04324
500000	499998	1426ms	0	829143.0	1.045
500000	499998	1347ms	0	830316.0	1.04648
1000000	999998	2929ms	0	814317.0	1.02631
1000000	999998	2967ms	0	817208.0	1.02996
1000000	999998	2935ms	0	805157.0	1.01477
1000000	999998	2970ms	0	824418.0	1.03904
1000000	999998	2962ms	0	819225.0	1.0325
1000000	999998	2989ms	0	829540.0	1.0455
1000000	999998	2922ms	0	825724.0	1.04069
1000000	999998	2936ms	0	812316.0	1.02379
1000000	999998	2907ms	0	825608.0	1.04054
1000000	999998	2942ms	0	816759.0	1.02939
1000000	999998	2780ms	0	816511.0	1.02908
5000000	4999998	14761ms	0	810561.0	1.02158
5000000	4999998	14982ms	0	814848.0	1.02698
5000000	4999998	14892ms	0	807219.0	1.01737
5000000	4999998	14689ms	0	820162.0	1.03368
5000000	4999998	14767ms	0	814213.0	1.02618
5000000	4999998	14831ms	0	819810.0	1.03323
5000000	4999998	14854ms	0	833479.0	1.05046
5000000	4999998	14908ms	0	808005.0	1.01836
5000000	4999998	14871ms	0	819595.0	1.03296
5000000	4999998	14905ms	0	824138.0	1.03869
5000000	4999998	14696ms	0	815908.0	1.02832

Table 4: local search: wl_50_1

evaluations	generations	time	violations	objective	ratio with optimum
1000	998	18ms	0	179545000.0	10.1066
1000	998	17ms	0	180981000.0	10.1874
1000	998	17ms	0	179553000.0	10.107
1000	998	17ms	0	181199000.0	10.1997
1000	998	17ms	0	181199000.0	10.1997
1000	998	17ms	0	179554000.0	10.107
1000	998	17ms	0	179541000.0	10.1063
1000	998	17ms	0	181199000.0	10.1997
1000	998	17ms	0	181199000.0	10.1997
1000	998	19ms	0	179537000.0	10.1061
1000	998	20ms	0	181199000.0	10.1997
5000	4998	157ms	0	179531000.0	10.1058
5000	4998	155ms	0	179541000.0	10.1064
5000	4998	155ms	0	179540000.0	10.1062
5000	4998	151ms	0	179536000.0	10.1061
5000	4998	174ms	0	179541000.0	10.1063
5000	4998	196ms	0	179534000.0	10.1059
5000	4998	168ms	0	181199000.0	10.1997
5000	4998	163ms	0	179534000.0	10.1059
5000	4998	156ms	0	181199000.0	10.1997
5000	4998	156ms	0	179540000.0	10.1062
5000	4998	96ms	0	179545000.0	10.1065
10000	9998	295ms	0	179543000.0	10.1065
10000	9998	298ms	0	179531000.0	10.1058
10000	9998	322ms	0	179537000.0	10.1061
10000	9998	297ms	0	179534000.0	10.1059
10000	9998	297ms	0	179534000.0	10.1059
10000	9998	299ms	0	179534000.0	10.1059
10000	9998	296ms	0	179544000.0	10.1065
10000	9998	298ms	0	179536000.0	10.1061
10000	9998	295ms	0	179534000.0	10.1059
10000	9998	296ms	0	179531000.0	10.1058
10000	9998	194ms	0	179532000.0	10.1058
50000	49998	1041ms	0	179534000.0	10.1059
50000	49998	1038ms	0	179534000.0	10.1059
50000	49998	1035ms	0	179532000.0	10.1058
50000	49998	1032ms	0	179536000.0	10.106
50000	49998	1043ms	0	179531000.0	10.1058
50000	49998	1047ms	0	179534000.0	10.1059
50000	49998	1039ms	0	179530000.0	10.1057
50000	49998	1035ms	0	179534000.0	10.1059
50000	49998	1052ms	0	179530000.0	10.1057
50000	49998	1045ms	0	179534000.0	10.1059
50000	49998	986ms	0	179530000.0	10.1057
100000	99998	2277ms	0	179531000.0	10.1058
100000	99998	2259ms	0	179530000.0	10.1057
100000	99998	2313ms	0	179530000.0	10.1057
100000	99998	2250ms	0	179530000.0	10.1057
100000	99998	2277ms	0	179534000.0	10.1059
100000	99998	2295ms	0	179530000.0	10.1057
100000	99998	2268ms	0	179530000.0	10.1057
100000	99998	2259ms	0	179530000.0	10.1057
100000	99998	2274ms	0	179531000.0	10.1058
100000	99998	2297ms	0	179530000.0	10.1057
100000	99998	2107ms	0	179530000.0	10.1057
500000	499998	11513ms	0	179530000.0	10.1057
500000	499998	11557ms	0	179530000.0	10.1057
500000	499998	11532ms	0	179530000.0	10.1057
500000	499998	11573ms	0	179530000.0	10.1057
500000	499998	11546ms	0	179530000.0	10.1057
500000	499998	11577ms	0	179530000.0	10.1057
500000	499998	11776ms	0	179530000.0	10.1057
500000	499998	11819ms	0	179530000.0	10.1057
500000	499998	11779ms	0	179530000.0	10.1057
500000	499998	11463ms	0	179530000.0	10.1057
500000	499998	10841ms	0	179530000.0	10.1057
1000000	999998	23593ms	0	179530000.0	10.1057
1000000	999998	23572ms	0	179530000.0	10.1057
1000000	999998	23611ms	0	179530000.0	10.1057
1000000	999998	23639ms	0	179530000.0	10.1057
1000000	999998	23892ms	0	179530000.0	10.1057
1000000	999998	23865ms	0	179530000.0	10.1057
1000000	999998	23666ms	0	179530000.0	10.1057
1000000	999998	24099ms	0	179530000.0	10.1057
1000000	999998	23812ms	0	179530000.0	10.1057
1000000	999998	23750ms	0	179530000.0	10.1057
1000000	999998	22458ms	0	179530000.0	10.1057
5000000	4999998	118836ms	0	179530000.0	10.1057
5000000	4999998	118960ms	0	179530000.0	10.1057
5000000	4999998	118145ms	0	179530000.0	10.1057
5000000	4999998	118734ms	0	179530000.0	10.1057
5000000	4999998	119143ms	0	179530000.0	10.1057
5000000	4999998	119436ms	0	179530000.0	10.1057
5000000	4999998	119223ms	0	179530000.0	10.1057
5000000	4999998	119629ms	0	179530000.0	10.1057
5000000	4999998	119034ms	0	179530000.0	10.1057
5000000	4999998	119567ms	0	179530000.0	10.1057
5000000	4999998	115482ms	0	179530000.0	10.1057

Table 5: local search: wl_100_4

evaluations	generations	time	violations	objective	ratio with optimum
1000	998	7ms	0	26442.8	9.84262
1000	998	7ms	0	25012.7	9.31033
1000	998	7ms	0	24769.6	9.21987
1000	998	7ms	0	26426.9	9.83667
1000	998	7ms	0	26223.6	9.7611
1000	998	7ms	0	26244.9	9.76892
1000	998	7ms	0	27865.8	10.3723
1000	998	7ms	0	26070.0	9.70378
1000	998	7ms	0	26168.9	9.74063
1000	998	7ms	0	26329.2	9.80056
1000	998	8ms	0	27303.8	10.1631
5000	4998	66ms	0	23581.0	8.77729
5000	4998	63ms	0	22616.6	8.41845
5000	4998	64ms	0	23268.0	8.66115
5000	4998	64ms	0	21994.5	8.18692
5000	4998	64ms	0	23485.2	8.74193
5000	4998	64ms	0	22528.4	8.3857
5000	4998	63ms	0	21653.8	8.05999
5000	4998	63ms	0	23181.7	8.62877
5000	4998	63ms	0	22029.7	8.19995
5000	4998	60ms	0	23269.6	8.66152
5000	4998	39ms	0	23735.9	8.83498
10000	9998	120ms	0	22870.2	8.513
10000	9998	121ms	0	22535.3	8.3883
10000	9998	121ms	0	21525.4	8.01235
10000	9998	120ms	0	22638.3	8.42664
10000	9998	121ms	0	21888.1	8.14747
10000	9998	121ms	0	21868.2	8.14002
10000	9998	120ms	0	21798.8	8.11397
10000	9998	120ms	0	21661.0	8.0626
10000	9998	121ms	0	23035.5	8.57442
10000	9998	122ms	0	23486.5	8.7423
10000	9998	94ms	0	22454.6	8.35815
50000	49998	447ms	0	20593.0	7.66505
50000	49998	438ms	0	21124.5	7.86308
50000	49998	429ms	0	21369.4	7.95428
50000	49998	427ms	0	20965.8	7.80389
50000	49998	430ms	0	21798.7	8.11397
50000	49998	435ms	0	21883.1	8.14561
50000	49998	444ms	0	21160.7	7.87648
50000	49998	438ms	0	20563.5	7.65426
50000	49998	442ms	0	21759.3	8.09945
50000	49998	435ms	0	21130.3	7.86531
50000	49998	403ms	0	21841.3	8.12997
100000	99998	908ms	0	20787.4	7.73764
100000	99998	910ms	0	20932.6	7.79161
100000	99998	907ms	0	21429.1	7.97661
100000	99998	923ms	0	21173.8	7.88132
100000	99998	922ms	0	21838.9	8.12886
100000	99998	941ms	0	20255.9	7.53961
100000	99998	914ms	0	21118.9	7.86085
100000	99998	915ms	0	21974.2	8.17948
100000	99998	926ms	0	20651.4	7.68701
100000	99998	911ms	0	21316.8	7.93455
100000	99998	851ms	0	21192.2	7.88839
500000	499998	4660ms	0	21410.8	7.96954
500000	499998	4649ms	0	20889.6	7.77561
500000	499998	4640ms	0	21200.4	7.89137
500000	499998	4659ms	0	21126.5	7.86382
500000	499998	4698ms	0	22201.7	8.26398
500000	499998	4690ms	0	20947.9	7.79719
500000	499998	4724ms	0	21583.4	8.03394
500000	499998	4707ms	0	21009.4	7.82027
500000	499998	4717ms	0	22065.9	8.21335
500000	499998	4670ms	0	21286.2	7.92338
500000	499998	4411ms	0	20667.4	7.69297
1000000	999998	9532ms	0	22003.9	8.19027
1000000	999998	9444ms	0	21419.7	7.97289
1000000	999998	9516ms	0	21556.7	8.02389
1000000	999998	9530ms	0	20868.9	7.76779
1000000	999998	9565ms	0	21596.9	8.03877
1000000	999998	9557ms	0	21692.1	8.07451
1000000	999998	9667ms	0	21263.7	7.91482
1000000	999998	9677ms	0	21034.3	7.82958
1000000	999998	9702ms	0	22149.9	8.24462
1000000	999998	9662ms	0	21595.9	8.0384
1000000	999998	9093ms	0	20644.0	7.68404
5000000	4999998	47950ms	0	20882.0	7.773
5000000	4999998	48211ms	0	20418.3	7.60028
5000000	4999998	48352ms	0	20901.5	7.78007
5000000	4999998	48041ms	0	21251.6	7.91035
5000000	4999998	48175ms	0	20509.1	7.63416
5000000	4999998	48001ms	0	21752.1	8.09684
5000000	4999998	48190ms	0	20418.3	7.60028
5000000	4999998	48545ms	0	21483.6	7.99671
5000000	4999998	48310ms	0	21296.9	7.9271
5000000	4999998	48263ms	0	21069.3	7.84261
5000000	4999998	46512ms	0	20757.4	7.72647

Table 6: local search: wl_200_1

evaluations	generations	time	violations	objective	ratio with optimum
1000	998	19ms	0	76748.7	29.4262
1000	998	19ms	0	75266.2	28.858
1000	998	19ms	0	74151.3	28.4305
1000	998	19ms	0	77336.8	29.6517
1000	998	19ms	0	76574.2	29.3595
1000	998	20ms	0	75321.1	28.8791
1000	998	19ms	0	78500.0	30.0976
1000	998	19ms	0	77766.1	29.8166
1000	998	19ms	0	78951.5	30.2709
1000	998	19ms	0	77029.4	29.534
1000	998	22ms	0	77391.7	29.6728
5000	4998	152ms	0	60098.0	23.0424
5000	4998	158ms	0	61085.6	23.4208
5000	4998	150ms	0	56000.9	21.4712
5000	4998	156ms	0	58931.8	22.595
5000	4998	150ms	0	58817.0	22.5509
5000	4998	154ms	0	58702.7	22.5072
5000	4998	154ms	0	59676.9	22.8806
5000	4998	157ms	0	58732.6	22.5187
5000	4998	150ms	0	60818.4	23.3185
5000	4998	158ms	0	58471.0	22.4182
5000	4998	99ms	0	59182.3	22.6912
10000	9998	299ms	0	56279.7	21.5781
10000	9998	296ms	0	55080.0	21.1181
10000	9998	317ms	0	57703.3	22.1241
10000	9998	297ms	0	55252.3	21.1844
10000	9998	301ms	0	55167.6	21.1518
10000	9998	298ms	0	57247.3	21.9493
10000	9998	297ms	0	52725.5	20.2155
10000	9998	300ms	0	57481.9	22.039
10000	9998	298ms	0	52796.4	20.2427
10000	9998	296ms	0	55893.0	21.4301
10000	9998	195ms	0	56998.5	21.8538
50000	49998	1066ms	0	50890.9	19.5119
50000	49998	1059ms	0	50848.4	19.4958
50000	49998	1059ms	0	48989.8	18.7831
50000	49998	1069ms	0	50056.0	19.1918
50000	49998	1082ms	0	51290.7	19.6653
50000	49998	1075ms	0	49736.0	19.0695
50000	49998	1071ms	0	50850.4	19.4966
50000	49998	1072ms	0	49716.1	19.0618
50000	49998	1075ms	0	49058.2	18.8095
50000	49998	1089ms	0	50388.8	19.3195
50000	49998	976ms	0	47963.1	18.3897
100000	99998	2175ms	0	49742.9	19.0718
100000	99998	2227ms	0	49874.7	19.1224
100000	99998	2194ms	0	49805.3	19.0959
100000	99998	2204ms	0	49342.0	18.9184
100000	99998	2214ms	0	49510.7	18.9828
100000	99998	2219ms	0	46165.3	17.7003
100000	99998	2235ms	0	49209.1	18.8674
100000	99998	2233ms	0	48953.1	18.7693
100000	99998	2232ms	0	48287.1	18.5139
100000	99998	2229ms	0	48630.0	18.6454
100000	99998	2036ms	0	48348.3	18.5373
500000	499998	11101ms	0	46964.3	18.0066
500000	499998	11091ms	0	46524.4	17.8379
500000	499998	11107ms	0	47347.7	18.1535
500000	499998	11138ms	0	47741.3	18.3046
500000	499998	11077ms	0	46882.2	17.9752
500000	499998	11041ms	0	47257.6	18.119
500000	499998	11079ms	0	47261.4	18.1205
500000	499998	11189ms	0	49325.9	18.9119
500000	499998	11126ms	0	48384.9	18.5511
500000	499998	11391ms	0	47740.6	18.3042
500000	499998	10551ms	0	48547.4	18.6136
1000000	999998	22811ms	0	47296.5	18.1339
1000000	999998	22792ms	0	45764.2	17.5466
1000000	999998	22841ms	0	47508.5	18.2152
1000000	999998	22703ms	0	46823.9	17.9526
1000000	999998	22936ms	0	47011.5	18.0247
1000000	999998	22884ms	0	46854.8	17.9645
1000000	999998	22827ms	0	46970.6	18.0089
1000000	999998	22899ms	0	47198.5	18.0964
1000000	999998	22839ms	0	47194.9	18.0948
1000000	999998	22866ms	0	47579.2	18.2424
1000000	999998	21478ms	0	47020.7	18.0281
5000000	4999998	114810ms	0	48229.1	18.4917
5000000	4999998	115591ms	0	49517.3	18.9855
5000000	4999998	113698ms	0	46462.8	17.8142
5000000	4999998	114912ms	0	48255.5	18.5016
5000000	4999998	114352ms	0	48443.2	18.5737
5000000	4999998	115080ms	0	48631.5	18.6458
5000000	4999998	115283ms	0	47660.1	18.2735
5000000	4999998	114535ms	0	46268.4	17.7398
5000000	4999998	114709ms	0	48365.1	18.5438
5000000	4999998	113706ms	0	48616.8	18.64
5000000	4999998	114971ms	0	47181.8	18.0898

Table 7: local search: wl_500_1

evaluations	generations	time	violations	objective	ratio with optimum
1000	998	43ms	0	341736.0	64.6765
1000	998	43ms	0	344342.0	65.1697
1000	998	50ms	0	339663.0	64.2844
1000	998	48ms	0	342643.0	64.8482
1000	998	49ms	0	338227.0	64.0126
1000	998	49ms	0	337914.0	63.9534
1000	998	48ms	0	341378.0	64.609
1000	998	49ms	0	344850.0	65.2661
1000	998	49ms	0	347461.0	65.7602
1000	998	49ms	0	340638.0	64.4687
1000	998	50ms	0	344038.0	65.1124
5000	4998	318ms	0	256371.0	48.5206
5000	4998	331ms	0	262124.0	49.6094
5000	4998	324ms	0	258617.0	48.9457
5000	4998	326ms	0	262333.0	49.6488
5000	4998	328ms	0	257571.0	48.7475
5000	4998	321ms	0	254629.0	48.1907
5000	4998	322ms	0	260191.0	49.2434
5000	4998	316ms	0	261798.0	49.5475
5000	4998	331ms	0	253470.0	47.9715
5000	4998	322ms	0	259698.0	49.1503
5000	4998	210ms	0	262231.0	49.6295
10000	9998	612ms	0	240905.0	45.5933
10000	9998	614ms	0	245740.0	46.5086
10000	9998	620ms	0	233751.0	44.2395
10000	9998	619ms	0	239628.0	45.3518
10000	9998	610ms	0	234652.0	44.4101
10000	9998	623ms	0	237108.0	44.8749
10000	9998	619ms	0	238186.0	45.0789
10000	9998	616ms	0	237446.0	44.9389
10000	9998	619ms	0	238486.0	45.1355
10000	9998	611ms	0	242821.0	45.9561
10000	9998	407ms	0	235299.0	44.5323
50000	49998	2185ms	0	214376.0	40.5725
50000	49998	2222ms	0	218661.0	41.3834
50000	49998	2201ms	0	213253.0	40.3601
50000	49998	2219ms	0	213750.0	40.4542
50000	49998	2202ms	0	208760.0	39.5096
50000	49998	2218ms	0	220368.0	41.7067
50000	49998	2217ms	0	214051.0	40.5111
50000	49998	2222ms	0	209591.0	39.6669
50000	49998	2223ms	0	217308.0	41.1276
50000	49998	2243ms	0	213784.0	40.4606
50000	49998	1990ms	0	213721.0	40.4485
100000	99998	4544ms	0	209634.0	39.6752
100000	99998	4535ms	0	208811.0	39.5194
100000	99998	4549ms	0	211243.0	39.9797
100000	99998	4574ms	0	214609.0	40.6166
100000	99998	4551ms	0	208720.0	39.5022
100000	99998	4571ms	0	213582.0	40.4222
100000	99998	4566ms	0	209115.0	39.577
100000	99998	4527ms	0	210116.0	39.7664
100000	99998	4558ms	0	209335.0	39.6184
100000	99998	4571ms	0	210271.0	39.7955
100000	99998	4155ms	0	208943.0	39.5444
500000	499998	23315ms	0	205332.0	38.861
500000	499998	22936ms	0	203185.0	38.4545
500000	499998	23041ms	0	202688.0	38.3606
500000	499998	23100ms	0	202514.0	38.3275
500000	499998	23058ms	0	204309.0	38.6674
500000	499998	23123ms	0	203106.0	38.4395
500000	499998	23143ms	0	207066.0	39.189
500000	499998	23175ms	0	205196.0	38.8352
500000	499998	23165ms	0	201864.0	38.2044
500000	499998	23115ms	0	205134.0	38.8235
500000	499998	21543ms	0	203851.0	38.5805
1000000	999998	46615ms	0	204776.0	38.7556
1000000	999998	46733ms	0	202496.0	38.3242
1000000	999998	46902ms	0	203113.0	38.4408
1000000	999998	47037ms	0	203236.0	38.4641
1000000	999998	46848ms	0	202607.0	38.3451
1000000	999998	46259ms	0	198406.0	37.55
1000000	999998	47194ms	0	201244.0	38.0871
1000000	999998	46835ms	0	203070.0	38.4329
1000000	999998	46967ms	0	203507.0	38.5156
1000000	999998	46654ms	0	204755.0	38.7518
1000000	999998	43558ms	0	201908.0	38.213
5000000	4999998	229200ms	0	203323.0	38.4808
5000000	4999998	229779ms	0	203210.0	38.4592
5000000	4999998	229974ms	0	201084.0	38.057
5000000	4999998	230014ms	0	202668.0	38.3568
5000000	4999998	231691ms	0	203423.0	38.4997
5000000	4999998	232698ms	0	201397.0	38.1161
5000000	4999998	232670ms	0	205133.0	38.8233
5000000	4999998	233371ms	0	203150.0	38.448
5000000	4999998	228862ms	0	203052.0	38.4295
5000000	4999998	225899ms	0	202178.0	38.2641
5000000	4999998	232776ms	0	201000.0	38.0409

Table 8: local search: wl_1000_1

evaluations	generations	time	violations	objective	ratio with optimum
1000	998	123ms	0	1426840.0	141.695
1000	998	121ms	0	1442460.0	143.246
1000	998	121ms	0	1437280.0	142.731
1000	998	122ms	0	1443550.0	143.355
1000	998	122ms	0	1423150.0	141.329
1000	998	122ms	0	1474420.0	146.42
1000	998	124ms	0	1425000.0	141.513
1000	998	142ms	0	1443480.0	143.348
1000	998	191ms	0	1438590.0	142.861
1000	998	192ms	0	1418680.0	140.885
1000	998	118ms	0	1427570.0	141.767
5000	4998	744ms	0	1090390.0	108.283
5000	4998	780ms	0	1088900.0	108.135
5000	4998	730ms	0	1087260.0	107.973
5000	4998	742ms	0	1089650.0	108.21
5000	4998	729ms	0	1087320.0	107.978
5000	4998	734ms	0	1092680.0	108.51
5000	4998	724ms	0	1097670.0	109.006
5000	4998	712ms	0	1081650.0	107.415
5000	4998	718ms	0	1094780.0	108.719
5000	4998	723ms	0	1119000.0	111.125
5000	4998	480ms	0	1095560.0	108.796
10000	9998	1412ms	0	979887.0	97.3094
10000	9998	1384ms	0	975050.0	96.829
10000	9998	1408ms	0	976935.0	97.0162
10000	9998	1394ms	0	966719.0	96.0018
10000	9998	1389ms	0	969105.0	96.2387
10000	9998	1386ms	0	988451.0	98.1598
10000	9998	1386ms	0	984221.0	97.7398
10000	9998	1394ms	0	987200.0	98.0356
10000	9998	1373ms	0	973555.0	96.6805
10000	9998	981ms	0	988175.0	98.1325
10000	9998	911ms	0	993931.0	98.7041
50000	49998	4942ms	0	825848.0	82.0122
50000	49998	5111ms	0	836550.0	83.075
50000	49998	4986ms	0	836384.0	83.0585
50000	49998	4981ms	0	834856.0	82.9068
50000	49998	4982ms	0	827025.0	82.1292
50000	49998	5018ms	0	833896.0	82.8115
50000	49998	4891ms	0	829740.0	82.3988
50000	49998	4918ms	0	819507.0	81.3826
50000	49998	4952ms	0	837066.0	83.1264
50000	49998	4971ms	0	834670.0	82.8883
50000	49998	4455ms	0	830684.0	82.4925
100000	99998	10006ms	0	801508.0	79.5951
100000	99998	10041ms	0	803053.0	79.7485
100000	99998	10127ms	0	798293.0	79.2758
100000	99998	10158ms	0	818035.0	81.2363
100000	99998	10218ms	0	817103.0	81.1438
100000	99998	10131ms	0	796237.0	79.0717
100000	99998	10169ms	0	810327.0	80.471
100000	99998	10124ms	0	812070.0	80.6441
100000	99998	10020ms	0	815233.0	80.9582
100000	99998	10017ms	0	818797.0	81.312
100000	99998	9322ms	0	808499.0	80.2894
500000	499998	50636ms	0	779002.0	77.3602
500000	499998	50901ms	0	774792.0	76.9421
500000	499998	51013ms	0	780989.0	77.5574
500000	499998	50806ms	0	776857.0	77.1472
500000	499998	50633ms	0	768357.0	76.303
500000	499998	49852ms	0	770507.0	76.5165
500000	499998	50377ms	0	778048.0	77.2655
500000	499998	50071ms	0	780619.0	77.5208
500000	499998	50056ms	0	777639.0	77.2247
500000	499998	50408ms	0	778903.0	77.3504
500000	499998	47656ms	0	777139.0	77.1752
1000000	999998	101372ms	0	770681.0	76.5338
1000000	999998	101381ms	0	776682.0	77.1297
1000000	999998	100949ms	0	776359.0	77.0977
1000000	999998	98495ms	0	760981.0	75.5705
1000000	999998	100333ms	0	775680.0	77.0302
1000000	999998	101403ms	0	767073.0	76.1756
1000000	999998	100738ms	0	760313.0	75.5042
1000000	999998	100621ms	0	768239.0	76.2914
1000000	999998	100355ms	0	772761.0	76.7403
1000000	999998	100279ms	0	781185.0	77.577
1000000	999998	105328ms	0	763903.0	75.8607
5000000	4999998	488263ms	0	762895.0	75.7606
5000000	4999998	495507ms	0	770316.0	76.4975
5000000	4999998	491997ms	0	763000.0	75.771
5000000	4999998	494489ms	0	765458.0	76.0151
5000000	4999998	499781ms	0	754147.0	74.8919
5000000	4999998	499095ms	0	753004.0	74.7783
5000000	4999998	499321ms	0	759618.0	75.4352
5000000	4999998	499470ms	0	768611.0	76.3283
5000000	4999998	498681ms	0	762510.0	75.7224
5000000	4999998	496269ms	0	759152.0	75.3889
5000000	4999998	500044ms	0	753239.0	74.8017

Table 9: local search: wl_2000_1

3.2 Evolution algorithm

Second algorithm is basic evolution algorithm. Solver is implemented in *src/ea/ea.cpp* and is run by binary *out/ea* made from main file *src/solver/ls.cpp*.

3.2.1 Description

Algorithms keeps a population of 50 candidate solutions (mainly due to performance reasons, evaluating larger population is too slow). Each of this solutions is randomly initialized.

In each iteration are chosen 5 candidates as parents for crossover using tournament selection. Size of each tournament is 4 candidates and are compared by weighted sum of their objective functions and constraint violations, while penalty constant being 1000.

Each pair of the 5 selected parents is bred using single point crossover at randomly selected point and so for each pair of parents there is a new pair of offsprings.

After crossover, there are actually two mutation operators each with different probability. First operator is the simple mutation from local search, where one random candidate is randomly assigned some warehouse. This operator is chosen with probability $Settings.mutation\_prob = 0.5$.

When the first operator is not selected for mutation, the second operator is used with probability $Settings.shuffle\_prob = 0.3$. This operator randomly shuffles the chromosome and has shown to be powerful in exploring new parts of search space.

After evaluation and update of *bsf* solution, the new population is recombined with the old one. All candidates from the new population are kept and then candidates from the old one are chosed with the same tournament procedure as in selection phase to get the recombined population to 50 members.

When algorithm detects number of evaluations equal or higher to the limit, it does not update best so far solution and terminates.

3.2.2 Experiments

Each instance of problem was run 11 times (so there is a median) for increasing number of evaluations. Each batch with the same number of evaluations has highlighted it's median.

As can be seen from the results, this algorithm is really slow. On the easier instances, it is necessary to make many evaluations and generations to come closer to global optimum. However, on the more difficult instances, it starts to get closer, even though it takes very long. Also, all solutions are feasible. It is quite possible, that the population starts to stagnate as it's progressing and rely only on mutation and that it is not enough to search fast enough.

evaluations	generations	time	violations	objective	ratio with optimum
1010	47	6ms	0	1802100.0	1.84502
1010	47	6ms	0	1609530.0	1.64786
1010	47	6ms	0	1809600.0	1.85269
1010	47	6ms	0	1699310.0	1.73978
1010	47	6ms	0	1877720.0	1.92243
1010	47	6ms	0	1857140.0	1.90137
1010	47	6ms	0	1496250.0	1.53188
1010	47	6ms	0	1592970.0	1.63091
1010	47	6ms	0	1862350.0	1.90671
1010	47	6ms	0	1543010.0	1.57975
1010	47	6ms	0	1424770.0	1.4587
5010	247	54ms	0	1142700.0	1.16991
5010	247	55ms	0	1286700.0	1.31734
5010	247	54ms	0	1549410.0	1.58631
5010	247	55ms	0	1310520.0	1.34173
5010	247	53ms	0	1431220.0	1.46531
5010	247	52ms	0	1213750.0	1.24266
5010	247	52ms	0	1293940.0	1.32476
5010	247	54ms	0	1226290.0	1.25549
5010	247	55ms	0	1319650.0	1.35108
5010	247	54ms	0	1456470.0	1.49115
5010	247	31ms	0	1202320.0	1.23096
10010	497	105ms	0	1231640.0	1.26097
10010	497	105ms	0	1399080.0	1.4324
10010	497	105ms	0	1208240.0	1.23701
10010	497	105ms	0	1210630.0	1.23946
10010	497	105ms	0	1289170.0	1.31987
10010	497	105ms	0	1572370.0	1.60982
10010	497	106ms	0	1212050.0	1.24091
10010	497	107ms	0	1134200.0	1.16121
10010	497	105ms	0	1332340.0	1.36407
10010	497	105ms	0	1343490.0	1.37548
10010	497	70ms	0	1288950.0	1.31964
50010	2497	394ms	0	1166170.0	1.19394
50010	2497	394ms	0	1105970.0	1.13231
50010	2497	394ms	0	1156150.0	1.18368
50010	2497	395ms	0	1493330.0	1.5289
50010	2497	396ms	0	1032350.0	1.05693
50010	2497	396ms	0	1240710.0	1.27026
50010	2497	397ms	0	1232330.0	1.26168
50010	2497	394ms	0	1126380.0	1.15321
50010	2497	396ms	0	1149500.0	1.17687
50010	2497	397ms	0	1285190.0	1.3158
50010	2497	351ms	0	1265060.0	1.29519
100010	4997	833ms	0	1069520.0	1.09499
100010	4997	825ms	0	1247260.0	1.27696
100010	4997	820ms	0	1222440.0	1.25155
100010	4997	821ms	0	1404850.0	1.43831
100010	4997	820ms	0	1176990.0	1.20502
100010	4997	827ms	0	1177660.0	1.2057
100010	4997	835ms	0	1304540.0	1.33561
100010	4997	827ms	0	1180210.0	1.20832
100010	4997	823ms	0	1249160.0	1.2789
100010	4997	818ms	0	1216520.0	1.24549
100010	4997	755ms	0	1197710.0	1.22624
500010	24997	4187ms	0	1268830.0	1.29904
500010	24997	4181ms	0	1190540.0	1.21889
500010	24997	4255ms	0	1209600.0	1.23841
500010	24997	4307ms	0	1108220.0	1.13462
500010	24997	4201ms	0	1158350.0	1.18594
500010	24997	4181ms	0	1145240.0	1.17251
500010	24997	4191ms	0	1156240.0	1.18377
500010	24997	4181ms	0	1185140.0	1.21337
500010	24997	4186ms	0	1377530.0	1.41033
500010	24997	4194ms	0	997198.0	1.02095
500010	24997	3903ms	0	1180970.0	1.20909
1000010	49997	8445ms	0	1143110.0	1.17034
1000010	49997	8479ms	0	1232450.0	1.2618
1000010	49997	8455ms	0	1100530.0	1.12673
1000010	49997	8482ms	0	1094900.0	1.12098
1000010	49997	8517ms	0	1079090.0	1.10478
1000010	49997	8364ms	0	1191840.0	1.22023
1000010	49997	8431ms	0	1089150.0	1.11509
1000010	49997	8462ms	0	1137460.0	1.16454
1000010	49997	8441ms	0	1162770.0	1.19047
1000010	49997	8433ms	0	1147900.0	1.17524
1000010	49997	9590ms	0	1164500.0	1.19224
5000010	249997	42277ms	0	1124060.0	1.15082
5000010	249997	42281ms	0	1143950.0	1.17119
5000010	249997	42272ms	0	1098140.0	1.12429
5000010	249997	42266ms	0	1314720.0	1.34603
5000010	249997	42260ms	0	1245780.0	1.27544
5000010	249997	42286ms	0	1116920.0	1.14352
5000010	249997	42200ms	0	1421600.0	1.45546
5000010	249997	42177ms	0	1180440.0	1.20856
5000010	249997	42176ms	0	1039630.0	1.06439
5000010	249997	42275ms	0	1124800.0	1.15159
5000010	249997	42744ms	0	1348120.0	1.38023

Table 10: ea: wl_16_1

evaluations	generations	time	violations	objective	ratio with optimum
1010	47	6ms	0	1162040.0	1.45866
1010	47	6ms	0	1212180.0	1.5216
1010	47	6ms	0	1243420.0	1.56082
1010	47	6ms	0	1144410.0	1.43654
1010	47	6ms	0	1151250.0	1.44511
1010	47	6ms	0	1184920.0	1.48738
1010	47	6ms	0	1143180.0	1.43499
1010	47	6ms	0	1067880.0	1.34047
1010	47	6ms	0	1239790.0	1.55626
1010	47	6ms	0	1211580.0	1.52085
1010	47	6ms	0	1203850.0	1.51114
5010	247	56ms	0	837032.0	1.05069
5010	247	54ms	0	838874.0	1.053
5010	247	54ms	0	830209.0	1.04213
5010	247	54ms	0	853666.0	1.07157
5010	247	54ms	0	831704.0	1.044
5010	247	57ms	0	864266.0	1.08488
5010	247	57ms	0	836298.0	1.04977
5010	247	56ms	0	833727.0	1.04654
5010	247	56ms	0	840747.0	1.05536
5010	247	56ms	0	854722.0	1.0729
5010	247	31ms	0	841728.0	1.05659
10010	497	113ms	0	815118.0	1.02318
10010	497	110ms	0	812878.0	1.02037
10010	497	108ms	0	859200.0	1.07852
10010	497	108ms	0	821443.0	1.03112
10010	497	109ms	0	816720.0	1.0252
10010	497	109ms	0	817522.0	1.0262
10010	497	110ms	0	806718.0	1.01264
10010	497	111ms	0	815828.0	1.02408
10010	497	112ms	0	811212.0	1.01828
10010	497	108ms	0	821143.0	1.03075
10010	497	72ms	0	855583.0	1.07398
50010	2497	405ms	0	815721.0	1.02394
50010	2497	419ms	0	811835.0	1.01906
50010	2497	408ms	0	807789.0	1.01398
50010	2497	406ms	0	807831.0	1.01404
50010	2497	408ms	0	811430.0	1.01855
50010	2497	406ms	0	801836.0	1.00651
50010	2497	405ms	0	812124.0	1.01942
50010	2497	407ms	0	812382.0	1.01975
50010	2497	408ms	0	810712.0	1.01765
50010	2497	406ms	0	808775.0	1.01522
50010	2497	359ms	0	820020.0	1.02934
100010	4997	846ms	0	813230.0	1.02081
100010	4997	847ms	0	818726.0	1.02771
100010	4997	856ms	0	815572.0	1.02375
100010	4997	843ms	0	809361.0	1.01596
100010	4997	845ms	0	811533.0	1.01868
100010	4997	847ms	0	813110.0	1.02066
100010	4997	842ms	0	810013.0	1.01678
100010	4997	842ms	0	816533.0	1.02496
100010	4997	854ms	0	814120.0	1.02193
100010	4997	864ms	0	815288.0	1.0234
100010	4997	780ms	0	806439.0	1.01229
500010	24997	4315ms	0	819718.0	1.02896
500010	24997	4291ms	0	806193.0	1.01198
500010	24997	4298ms	0	808216.0	1.01452
500010	24997	4309ms	0	800326.0	1.00462
500010	24997	4323ms	0	807222.0	1.01327
500010	24997	4320ms	0	816283.0	1.02465
500010	24997	4319ms	0	800253.0	1.00452
500010	24997	4315ms	0	812465.0	1.01985
500010	24997	4316ms	0	803271.0	1.00831
500010	24997	4315ms	0	810755.0	1.01771
500010	24997	4015ms	0	810586.0	1.0175
1000010	49997	8650ms	0	811857.0	1.01909
1000010	49997	8654ms	0	808483.0	1.01486
1000010	49997	8620ms	0	810564.0	1.01747
1000010	49997	8669ms	0	813838.0	1.02158
1000010	49997	8677ms	0	814449.0	1.02234
1000010	49997	8673ms	0	802477.0	1.00732
1000010	49997	8669ms	0	807811.0	1.01401
1000010	49997	8680ms	0	819482.0	1.02866
1000010	49997	8724ms	0	816564.0	1.025
1000010	49997	8646ms	0	808972.0	1.01547
1000010	49997	9353ms	0	811198.0	1.01826
5000010	249997	43529ms	0	813486.0	1.02114
5000010	249997	43720ms	0	808936.0	1.01542
5000010	249997	43618ms	0	801032.0	1.0055
5000010	249997	43643ms	0	812087.0	1.01938
5000010	249997	43617ms	0	809733.0	1.01642
5000010	249997	43787ms	0	801555.0	1.00616
5000010	249997	43902ms	0	811732.0	1.01893
5000010	249997	43728ms	0	812465.0	1.01985
5000010	249997	43766ms	0	818383.0	1.02728
5000010	249997	43642ms	0	811418.0	1.01854
5000010	249997	43863ms	0	808348.0	1.01468

Table 11: ea: wl_25_2

evaluations	generations	time	violations	objective	ratio with optimum
1010	47	7ms	0	1282750.0	1.6167
1010	47	6ms	0	1294080.0	1.63097
1010	47	6ms	0	1412900.0	1.78073
1010	47	6ms	0	1316850.0	1.65967
1010	47	6ms	0	1370300.0	1.72704
1010	47	6ms	0	1271590.0	1.60263
1010	47	6ms	0	1462280.0	1.84297
1010	47	6ms	0	1312270.0	1.6539
1010	47	6ms	0	1321890.0	1.66602
1010	47	6ms	0	1320590.0	1.66439
1010	47	7ms	0	1298160.0	1.63612
5010	247	58ms	0	958989.0	1.20865
5010	247	58ms	0	997962.0	1.25777
5010	247	58ms	0	924125.0	1.16471
5010	247	59ms	0	1007200.0	1.2694
5010	247	58ms	0	920213.0	1.15978
5010	247	58ms	0	969462.0	1.22185
5010	247	58ms	0	984886.0	1.24129
5010	247	58ms	0	896042.0	1.12931
5010	247	58ms	0	931261.0	1.1737
5010	247	58ms	0	895580.0	1.12873
5010	247	34ms	0	981636.0	1.23719
10010	497	117ms	0	828621.0	1.04434
10010	497	117ms	0	839265.0	1.05775
10010	497	117ms	0	873690.0	1.10114
10010	497	117ms	0	862735.0	1.08733
10010	497	117ms	0	844437.0	1.06427
10010	497	121ms	0	846007.0	1.06625
10010	497	122ms	0	834799.0	1.05213
10010	497	116ms	0	835383.0	1.05286
10010	497	117ms	0	833366.0	1.05032
10010	497	117ms	0	864722.0	1.08984
10010	497	77ms	0	833377.0	1.05033
50010	2497	438ms	0	814747.0	1.02685
50010	2497	440ms	0	813945.0	1.02584
50010	2497	436ms	0	821546.0	1.03542
50010	2497	449ms	0	824618.0	1.0393
50010	2497	438ms	0	821831.0	1.03578
50010	2497	437ms	0	820029.0	1.03351
50010	2497	436ms	0	812259.0	1.02372
50010	2497	434ms	0	818888.0	1.03207
50010	2497	435ms	0	815661.0	1.02801
50010	2497	437ms	0	811216.0	1.0224
50010	2497	388ms	0	814564.0	1.02662
100010	4997	930ms	0	829624.0	1.0456
100010	4997	921ms	0	817747.0	1.03064
100010	4997	926ms	0	812170.0	1.02361
100010	4997	930ms	0	825776.0	1.04075
100010	4997	936ms	0	811060.0	1.02221
100010	4997	921ms	0	811911.0	1.02328
100010	4997	926ms	0	815754.0	1.02812
100010	4997	925ms	0	810414.0	1.02139
100010	4997	928ms	0	814801.0	1.02692
100010	4997	939ms	0	821911.0	1.03588
100010	4997	843ms	0	808620.0	1.01913
500010	24997	4728ms	0	812277.0	1.02374
500010	24997	4669ms	0	816450.0	1.029
500010	24997	4676ms	0	817128.0	1.02985
500010	24997	4654ms	0	814525.0	1.02657
500010	24997	4670ms	0	811730.0	1.02305
500010	24997	4662ms	0	814366.0	1.02637
500010	24997	4655ms	0	816666.0	1.02927
500010	24997	4661ms	0	826623.0	1.04182
500010	24997	4662ms	0	816476.0	1.02903
500010	24997	4659ms	0	829302.0	1.0452
500010	24997	4316ms	0	813701.0	1.02554
1000010	49997	9013ms	0	816444.0	1.02899
1000010	49997	9090ms	0	816478.0	1.02904
1000010	49997	9126ms	0	817301.0	1.03007
1000010	49997	9155ms	0	813530.0	1.02532
1000010	49997	9142ms	0	815437.0	1.02772
1000010	49997	9135ms	0	824450.0	1.03908
1000010	49997	9132ms	0	827967.0	1.04352
1000010	49997	9123ms	0	818705.0	1.03184
1000010	49997	9174ms	0	822903.0	1.03713
1000010	49997	9189ms	0	823849.0	1.03833
1000010	49997	11643ms	0	826282.0	1.04139
5000010	249997	46707ms	0	830638.0	1.04688
5000010	249997	46875ms	0	812807.0	1.02441
5000010	249997	46529ms	0	818923.0	1.03212
5000010	249997	46598ms	0	821073.0	1.03483
5000010	249997	47056ms	0	817063.0	1.02977
5000010	249997	46743ms	0	822070.0	1.03608
5000010	249997	47034ms	0	825603.0	1.04054
5000010	249997	47501ms	0	799044.0	1.00706
5000010	249997	47298ms	0	802866.0	1.01188
5000010	249997	47079ms	0	809518.0	1.02026
5000010	249997	47205ms	0	816284.0	1.02879

Table 12: ea: wl_50_1

evaluations	generations	time	violations	objective	ratio with optimum
1010	47	40ms	0	204928000.0	11.5354
1010	47	39ms	0	206638000.0	11.6316
1010	47	38ms	0	206276000.0	11.6112
1010	47	39ms	0	207170000.0	11.6616
1010	47	38ms	0	206685000.0	11.6343
1010	47	38ms	0	206546000.0	11.6265
1010	47	39ms	0	207033000.0	11.6538
1010	47	39ms	0	206764000.0	11.6387
1010	47	38ms	0	206832000.0	11.6425
1010	47	38ms	0	205401000.0	11.562
1010	47	38ms	0	207025000.0	11.6534
5010	247	353ms	0	203290000.0	11.4432
5010	247	337ms	0	203511000.0	11.4556
5010	247	329ms	0	203427000.0	11.4509
5010	247	330ms	0	203241000.0	11.4404
5010	247	339ms	0	198452000.0	11.1709
5010	247	331ms	0	203304000.0	11.4439
5010	247	346ms	0	203223000.0	11.4394
5010	247	329ms	0	203473000.0	11.4535
5010	247	339ms	0	203756000.0	11.4694
5010	247	334ms	0	203922000.0	11.4787
5010	247	192ms	0	203362000.0	11.4472
10010	497	668ms	0	197285000.0	11.1051
10010	497	654ms	0	198363000.0	11.1658
10010	497	688ms	0	200211000.0	11.2698
10010	497	655ms	0	198655000.0	11.1823
10010	497	660ms	0	197454000.0	11.1146
10010	497	655ms	0	196824000.0	11.0792
10010	497	648ms	0	200243000.0	11.2717
10010	497	657ms	0	199087000.0	11.2066
10010	497	656ms	0	199791000.0	11.2462
10010	497	675ms	0	200472000.0	11.2845
10010	497	430ms	0	192687000.0	10.8463
50010	2497	2475ms	0	169163000.0	9.52217
50010	2497	2455ms	0	187374000.0	10.5473
50010	2497	2484ms	0	189265000.0	10.6537
50010	2497	2470ms	0	189222000.0	10.6512
50010	2497	2493ms	0	187862000.0	10.5747
50010	2497	2477ms	0	187280000.0	10.542
50010	2497	2505ms	0	183138000.0	10.3088
50010	2497	2460ms	0	189221000.0	10.6512
50010	2497	2626ms	0	181867000.0	10.2373
50010	2497	2481ms	0	189199000.0	10.65
50010	2497	2220ms	0	175816000.0	9.89668
100010	4997	5148ms	0	185795000.0	10.4584
100010	4997	5171ms	0	182110000.0	10.251
100010	4997	5162ms	0	186015000.0	10.4708
100010	4997	5164ms	0	182851000.0	10.2926
100010	4997	5143ms	0	185809000.0	10.4591
100010	4997	5160ms	0	184157000.0	10.3662
100010	4997	5144ms	0	177042000.0	9.96564
100010	4997	5136ms	0	180846000.0	10.1798
100010	4997	5130ms	0	181633000.0	10.2241
100010	4997	5113ms	0	183849000.0	10.3489
100010	4997	4718ms	0	184448000.0	10.3826
500010	24997	26058ms	0	171607000.0	9.65975
500010	24997	26037ms	0	163725000.0	9.21603
500010	24997	26000ms	0	177850000.0	10.0111
500010	24997	26176ms	0	170873000.0	9.61843
500010	24997	26058ms	0	167222000.0	9.41287
500010	24997	26067ms	0	170772000.0	9.61273
500010	24997	26047ms	0	176470000.0	9.93348
500010	24997	26053ms	0	172121000.0	9.68864
500010	24997	26063ms	0	172178000.0	9.69185
500010	24997	26024ms	0	170429000.0	9.59339
500010	24997	24437ms	0	173482000.0	9.76526
1000010	49997	51694ms	0	166539000.0	9.37446
1000010	49997	52271ms	0	172430000.0	9.70603
1000010	49997	52419ms	0	170767000.0	9.61242
1000010	49997	52503ms	0	165476000.0	9.31463
1000010	49997	52480ms	0	169350000.0	9.53269
1000010	49997	51996ms	0	170493000.0	9.59703
1000010	49997	51911ms	0	172692000.0	9.7208
1000010	49997	52103ms	0	169708000.0	9.55282
1000010	49997	52101ms	0	151030000.0	8.50145
1000010	49997	51978ms	0	173840000.0	9.78545
1000010	49997	52035ms	0	172448000.0	9.70708
5000010	249997	264029ms	0	171890000.0	9.67563
5000010	249997	263127ms	0	172973000.0	9.73661
5000010	249997	259826ms	0	168191000.0	9.46745
5000010	249997	257661ms	0	172539000.0	9.71217
5000010	249997	253472ms	0	172626000.0	9.71707
5000010	249997	253768ms	0	170285000.0	9.58533
5000010	249997	254200ms	0	171055000.0	9.62863
5000010	249997	261074ms	0	173034000.0	9.74004
5000010	249997	253699ms	0	173983000.0	9.79345
5000010	249997	256436ms	0	168092000.0	9.46188
5000010	249997	261884ms	0	172951000.0	9.73537

Table 13: ea: wl_100_4

evaluations	generations	time	violations	objective	ratio with optimum
1010	47	15ms	0	14487.5	5.39256
1010	47	15ms	0	15409.1	5.73576
1010	47	15ms	0	15461.6	5.75512
1010	47	14ms	0	11590.4	4.3142
1010	47	15ms	0	12989.3	4.83495
1010	47	15ms	0	11284.3	4.20029
1010	47	16ms	0	12152.3	4.52339
1010	47	17ms	0	12105.2	4.5059
1010	47	17ms	0	14408.6	5.36315
1010	47	17ms	0	11544.6	4.29707
1010	47	15ms	0	13256.9	4.93434
5010	247	125ms	0	9758.51	3.63226
5010	247	124ms	0	8584.88	3.19526
5010	247	127ms	0	9448.9	3.51687
5010	247	126ms	0	8823.11	3.28422
5010	247	125ms	0	10169.0	3.78525
5010	247	124ms	0	9606.07	3.57568
5010	247	124ms	0	9516.18	3.54218
5010	247	125ms	0	11973.4	4.45676
5010	247	129ms	0	8639.69	3.21573
5010	247	140ms	0	9160.4	3.40967
5010	247	72ms	0	11118.0	4.13813
10010	497	246ms	0	9131.8	3.39887
10010	497	250ms	0	10247.0	3.81429
10010	497	247ms	0	9220.73	3.432
10010	497	246ms	0	8064.87	3.0017
10010	497	256ms	0	18093.2	6.73484
10010	497	256ms	0	10090.0	3.75547
10010	497	246ms	0	9553.51	3.55596
10010	497	248ms	0	11289.9	4.20215
10010	497	251ms	0	7554.3	2.81186
10010	497	253ms	0	9999.65	3.72197
10010	497	170ms	0	13559.4	5.04713
50010	2497	938ms	0	8147.19	3.03259
50010	2497	938ms	0	8860.69	3.298
50010	2497	953ms	0	8023.34	2.98644
50010	2497	937ms	0	8063.72	3.00133
50010	2497	943ms	0	7453.78	2.77426
50010	2497	948ms	0	8505.28	3.16585
50010	2497	940ms	0	7990.75	2.97415
50010	2497	951ms	0	7415.15	2.76012
50010	2497	947ms	0	9277.96	3.45322
50010	2497	940ms	0	8284.58	3.08359
50010	2497	826ms	0	8250.57	3.07093
100010	4997	1902ms	0	8421.01	3.13459
100010	4997	1919ms	0	8865.54	3.29986
100010	4997	1924ms	0	10116.9	3.76552
100010	4997	1898ms	0	7986.21	2.97266
100010	4997	1913ms	0	8718.99	3.24514
100010	4997	1945ms	0	9422.25	3.50719
100010	4997	1930ms	0	9029.77	3.3609
100010	4997	1900ms	0	6719.31	2.50104
100010	4997	1904ms	0	7480.82	2.78431
100010	4997	1906ms	0	5687.18	2.1169
100010	4997	1789ms	0	8713.83	3.24328
500010	24997	9859ms	0	8759.78	3.2604
500010	24997	9751ms	0	8373.04	3.11672
500010	24997	9694ms	0	6213.01	2.31269
500010	24997	9751ms	0	7386.15	2.74932
500010	24997	9854ms	0	9820.13	3.65534
500010	24997	9809ms	0	7544.87	2.80814
500010	24997	9776ms	0	6744.76	2.51035
500010	24997	9823ms	0	7359.48	2.73927
500010	24997	9813ms	0	8848.91	3.29353
500010	24997	9817ms	0	8341.82	3.10481
500010	24997	9189ms	0	8093.72	3.01249
1000010	49997	19711ms	0	8569.12	3.18968
1000010	49997	19538ms	0	7460.1	2.77687
1000010	49997	19716ms	0	8487.3	3.15915
1000010	49997	19587ms	0	8112.32	3.01957
1000010	49997	20014ms	0	11260.6	4.19136
1000010	49997	19851ms	0	9121.53	3.39515
1000010	49997	19755ms	0	7898.44	2.93991
1000010	49997	19752ms	0	8310.23	3.09327
1000010	49997	19800ms	0	9285.11	3.4562
1000010	49997	19801ms	0	8387.48	3.12193
1000010	49997	19030ms	0	9166.01	3.4119
5000010	249997	99338ms	0	8152.5	3.03446
5000010	249997	97202ms	0	10014.7	3.72756
5000010	249997	96079ms	0	8698.31	3.2377
5000010	249997	95550ms	0	7541.1	2.80702
5000010	249997	95936ms	0	8467.57	3.15171
5000010	249997	99624ms	0	10455.3	3.89171
5000010	249997	99196ms	0	8861.43	3.29837
5000010	249997	100126ms	0	11856.2	4.41321
5000010	249997	98994ms	0	10622.9	3.95387
5000010	249997	98819ms	0	9498.26	3.53548
5000010	249997	98242ms	0	8653.8	3.22094

Table 14: ea: wl_200_1

evaluations	generations	time	violations	objective	ratio with optimum
1010	47	39ms	0	33731.6	12.9329
1010	47	37ms	0	29401.5	11.2727
1010	47	38ms	0	33546.2	12.862
1010	47	37ms	0	31634.0	12.1285
1010	47	38ms	0	32017.6	12.2758
1010	47	38ms	0	28353.2	10.8709
1010	47	38ms	0	34443.4	13.2059
1010	47	38ms	0	33893.4	12.995
1010	47	40ms	0	32615.6	12.505
1010	47	39ms	0	36466.6	13.9816
1010	47	33ms	0	34407.9	13.1921
5010	247	273ms	0	19694.3	7.55095
5010	247	261ms	0	16407.8	6.29067
5010	247	271ms	0	16513.9	6.33131
5010	247	265ms	0	16968.2	6.50577
5010	247	272ms	0	15833.0	6.07021
5010	247	280ms	0	15657.4	6.00311
5010	247	268ms	0	19700.2	7.55325
5010	247	278ms	0	20972.3	8.04095
5010	247	268ms	0	16344.1	6.26652
5010	247	278ms	0	15255.5	5.84898
5010	247	154ms	0	14570.0	5.58596
10010	497	517ms	0	17585.7	6.74233
10010	497	521ms	0	14858.3	5.69676
10010	497	535ms	0	17943.0	6.87959
10010	497	525ms	0	18280.9	7.0088
10010	497	521ms	0	12777.7	4.89888
10010	497	515ms	0	14707.0	5.63848
10010	497	522ms	0	15491.5	5.93946
10010	497	525ms	0	11435.6	4.38434
10010	497	518ms	0	14855.0	5.69523
10010	497	522ms	0	14832.4	5.68679
10010	497	339ms	0	13436.0	5.15116
50010	2497	1955ms	0	15105.2	5.79147
50010	2497	1977ms	0	16533.9	6.33898
50010	2497	1967ms	0	14563.7	5.58366
50010	2497	1979ms	0	15923.4	6.1051
50010	2497	1968ms	0	14547.2	5.57752
50010	2497	1973ms	0	18083.7	6.93327
50010	2497	1982ms	0	16124.7	6.18216
50010	2497	1967ms	0	16729.3	6.41413
50010	2497	1939ms	0	12906.9	4.94834
50010	2497	1923ms	0	15225.1	5.83748
50010	2497	1752ms	0	15121.3	5.7976
100010	4997	3968ms	0	13354.0	5.11972
100010	4997	4018ms	0	18643.3	7.14798
100010	4997	3966ms	0	11677.3	4.47712
100010	4997	3977ms	0	13115.8	5.02847
100010	4997	4015ms	0	13912.8	5.33405
100010	4997	3980ms	0	16120.7	6.18063
100010	4997	3949ms	0	13441.7	5.15347
100010	4997	4006ms	0	13702.7	5.25354
100010	4997	3978ms	0	14400.2	5.52116
100010	4997	4006ms	0	18254.1	6.99884
100010	4997	3813ms	0	10543.6	4.04233
500010	24997	20362ms	0	12002.4	4.60173
500010	24997	20016ms	0	12367.1	4.74168
500010	24997	20173ms	0	14382.1	5.51426
500010	24997	20337ms	0	15418.1	5.91147
500010	24997	20239ms	0	13129.6	5.03384
500010	24997	20240ms	0	12668.7	4.85709
500010	24997	20357ms	0	14960.5	5.73587
500010	24997	20246ms	0	15471.9	5.9318
500010	24997	20322ms	0	13671.1	5.24165
500010	24997	20296ms	0	12933.6	4.95869
500010	24997	19233ms	0	15411.5	5.90879
1000010	49997	41303ms	0	17752.4	6.80636
1000010	49997	40954ms	0	11412.3	4.37552
1000010	49997	40898ms	0	13653.0	5.23475
1000010	49997	40990ms	0	14608.4	5.60091
1000010	49997	40950ms	0	11738.1	4.50051
1000010	49997	40800ms	0	12085.5	4.63356
1000010	49997	41176ms	0	13845.9	5.30836
1000010	49997	41131ms	0	14361.5	5.50621
1000010	49997	41507ms	0	19860.0	7.6146
1000010	49997	41241ms	0	14024.0	5.377
1000010	49997	39505ms	0	12955.6	4.96713
5000010	249997	211146ms	0	12443.5	4.77082
5000010	249997	211506ms	0	12557.9	4.81453
5000010	249997	212151ms	0	15661.8	6.00464
5000010	249997	212093ms	0	15512.7	5.94752
5000010	249997	210450ms	0	11794.7	4.52198
5000010	249997	211334ms	0	14566.3	5.58481
5000010	249997	210956ms	0	13731.5	5.26466
5000010	249997	210877ms	0	13692.6	5.2497
5000010	249997	209904ms	0	10298.3	3.9484
5000010	249997	209744ms	0	11944.8	4.57949
5000010	249997	205234ms	0	15621.7	5.98931

Table 15: ea: wl_500_1

evaluations	generations	time	violations	objective	ratio with optimum
1010	47	83ms	0	136269.0	25.7902
1010	47	83ms	0	149348.0	28.2655
1010	47	83ms	0	131505.0	24.8885
1010	47	84ms	0	123845.0	23.4386
1010	47	85ms	0	117752.0	22.2855
1010	47	86ms	0	132345.0	25.0475
1010	47	85ms	0	124117.0	23.4901
1010	47	81ms	0	120473.0	22.8004
1010	47	85ms	0	143951.0	27.2439
1010	47	82ms	0	113733.0	21.525
1010	47	72ms	0	116534.0	22.0551
5010	247	581ms	0	56764.9	10.7431
5010	247	587ms	0	47288.0	8.94969
5010	247	577ms	0	47158.5	8.92509
5010	247	550ms	0	52977.5	10.0264
5010	247	551ms	0	53972.5	10.2147
5010	247	546ms	0	48011.0	9.08634
5010	247	576ms	0	41308.8	7.81792
5010	247	554ms	0	46833.1	8.86358
5010	247	546ms	0	51214.1	9.69272
5010	247	550ms	0	41863.1	7.92296
5010	247	370ms	0	41139.4	7.78594
10010	497	1081ms	0	42796.2	8.09954
10010	497	1052ms	0	39231.7	7.42483
10010	497	1083ms	0	48806.3	9.23699
10010	497	1076ms	0	48955.8	9.26519
10010	497	1063ms	0	44423.2	8.40746
10010	497	1051ms	0	41281.0	7.81262
10010	497	1054ms	0	43962.4	8.32022
10010	497	791ms	0	40827.2	7.72689
10010	497	740ms	0	41951.1	7.93962
10010	497	760ms	0	57301.3	10.8447
10010	497	726ms	0	40843.4	7.72992
50010	2497	3945ms	0	36496.6	6.90721
50010	2497	3954ms	0	42797.9	8.09973
50010	2497	3995ms	0	43283.7	8.19171
50010	2497	3942ms	0	44467.5	8.41579
50010	2497	3940ms	0	40490.3	7.66311
50010	2497	3964ms	0	40037.6	7.57737
50010	2497	3968ms	0	41964.6	7.94208
50010	2497	3940ms	0	33355.9	6.31274
50010	2497	3981ms	0	42499.1	8.04333
50010	2497	4081ms	0	53136.2	10.0565
50010	2497	3683ms	0	52622.1	9.9592
100010	4997	8132ms	0	43628.4	8.257
100010	4997	8038ms	0	36365.7	6.88241
100010	4997	8177ms	0	40721.2	7.70683
100010	4997	8116ms	0	41935.7	7.93659
100010	4997	8066ms	0	37452.9	7.08814
100010	4997	8201ms	0	50841.2	9.62213
100010	4997	8138ms	0	42238.4	7.99393
100010	4997	8124ms	0	41017.8	7.76285
100010	4997	8177ms	0	43373.8	8.20874
100010	4997	8230ms	0	45351.3	8.5831
100010	4997	7539ms	0	40594.1	7.68279
500010	24997	40424ms	0	30854.2	5.83941
500010	24997	41088ms	0	38617.0	7.30863
500010	24997	40924ms	0	37654.2	7.12637
500010	24997	41140ms	0	38762.5	7.33607
500010	24997	41062ms	0	42666.1	8.07494
500010	24997	41124ms	0	39812.6	7.53479
500010	24997	41224ms	0	44184.8	8.36223
500010	24997	41129ms	0	29720.2	5.62479
500010	24997	40976ms	0	35383.7	6.69656
500010	24997	40938ms	0	34529.1	6.53493
500010	24997	38900ms	0	37325.6	7.0641
1000010	49997	83047ms	0	37619.1	7.11974
1000010	49997	83767ms	0	41366.9	7.8289
1000010	49997	83388ms	0	39566.7	7.48823
1000010	49997	83665ms	0	37931.7	7.17879
1000010	49997	83334ms	0	44036.9	8.33422
1000010	49997	83197ms	0	38056.9	7.20245
1000010	49997	83040ms	0	41338.0	7.82341
1000010	49997	82874ms	0	43537.7	8.23978
1000010	49997	82256ms	0	35817.7	6.7787
1000010	49997	82823ms	0	42647.8	8.07134
1000010	49997	79896ms	0	37375.2	7.07357
5000010	249997	394530ms	0	30390.0	5.7514
5000010	249997	355312ms	0	34611.1	6.55045
5000010	249997	357221ms	0	40799.3	7.72159
5000010	249997	353904ms	0	36758.6	6.95679
5000010	249997	355823ms	0	36714.9	6.94846
5000010	249997	361646ms	0	54258.4	10.2688
5000010	249997	360857ms	0	46609.1	8.82119
5000010	249997	359416ms	0	41774.3	7.90612
5000010	249997	357383ms	0	40689.1	7.70077
5000010	249997	296798ms	0	35527.4	6.72381
5000010	249997	359418ms	0	43307.7	8.19625

Table 16: ea: wl_1000_1

evaluations	generations	time	violations	objective	ratio with optimum
1010	47	172ms	0	489922.0	48.6526
1010	47	173ms	0	452262.0	44.9126
1010	47	177ms	0	452520.0	44.9382
1010	47	176ms	0	464185.0	46.0966
1010	47	178ms	0	494267.0	49.084
1010	47	232ms	0	418614.0	41.5711
1010	47	253ms	0	477875.0	47.4562
1010	47	260ms	0	478329.0	47.5012
1010	47	258ms	0	502527.0	49.9043
1010	47	251ms	0	472698.0	46.942
1010	47	154ms	0	399107.0	39.634
5010	247	1200ms	0	129613.0	12.8714
5010	247	1151ms	0	147058.0	14.6038
5010	247	1166ms	0	140421.0	13.9448
5010	247	1168ms	0	143247.0	14.2253
5010	247	1173ms	0	134913.0	13.3978
5010	247	1146ms	0	174385.0	17.3175
5010	247	1157ms	0	139517.0	13.8549
5010	247	1162ms	0	139344.0	13.8377
5010	247	1171ms	0	137783.0	13.6828
5010	247	1194ms	0	138790.0	13.7827
5010	247	790ms	0	135589.0	13.4649
10010	497	1645ms	0	137845.0	13.6889
10010	497	1624ms	0	123516.0	12.2659
10010	497	1642ms	0	121985.0	12.1139
10010	497	1634ms	0	113469.0	11.2682
10010	497	1669ms	0	128093.0	12.7205
10010	497	1679ms	0	104826.0	10.4098
10010	497	1680ms	0	109323.0	10.8564
10010	497	1744ms	0	127728.0	12.6843
10010	497	1718ms	0	114575.0	11.3781
10010	497	1741ms	0	131781.0	13.0867
10010	497	1544ms	0	141825.0	14.0842
50010	2497	8539ms	0	92116.3	9.14775
50010	2497	8667ms	0	125167.0	12.4299
50010	2497	8536ms	0	85823.7	8.52281
50010	2497	8699ms	0	97805.3	9.7127
50010	2497	8787ms	0	102790.0	10.2076
50010	2497	8764ms	0	107386.0	10.6642
50010	2497	8777ms	0	122695.0	12.1843
50010	2497	8674ms	0	91293.4	9.06602
50010	2497	8750ms	0	99072.7	9.83852
50010	2497	8795ms	0	115175.0	11.4376
50010	2497	8098ms	0	118823.0	11.7998
100010	4997	17599ms	0	93994.2	9.33424
100010	4997	17370ms	0	127239.0	12.6357
100010	4997	17394ms	0	137976.0	13.7019
100010	4997	17530ms	0	126548.0	12.5671
100010	4997	17230ms	0	97353.2	9.66782
100010	4997	17320ms	0	101786.0	10.1079
100010	4997	17254ms	0	89714.5	8.90921
100010	4997	17283ms	0	97271.7	9.65967
100010	4997	17106ms	0	88807.0	8.81914
100010	4997	17771ms	0	140384.0	13.941
100010	4997	16681ms	0	119588.0	11.8758
500010	24997	88222ms	0	97265.2	9.65908
500010	24997	89129ms	0	103777.0	10.3058
500010	24997	88915ms	0	82429.2	8.18576
500010	24997	90026ms	0	91214.4	9.05817
500010	24997	90721ms	0	114492.0	11.3698
500010	24997	88872ms	0	100393.0	9.96971
500010	24997	90404ms	0	124574.0	12.3709
500010	24997	89352ms	0	88856.5	8.82401
500010	24997	89946ms	0	101420.0	10.0716
500010	24997	90166ms	0	124629.0	12.3764
500010	24997	84924ms	0	100700.0	10.0001
1000010	49997	179585ms	0	110561.0	10.9794
1000010	49997	178603ms	0	105136.0	10.4407
1000010	49997	177775ms	0	103635.0	10.2916
1000010	49997	177388ms	0	95555.7	9.48926
1000010	49997	176863ms	0	85560.6	8.49669
1000010	49997	178634ms	0	106090.0	10.5355
1000010	49997	178008ms	0	104379.0	10.3654
1000010	49997	179557ms	0	124422.0	12.3559
1000010	49997	177541ms	0	102157.0	10.1449
1000010	49997	177651ms	0	99760.6	9.90685
1000010	49997	178481ms	0	102941.0	10.2226
5000010	249997	659814ms	0	104188.0	10.3465
5000010	249997	647437ms	0	76524.9	7.59935
5000010	249997	663265ms	0	113580.0	11.2793
5000010	249997	652777ms	0	84315.0	8.37295
5000010	249997	666679ms	0	120046.0	11.9213
5000010	249997	647529ms	0	85497.3	8.49043
5000010	249997	653707ms	0	88270.2	8.76581
5000010	249997	665438ms	0	115494.0	11.4692
5000010	249997	656144ms	0	94968.4	9.43097
5000010	249997	652550ms	0	91547.7	9.09124
5000010	249997	679217ms	0	123977.0	12.3118

Table 17: ea: wl_2000_1

3.3 Memetic algorithm

Third algorithm is a memetic algorithm in which I tried to combine good things from local search and good things from evolution algorithms and get the best results. Solver is implemented in *src/specialized/specialized.cpp* and is run by binary *out/specialized* made from main file *src/solver/specialized.c*

3.3.1 Description

A smaller population of only 20 candidates is held by the algorithm. This is mostly to reduce execution time and keep more evaluations for the local search part. Those candidates are initialized randomly as in the basic evolution algorithm, but then one of them is replaced by a greedily initialized candidate as in the simple local search. The main idea of this one candidate is to get some good "genes" into the population even before the evolution starts.

The breeding phase is very similar to the basic evolution algorithm. First, 5 parents are selected from old population by tournaments of size 4. Secondly, in the crossover phase, a uniform crossover is used instead of single point one. This crossover selects an assignment from a parent with probability 0.5. Lastly, in the mutation phase, an offspring is either changed in random 5 assignments (note, that the evolution algorithm mutated only 1) with probability 0.2, or is shuffled with probability 0.6. The mutation is more aggressive than in the evolution algorithm as an attempt to decrease stagnation of population and to explore larger space. Also, the probabilies were adjusted to prefer shuffle over random perturbation.

After breeding phase, a local search is started for each solution with probability 0.3. The search lasts 100 iterations and as perturbation, the candidate is either again changed in random 5 assignments with probability 0.5, or an assignment with highest cost is found and to this customer is assigned cheapest possible warehouse. Idea behind this is, that it should try to push some candidates to cheaper state at the cost of possible infeasibility and thus introduce some different genes. These improved candidates are added to the new population and they participate in evaluation and recombination.

Recombination is the same as in the evolution algorithm.

3.3.2 Experiments

Each instance of problem was run 11 times (so there is a median) for increasing number of evaluations. Each batch with the same number of evaluations has highlighted it's median.

It can be said, that this algorithm performs well on all instances, given enough iterations. However, on some easier ones is not as good as it could be, but on the larger instances, it gets really close to global optimum. It is not too slow and it seems that it always finds a valid solution.

evaluations	generations	time	violations	objective	ratio with optimum
1360	1	4ms	0	1679720.0	1.71972
1480	2	4ms	0	1480860.0	1.51612
1860	1	5ms	0	1788540.0	1.83113
1380	2	4ms	0	1732830.0	1.77409
1360	1	4ms	0	2114290.0	2.16464
1060	1	3ms	55	1670130.0	1.7099
1260	1	3ms	63	1581340.0	1.619
1360	1	4ms	0	1677710.0	1.71766
1280	2	3ms	0	1775420.0	1.81771
1260	1	3ms	0	1660170.0	1.69971
1760	1	8ms	0	1574400.0	1.61189
5180	7	23ms	0	1492740.0	1.52829
5000	8	22ms	0	1640730.0	1.6798
5180	7	23ms	0	1607510.0	1.64579
5000	8	22ms	0	1643570.0	1.68271
5500	8	24ms	0	1555630.0	1.59268
5000	8	22ms	0	1594080.0	1.63204
5060	6	22ms	0	1469770.0	1.50478
5060	6	22ms	0	1445460.0	1.47988
5180	7	23ms	0	1492860.0	1.52842
5200	8	23ms	0	1374110.0	1.40684
5020	9	13ms	0	1589880.0	1.62774
10120	14	45ms	0	1544690.0	1.58148
10720	14	47ms	0	1473840.0	1.50894
10000	13	44ms	0	1561580.0	1.59876
10740	15	48ms	0	1538780.0	1.57543
10040	15	45ms	0	1580120.0	1.61775
10440	15	48ms	0	1503240.0	1.53904
10540	15	49ms	0	1411690.0	1.44531
10360	16	48ms	0	1463230.0	1.49807
10440	15	47ms	0	1627850.0	1.66661
10420	14	46ms	0	1609520.0	1.64785
10040	15	26ms	0	1497880.0	1.53355
50320	84	167ms	0	1562970.0	1.60019
50500	83	167ms	0	1377280.0	1.41008
50440	75	166ms	0	1380100.0	1.41297
50140	75	165ms	0	1400200.0	1.43354
50340	80	165ms	0	1532810.0	1.56931
50220	79	165ms	0	1448530.0	1.48302
50220	79	165ms	0	1479310.0	1.51454
50500	78	166ms	0	1490110.0	1.5256
50540	80	166ms	0	1462940.0	1.49778
50340	80	166ms	0	1438200.0	1.47245
50480	82	150ms	0	1474020.0	1.50913
100320	154	351ms	0	1443060.0	1.47742
100340	160	352ms	0	1328550.0	1.36019
100740	165	353ms	0	1492400.0	1.52794
100260	161	352ms	0	1469860.0	1.50486
100180	162	352ms	0	1472680.0	1.50775
100200	163	352ms	0	1424480.0	1.45841
100400	158	352ms	0	1393200.0	1.42638
100000	168	351ms	0	1313570.0	1.34485
100040	155	349ms	0	1428240.0	1.46226
100740	165	354ms	0	1376430.0	1.40921
100360	161	312ms	0	1421460.0	1.45532
500160	801	1809ms	0	1373140.0	1.40584
500340	785	1810ms	0	1402480.0	1.43588
500320	799	1838ms	0	1304180.0	1.33524
500800	813	1815ms	0	1409780.0	1.44335
500160	811	1812ms	0	1407460.0	1.44098
500620	814	1827ms	0	1382070.0	1.41499
500560	796	1817ms	0	1401370.0	1.43475
500100	808	1811ms	0	1355470.0	1.38776
500000	793	1821ms	0	1399430.0	1.43276
500400	798	1807ms	0	1362640.0	1.39509
500160	826	1662ms	0	1341210.0	1.37315
1000020	1604	3653ms	0	1380970.0	1.41386
1000620	1614	3641ms	0	1389810.0	1.42291
1000040	1630	3645ms	0	1369280.0	1.40189
1000340	1600	3627ms	0	1396330.0	1.42958
1000200	1593	3633ms	0	1386250.0	1.41926
1000120	1604	3640ms	0	1382260.0	1.41518
1000100	1608	3639ms	0	1352740.0	1.38495
1000020	1604	3627ms	0	1389200.0	1.42228
1000620	1619	3644ms	0	1378840.0	1.41168
1000500	1623	3645ms	0	1291390.0	1.32214
1000460	1631	3496ms	0	1361310.0	1.39373
5000400	8083	18405ms	0	1350140.0	1.38229
5000880	8112	18365ms	0	1338150.0	1.37002
5000920	8094	18361ms	0	1342770.0	1.37475
5000260	8071	18383ms	0	1336740.0	1.36858
5000000	8058	18385ms	0	1266930.0	1.2971
5000460	8076	18377ms	0	1336370.0	1.3682
5000800	8038	18373ms	0	1339030.0	1.37092
5000400	8048	18375ms	0	1309820.0	1.34101
5000620	8094	18345ms	0	1337400.0	1.36925
5000380	8067	18363ms	0	1356000.0	1.3883
5000480	8052	17623ms	0	1323390.0	1.35491

Table 18: specialized: wl_16_1

evaluations	generations	time	violations	objective	ratio with optimum
1560	1	4ms	0	832291.0	1.04474
1260	1	3ms	0	832291.0	1.04474
1060	1	3ms	0	832291.0	1.04474
1480	2	5ms	0	832291.0	1.04474
1060	1	3ms	0	832291.0	1.04474
1360	1	4ms	0	832291.0	1.04474
1660	1	5ms	0	832291.0	1.04474
1240	0	3ms	0	832291.0	1.04474
1360	1	4ms	0	832291.0	1.04474
1160	1	3ms	0	832291.0	1.04474
1360	1	5ms	0	832291.0	1.04474
5000	8	24ms	0	832291.0	1.04474
5380	7	26ms	0	832291.0	1.04474
5200	8	25ms	0	832291.0	1.04474
5160	6	25ms	0	832291.0	1.04474
5080	7	24ms	0	832291.0	1.04474
5680	7	27ms	0	832291.0	1.04474
5200	8	25ms	0	832291.0	1.04474
5120	9	29ms	0	832291.0	1.04474
5000	8	33ms	0	832291.0	1.04474
5620	9	30ms	0	832291.0	1.04474
5080	7	14ms	0	832291.0	1.04474
10140	15	48ms	0	832291.0	1.04474
10340	15	51ms	0	832291.0	1.04474
10460	16	50ms	0	832291.0	1.04474
10360	16	52ms	0	832291.0	1.04474
10280	17	52ms	0	832291.0	1.04474
10200	18	51ms	0	832291.0	1.04474
10220	14	51ms	0	832291.0	1.04474
10480	17	51ms	0	832291.0	1.04474
10420	19	51ms	0	832291.0	1.04474
10060	16	49ms	0	832291.0	1.04474
10320	14	29ms	0	832291.0	1.04474
50140	80	173ms	0	832291.0	1.04474
50320	79	174ms	0	832291.0	1.04474
50020	74	172ms	0	832291.0	1.04474
50520	79	177ms	0	832291.0	1.04474
50340	80	175ms	0	832291.0	1.04474
50520	84	190ms	0	832291.0	1.04474
50300	78	177ms	0	832291.0	1.04474
50240	80	174ms	0	832291.0	1.04474
50060	81	177ms	0	832291.0	1.04474
50460	86	178ms	0	832291.0	1.04474
50000	78	159ms	0	832291.0	1.04474
100560	171	385ms	0	832291.0	1.04474
100400	158	373ms	0	832291.0	1.04474
100540	155	364ms	0	832291.0	1.04474
100220	159	368ms	0	832291.0	1.04474
100540	155	369ms	0	832291.0	1.04474
100060	156	366ms	0	832291.0	1.04474
100380	157	376ms	0	832291.0	1.04474
100320	159	370ms	0	832291.0	1.04474
100220	164	373ms	0	832291.0	1.04474
100020	164	364ms	0	832291.0	1.04474
100080	157	324ms	0	832291.0	1.04474
500300	798	1893ms	0	832291.0	1.04474
500660	801	1890ms	0	832291.0	1.04474
500540	810	1896ms	0	832291.0	1.04474
500800	798	1887ms	0	832291.0	1.04474
500640	790	1857ms	0	832291.0	1.04474
500240	800	1843ms	0	832291.0	1.04474
500320	809	1922ms	0	832291.0	1.04474
500400	818	1894ms	0	832291.0	1.04474
500340	805	1872ms	0	832291.0	1.04474
500160	811	1809ms	0	832291.0	1.04474
500840	805	1733ms	0	832291.0	1.04474
1000000	1618	3687ms	0	832291.0	1.04474
1000120	1619	3785ms	0	832291.0	1.04474
1000920	1624	3766ms	0	832291.0	1.04474
1000100	1618	3785ms	0	832291.0	1.04474
1000280	1597	3788ms	0	832291.0	1.04474
1000100	1603	3767ms	0	832291.0	1.04474
1000000	1608	3791ms	0	832291.0	1.04474
1000040	1600	3808ms	0	832291.0	1.04474
1000260	1606	3741ms	0	832291.0	1.04474
1000460	1611	3804ms	0	832291.0	1.04474
1000480	1627	3553ms	0	832291.0	1.04474
5000780	8047	19142ms	0	832291.0	1.04474
5000020	8054	19150ms	0	832291.0	1.04474
5000380	8067	19204ms	0	832291.0	1.04474
5000260	8061	18906ms	0	832291.0	1.04474
5000280	8107	19075ms	0	832291.0	1.04474
5000020	8039	18927ms	0	832291.0	1.04474
5000380	8017	19038ms	0	832291.0	1.04474
5000120	8019	19171ms	0	832291.0	1.04474
5000100	7998	19113ms	0	832291.0	1.04474
5000480	8022	19065ms	0	832291.0	1.04474
5000400	8088	18212ms	0	832291.0	1.04474

Table 19: specialized: wl_25_2

evaluations	generations	time	violations	objective	ratio with optimum
1060	1	4ms	0	991571.0	1.24971
1160	1	4ms	0	983996.0	1.24016
1260	1	4ms	0	991571.0	1.24971
1360	1	5ms	0	991571.0	1.24971
1480	2	5ms	0	991571.0	1.24971
1380	2	5ms	0	991571.0	1.24971
1160	1	4ms	0	991571.0	1.24971
1360	1	5ms	0	991571.0	1.24971
1160	1	4ms	0	991571.0	1.24971
1280	2	5ms	0	991571.0	1.24971
1360	1	6ms	0	991571.0	1.24971
5400	8	32ms	0	991571.0	1.24971
5380	7	32ms	0	991571.0	1.24971
5000	8	30ms	0	991571.0	1.24971
5500	8	33ms	0	991571.0	1.24971
5760	6	34ms	0	991571.0	1.24971
5060	6	30ms	0	991571.0	1.24971
5460	6	32ms	0	975531.0	1.2295
5220	9	32ms	0	991571.0	1.24971
5100	8	30ms	0	991571.0	1.24971
5400	8	32ms	0	991571.0	1.24971
5820	9	19ms	0	991571.0	1.24971
10720	19	62ms	0	991571.0	1.24971
10440	15	61ms	0	991571.0	1.24971
10460	16	60ms	0	991571.0	1.24971
10280	17	59ms	0	991571.0	1.24971
10160	16	59ms	0	991571.0	1.24971
10140	15	59ms	0	991571.0	1.24971
10140	15	58ms	0	991571.0	1.24971
10720	14	63ms	0	991571.0	1.24971
10020	14	59ms	0	991571.0	1.24971
10460	16	61ms	0	991571.0	1.24971
10160	16	34ms	0	991571.0	1.24971
50160	71	209ms	0	991571.0	1.24971
50460	81	212ms	0	991571.0	1.24971
50100	78	210ms	0	991571.0	1.24971
50100	78	208ms	0	991571.0	1.24971
50000	78	209ms	0	991571.0	1.24971
50000	83	210ms	0	991571.0	1.24971
50340	85	211ms	0	991571.0	1.24971
50000	83	211ms	0	968055.0	1.22007
50320	84	213ms	0	991571.0	1.24971
50120	74	209ms	0	991571.0	1.24971
50540	80	191ms	0	991571.0	1.24971
100020	159	447ms	0	991571.0	1.24971
100280	162	446ms	0	991571.0	1.24971
100020	159	441ms	0	991571.0	1.24971
100100	158	461ms	0	991571.0	1.24971
100020	159	446ms	0	991571.0	1.24971
100040	165	447ms	0	991571.0	1.24971
100780	162	450ms	0	991571.0	1.24971
100760	151	444ms	0	991571.0	1.24971
100620	159	443ms	0	991571.0	1.24971
100300	163	448ms	0	991571.0	1.24971
100540	155	394ms	0	991571.0	1.24971
500140	805	2192ms	0	991571.0	1.24971
500400	798	2217ms	0	991571.0	1.24971
500140	815	2204ms	0	991571.0	1.24971
500000	793	2210ms	0	991571.0	1.24971
500560	806	2212ms	0	991571.0	1.24971
500000	818	2262ms	0	991571.0	1.24971
500280	807	2197ms	0	991571.0	1.24971
500180	797	2190ms	0	991571.0	1.24971
500160	816	2220ms	0	991571.0	1.24971
500060	791	2215ms	0	991571.0	1.24971
500180	812	2096ms	0	991571.0	1.24971
1000200	1608	4588ms	0	991571.0	1.24971
1000200	1603	4594ms	0	991571.0	1.24971
1000780	1637	4613ms	0	991571.0	1.24971
1000220	1614	4596ms	0	991571.0	1.24971
1000580	1602	4584ms	0	991571.0	1.24971
1000040	1590	4605ms	0	991571.0	1.24971
1000080	1602	4594ms	0	991571.0	1.24971
1000460	1616	4609ms	0	991571.0	1.24971
1000600	1623	4600ms	0	991571.0	1.24971
1000580	1597	4580ms	0	991571.0	1.24971
1000000	1593	4304ms	0	991571.0	1.24971
5000360	8051	23257ms	0	991571.0	1.24971
5000040	8045	23284ms	0	991571.0	1.24971
5000020	8049	23287ms	0	991571.0	1.24971
5000500	8033	23267ms	0	991571.0	1.24971
5000300	8053	23120ms	0	991571.0	1.24971
5000200	8033	23139ms	0	991571.0	1.24971
5000520	8064	23189ms	0	991571.0	1.24971
5000540	8070	23140ms	0	991571.0	1.24971
5000120	8104	23053ms	0	991571.0	1.24971
5000460	8076	23085ms	0	991571.0	1.24971
5000100	8048	22309ms	0	991571.0	1.24971

Table 20: specialized: wl_50_1

evaluations	generations	time	violations	objective	ratio with optimum
1060	1	35ms	0	181199000.0	10.1997
1360	1	42ms	0	181199000.0	10.1997
1660	1	49ms	0	181199000.0	10.1997
1060	1	32ms	0	181199000.0	10.1997
1460	1	43ms	0	181199000.0	10.1997
1180	2	38ms	0	181199000.0	10.1997
1680	2	51ms	0	181199000.0	10.1997
1180	2	38ms	0	181199000.0	10.1997
1160	1	36ms	0	181199000.0	10.1997
1360	1	41ms	0	181199000.0	10.1997
1360	1	38ms	0	181199000.0	10.1997
5480	7	253ms	0	181199000.0	10.1997
5080	7	231ms	0	181199000.0	10.1997
5300	8	247ms	0	181199000.0	10.1997
5600	8	258ms	0	181199000.0	10.1997
5380	7	253ms	0	181199000.0	10.1997
5200	8	241ms	0	181199000.0	10.1997
5620	9	270ms	0	177986000.0	10.0188
5000	8	237ms	0	181199000.0	10.1997
5580	7	254ms	0	181199000.0	10.1997
5680	7	262ms	0	181199000.0	10.1997
5320	9	140ms	0	181199000.0	10.1997
10020	14	455ms	0	181199000.0	10.1997
10200	13	455ms	0	181199000.0	10.1997
10660	16	474ms	0	181199000.0	10.1997
10480	17	481ms	0	181199000.0	10.1997
10300	18	473ms	0	179556000.0	10.1072
10560	16	499ms	0	181199000.0	10.1997
10340	15	459ms	0	181199000.0	10.1997
10640	15	482ms	0	181199000.0	10.1997
10100	13	459ms	0	181199000.0	10.1997
10760	16	495ms	0	181199000.0	10.1997
10740	15	286ms	0	181199000.0	10.1997
50200	78	1631ms	0	128017000.0	7.20606
50180	77	1635ms	0	135633000.0	7.63475
50060	81	1624ms	0	123212000.0	6.93559
50860	81	1646ms	0	126486000.0	7.11989
50580	77	1648ms	0	128507000.0	7.23366
50180	77	1626ms	0	134686000.0	7.58145
50000	83	1618ms	0	133972000.0	7.54125
50040	75	1664ms	0	138086000.0	7.77281
50580	82	1629ms	0	131022000.0	7.37518
50460	81	1647ms	0	146064000.0	8.22191
50360	76	1458ms	0	149112000.0	8.39348
100140	165	3408ms	0	94052100.0	5.29418
100220	164	3402ms	0	95373700.0	5.36857
100260	166	3369ms	0	106811000.0	6.01237
100120	159	3371ms	0	95972500.0	5.40227
100440	165	3403ms	0	99576600.0	5.60515
100080	157	3334ms	0	97976200.0	5.51506
100160	161	3353ms	0	84004200.0	4.72858
100440	160	3396ms	0	85717700.0	4.82503
100620	164	3404ms	0	81924300.0	4.6115
100180	162	3396ms	0	92209100.0	5.19043
100280	167	3079ms	0	80704900.0	4.54286
500360	806	16392ms	0	37322200.0	2.10086
500200	813	16679ms	0	39989200.0	2.25099
500160	801	16350ms	0	36053500.0	2.02944
500360	821	16603ms	0	38765100.0	2.18208
500540	805	16416ms	0	43129100.0	2.42773
500360	811	16615ms	0	35608000.0	2.00437
500240	795	16454ms	0	42210500.0	2.37602
500000	793	16740ms	0	37875100.0	2.13198
500480	812	16854ms	0	40041100.0	2.25391
500340	805	16834ms	0	34051800.0	1.91677
500280	807	15560ms	0	34820300.0	1.96003
1000140	1600	33961ms	0	37196800.0	2.0938
1000160	1606	33828ms	0	35185300.0	1.98058
1000480	1612	34141ms	0	33360000.0	1.87783
1000660	1626	33957ms	0	34445500.0	1.93893
1000580	1602	33946ms	0	31864800.0	1.79366
1000140	1600	34385ms	0	33319900.0	1.87557
1000160	1616	33939ms	0	36305400.0	2.04363
1000220	1589	33954ms	0	33374000.0	1.87862
1000060	1621	34192ms	0	36506600.0	2.05495
1000000	1633	34174ms	0	33433000.0	1.88194
1000480	1607	31917ms	0	33627900.0	1.89291
5000340	8040	168558ms	0	31541400.0	1.77546
5000360	8036	168390ms	0	31529300.0	1.77478
5000240	8085	168656ms	0	31879600.0	1.7945
5000080	8107	169192ms	0	32995600.0	1.85732
5000800	8073	167781ms	0	31731900.0	1.78618
5000420	8074	169516ms	0	31742100.0	1.78676
5000700	8043	168413ms	0	31787500.0	1.78931
5000340	8095	167717ms	0	31794500.0	1.78971
5000300	8048	168848ms	0	31494400.0	1.77282
5000080	8017	166728ms	0	31878100.0	1.79441
5000140	8130	165964ms	0	33533100.0	1.88757

Table 21: specialized: wl_100_4

evaluations	generations	time	violations	objective	ratio with optimum
1260	1	14ms	0	36219.7	13.482
1160	1	14ms	0	32016.8	11.9175
1380	2	16ms	0	33795.1	12.5797
1680	2	19ms	0	32718.7	12.1788
1560	1	18ms	0	35839.0	13.3401
1480	2	24ms	0	34087.9	12.6884
1460	1	17ms	0	34019.1	12.663
1060	1	12ms	0	37138.7	13.824
1160	1	13ms	0	36343.4	13.5281
1040	0	12ms	0	34705.6	12.9184
1160	1	12ms	0	34769.1	12.9422
5300	8	91ms	0	28021.5	10.4304
5100	8	87ms	0	25293.8	9.41493
5480	7	96ms	0	26270.4	9.7786
5100	8	89ms	0	26686.7	9.93345
5480	7	94ms	0	28107.5	10.4624
5800	8	98ms	0	25493.3	9.48937
5180	7	93ms	0	26959.5	10.0351
5580	7	98ms	0	26677.3	9.9301
5280	7	91ms	0	27338.7	10.1761
5100	8	87ms	0	24763.0	9.21764
5100	8	50ms	0	26106.2	9.71755
10040	15	167ms	0	19648.4	7.31366
10540	15	176ms	0	19254.8	7.167
10340	15	171ms	0	18881.6	7.02816
10320	14	174ms	0	21945.5	8.16868
10440	15	179ms	0	17478.5	6.50591
10260	16	171ms	0	18115.8	6.74303
10620	19	176ms	0	15962.2	5.94161
10420	14	175ms	0	21492.6	8.00006
10320	14	172ms	0	20297.4	7.55524
10540	15	185ms	0	20784.8	7.73652
10580	17	103ms	0	17368.1	6.46497
50200	78	605ms	0	7840.78	2.91832
50360	76	586ms	0	6711.34	2.49807
50220	84	587ms	0	7152.4	2.66222
50820	79	594ms	0	6750.35	2.51258
50280	77	591ms	0	8060.59	3.00021
50220	74	587ms	0	7720.44	2.87365
50540	80	590ms	0	7042.02	2.62127
50340	80	588ms	0	7470.65	2.78059
50560	81	611ms	0	8227.03	3.06237
50200	83	594ms	0	7538.81	2.8059
50500	88	533ms	0	7219.08	2.68716
100260	166	1191ms	0	5945.94	2.21293
100160	161	1188ms	0	6881.34	2.56135
100180	167	1209ms	0	6228.47	2.31828
100580	157	1198ms	0	6310.71	2.3488
100000	168	1192ms	0	7054.43	2.62574
100420	159	1193ms	0	5965.16	2.22038
100220	159	1200ms	0	4856.67	1.80757
100300	163	1199ms	0	6520.08	2.42697
100760	161	1197ms	0	5469.3	2.03575
100600	163	1197ms	0	6303.25	2.34619
100520	164	1085ms	0	5104.1	1.89988
500420	794	5913ms	0	4557.44	1.69627
500360	821	5930ms	0	4266.33	1.58795
500180	792	5937ms	0	4213.54	1.56822
500400	813	5921ms	0	4106.56	1.52839
500000	798	5906ms	0	4146.03	1.54328
500240	810	5910ms	0	3948.41	1.46958
500060	816	5933ms	0	4521.51	1.68287
500760	811	5940ms	0	4464.28	1.66165
500800	818	5930ms	0	4049.95	1.50718
500040	810	5949ms	0	3963.54	1.47517
500120	814	5512ms	0	4269.16	1.58907
1000380	1622	12005ms	0	4350.06	1.61922
1000540	1610	11974ms	0	3909.37	1.45506
1000040	1600	11979ms	0	3860.32	1.43682
1000700	1593	11956ms	0	3971.18	1.47814
1000380	1622	12003ms	0	3887.48	1.44688
1000580	1642	11931ms	0	3902.51	1.45246
1000420	1579	11953ms	0	4032.02	1.50085
1000520	1619	11958ms	0	4029.37	1.49973
1000500	1618	12035ms	0	3921.16	1.45953
1000400	1608	12147ms	0	4003.81	1.49005
1000520	1609	11232ms	0	3909.75	1.45506
5000440	8055	58883ms	0	3904.03	1.4532
5000380	8092	58890ms	0	3867.66	1.43943
5000540	8095	59020ms	0	3913.99	1.45655
5000360	8086	58775ms	0	3906.98	1.45395
5000400	8023	58723ms	0	3907.49	1.45432
5000680	8092	58813ms	0	3902.19	1.45246
5000580	8032	58831ms	0	3906.86	1.45395
5000480	8012	58854ms	0	3888.18	1.44725
5000460	8086	58996ms	0	3901.85	1.45209
5000280	8157	59186ms	0	3915.66	1.4573
5000080	8072	59846ms	0	3923.18	1.46028

Table 22: specialized: wl_200_1

evaluations	generations	time	violations	objective	ratio with optimum
1560	1	44ms	0	101304.0	38.841
1380	2	40ms	0	95172.9	36.4903
1380	2	41ms	0	93904.1	36.0041
1460	1	42ms	0	100471.0	38.522
1280	2	38ms	0	87386.1	33.505
1580	2	46ms	0	98380.6	37.7203
1780	2	51ms	0	99981.1	38.3341
1360	1	39ms	0	98143.7	37.6294
1040	0	30ms	0	105900.0	40.6035
1040	0	30ms	0	105768.0	40.5525
1040	0	25ms	0	104219.0	39.9586
5180	7	215ms	0	76302.6	29.2552
5780	7	260ms	0	72290.2	27.717
5040	5	218ms	0	79975.2	30.6635
5480	7	233ms	0	77556.2	29.736
5080	7	211ms	0	75069.2	28.7825
5240	5	222ms	0	79985.1	30.6674
5640	10	234ms	0	63330.1	24.2816
5380	7	233ms	0	79128.4	30.3388
5480	7	244ms	0	79352.5	30.4247
5500	8	232ms	0	67599.6	25.9184
5700	8	133ms	0	70264.9	26.9402
10060	16	408ms	0	51352.3	19.6891
10500	13	441ms	0	54807.9	21.0138
10360	16	414ms	0	47637.7	18.2647
10000	13	404ms	0	56552.4	21.6828
10040	15	404ms	0	52555.3	20.1503
10440	15	425ms	0	53427.2	20.4847
10340	15	414ms	0	57403.9	22.0091
10060	16	406ms	0	49841.9	19.1097
10360	16	422ms	0	52864.3	20.2688
10040	15	404ms	0	53765.2	20.6142
10180	17	254ms	0	53708.6	20.5924
50260	86	1407ms	0	15909.3	6.09973
50040	80	1406ms	0	16803.4	6.4425
50080	77	1419ms	0	16975.0	6.50807
50140	75	1413ms	0	15951.1	6.11583
50300	78	1427ms	0	16866.9	6.46666
50380	82	1415ms	0	16456.1	6.30946
50100	78	1434ms	0	17447.0	6.68942
50000	78	1404ms	0	16877.1	6.47088
50000	78	1413ms	0	17916.1	6.86924
50060	86	1430ms	0	14870.0	5.70098
50220	84	1257ms	0	18272.1	7.00574
100020	159	2859ms	0	11673.5	4.47559
100680	157	2857ms	0	12183.8	4.67113
100240	155	2855ms	0	10304.6	3.9507
100140	175	2875ms	0	11431.1	4.3828
100100	163	2853ms	0	12465.8	4.77925
100400	153	2841ms	0	10851.2	4.16042
100060	161	2823ms	0	11081.1	4.24861
100540	165	2860ms	0	10661.5	4.08757
100540	155	2852ms	0	11313.2	4.33756
100660	171	2833ms	0	11065.7	4.24247
100200	163	2617ms	0	12106.3	4.64161
500480	807	14038ms	0	5809.93	2.22725
500500	808	14012ms	0	6711.85	2.57309
500500	818	13980ms	0	6219.39	2.38445
500240	815	14001ms	0	5494.43	2.10648
500440	805	13935ms	0	5673.39	2.17511
500640	800	13999ms	0	5340.02	2.04743
500300	808	14003ms	0	6158.75	2.36106
500040	820	13985ms	0	5995.02	2.29857
500080	802	14000ms	0	5926.41	2.27211
500200	813	14111ms	0	6726.94	2.57884
500160	796	13015ms	0	5059.04	1.93969
1000380	1612	28410ms	0	5717.32	2.19198
1000100	1618	28326ms	0	5441.59	2.08615
1000380	1627	28314ms	0	5173.58	1.9834
1000060	1616	28306ms	0	5182.11	1.98685
1000020	1604	28375ms	0	4933.69	1.89138
1000340	1610	28262ms	0	5300.04	2.03209
1000100	1628	28111ms	0	5099.67	1.95503
1000000	1618	28165ms	0	5293.55	2.02941
1000040	1620	28183ms	0	5408.96	2.0735
1000180	1617	28179ms	0	5042.1	1.93317
1000280	1622	26800ms	0	5032.79	1.92934
5000280	8027	138160ms	0	4483.36	1.71884
5000260	8096	138080ms	0	4681.15	1.79476
5000000	8033	137831ms	0	4483.15	1.71884
5000400	8088	138407ms	0	4607.34	1.76639
5000060	8056	139439ms	0	4720.5	1.80971
5000560	8076	138804ms	0	4485.31	1.71961
5000460	8056	139019ms	0	4522.16	1.7338
5000060	8096	138761ms	0	4633.41	1.77636
5000020	8064	138474ms	0	4598.78	1.76294
5000000	8063	137458ms	0	4663.63	1.78786
5000860	8076	139319ms	0	4691.14	1.79859

Table 23: specialized: wl_500_1

evaluations	generations	time	violations	objective	ratio with optimum
1560	1	98ms	0	410912.0	77.7689
1580	2	99ms	0	355818.0	67.3417
1780	2	112ms	0	400150.0	75.7321
1460	1	90ms	0	410578.0	77.7057
1660	1	101ms	0	392579.0	74.299
1260	1	79ms	0	416638.0	78.8526
1360	1	84ms	0	363752.0	68.8434
2060	1	122ms	0	394700.0	74.7004
1760	1	107ms	0	393733.0	74.5174
1460	1	90ms	0	402584.0	76.1926
1280	2	72ms	0	395275.0	74.8095
5080	7	445ms	0	281749.0	53.3234
5400	8	486ms	0	291348.0	55.1401
5220	9	501ms	0	270407.0	51.177
5380	7	484ms	0	303065.0	57.3577
5380	7	477ms	0	313725.0	59.3752
5180	7	448ms	0	304614.0	57.651
5000	8	435ms	0	289292.0	54.751
5500	8	474ms	0	283400.0	53.6359
5000	8	456ms	0	287801.0	54.469
5320	9	463ms	0	255355.0	48.3281
5180	7	255ms	0	303032.0	57.3514
10360	16	879ms	0	210659.0	39.8692
10160	16	842ms	0	222491.0	42.1085
10500	18	862ms	0	189951.0	35.95
10480	17	864ms	0	202865.0	38.3941
10360	16	885ms	0	222238.0	42.0604
10720	14	891ms	0	233339.0	44.1616
10000	13	832ms	0	245371.0	46.4387
10180	17	843ms	0	190444.0	36.0433
10080	17	857ms	0	212440.0	40.2061
10740	15	890ms	0	230330.0	43.5921
10560	16	509ms	0	213606.0	40.4267
50260	76	2898ms	0	65599.5	12.4152
50220	79	2952ms	0	64637.0	12.233
50180	82	2867ms	0	66885.5	12.6586
50360	81	2864ms	0	61559.0	11.6504
50340	75	2895ms	0	65617.3	12.4186
50040	85	2859ms	0	56556.6	10.7037
50180	77	2907ms	0	64308.8	12.1709
50500	78	2897ms	0	62134.1	11.7594
50040	80	2875ms	0	66483.8	12.5825
50100	78	2880ms	0	63453.1	12.0091
50220	74	2524ms	0	63734.3	12.0623
100000	153	5694ms	0	37564.2	7.10934
100520	154	5757ms	0	45929.3	8.69249
100640	160	5737ms	0	39624.2	7.49921
100220	164	5729ms	0	37881.9	7.16933
100440	165	5736ms	0	38328.4	7.25393
100340	155	5733ms	0	40945.9	7.74922
100240	160	5722ms	0	37391.6	7.07659
100520	159	5748ms	0	39094.3	7.3989
100300	158	5683ms	0	38243.8	7.23784
100080	162	5735ms	0	35987.5	6.81087
100340	160	5248ms	0	39120.2	7.40382
500300	808	27802ms	0	16576.6	3.13716
500500	813	27787ms	0	17187.5	3.2528
500000	818	27783ms	0	16957.1	3.20927
500260	806	27878ms	0	16416.2	3.10688
500460	806	27880ms	0	17653.7	3.34099
500000	783	27791ms	0	14296.9	2.70565
500700	808	27703ms	0	18571.1	3.51473
500060	796	27698ms	0	16110.2	3.04897
500100	803	27753ms	0	14998.1	2.83851
500680	807	27752ms	0	18415.4	3.48521
500260	816	26151ms	0	18096.2	3.42484
1000600	1618	55875ms	0	12888.3	2.43917
1000260	1631	55288ms	0	11034.9	2.08829
1000680	1592	55550ms	0	12303.7	2.32846
1000360	1611	54475ms	0	13454.9	2.54629
1000040	1620	54145ms	0	13332.1	2.5232
1000660	1601	54713ms	0	13203.9	2.49879
1000400	1643	55474ms	0	13738.3	2.60004
1000580	1612	55965ms	0	12435.0	2.35344
1000340	1615	55503ms	0	13087.1	2.47684
1000080	1617	55510ms	0	12402.0	2.34719
1000400	1598	61095ms	0	11705.7	2.21528
5000780	8092	272251ms	0	9638.19	1.82408
5000140	8070	265179ms	0	9466.72	1.79153
5000400	8083	269887ms	0	9720.01	1.8396
5000300	8023	266809ms	0	9613.82	1.81935
5000120	8069	273195ms	0	9739.99	1.8432
5000480	8077	266072ms	0	9329.5	1.7656
5000020	8089	270281ms	0	9455.42	1.78945
5000460	8026	272492ms	0	9564.28	1.81008
5000560	8021	266298ms	0	9174.07	1.73626
5000240	8080	273685ms	0	9307.65	1.76144
5000020	8099	273968ms	0	9532.08	1.80402

Table 24: specialized: wl_1000_1

evaluations	generations	time	violations	objective	ratio with optimum
1660	1	232ms	0	1559610.0	154.88
1240	0	180ms	0	1631850.0	162.054
1260	1	190ms	0	1521810.0	151.126
1180	2	187ms	0	1451040.0	144.098
1460	1	220ms	0	1556210.0	154.542
1660	1	358ms	0	1505350.0	149.492
1560	1	346ms	0	1382080.0	137.249
1580	2	358ms	0	1479200.0	146.894
1580	2	347ms	0	1567660.0	155.679
1780	2	376ms	0	1452450.0	144.239
1480	2	189ms	0	1461370.0	145.124
5320	9	1011ms	0	1025770.0	101.865
5300	8	1033ms	0	1124970.0	111.717
5000	8	962ms	0	1086920.0	107.938
5380	7	1049ms	0	1201700.0	119.337
5200	8	995ms	0	1106710.0	109.904
5060	6	978ms	0	1061510.0	105.415
5400	8	1023ms	0	1082230.0	107.473
5000	8	976ms	0	1068700.0	106.129
5680	7	1077ms	0	1173190.0	116.506
5700	8	1080ms	0	1076290.0	106.883
5080	7	571ms	0	1134360.0	112.649
10640	15	1930ms	0	874351.0	86.8289
10260	16	1834ms	0	738816.0	73.3694
10320	14	1470ms	0	861561.0	85.5588
10560	16	1330ms	0	726451.0	72.1414
10220	14	1316ms	0	915190.0	90.8846
10520	14	1328ms	0	852730.0	84.6819
10240	15	1322ms	0	848310.0	84.2429
10380	17	1339ms	0	756019.0	75.0777
10620	14	1352ms	0	846906.0	84.1034
10580	17	1370ms	0	777601.0	77.2211
10320	14	1234ms	0	888038.0	88.1881
50280	82	6232ms	0	242074.0	24.0395
50080	77	6238ms	0	285266.0	28.3289
50160	76	6252ms	0	258878.0	25.7083
50120	74	6301ms	0	284864.0	28.2889
50300	78	6313ms	0	250108.0	24.8373
50340	75	6314ms	0	281830.0	27.9876
50500	88	6380ms	0	227763.0	22.6183
50120	79	6309ms	0	246728.0	24.5018
50480	82	6338ms	0	238443.0	23.679
50000	83	6282ms	0	227756.0	22.6177
50180	82	5667ms	0	250103.0	24.8369
100420	169	12441ms	0	133719.0	13.2792
100200	163	12398ms	0	129234.0	12.8337
100180	162	12498ms	0	150232.0	14.9191
100060	156	12450ms	0	144284.0	14.3284
100700	163	12583ms	0	125462.0	12.4591
100140	160	12549ms	0	141608.0	14.0625
100000	158	12462ms	0	144497.0	14.3494
100440	155	12525ms	0	140522.0	13.9547
100000	163	12535ms	0	136722.0	13.5774
100260	161	12547ms	0	129291.0	12.8395
100380	162	11690ms	0	146326.0	14.5312
500560	801	60511ms	0	50495.8	5.0145
500100	808	60511ms	0	45824.8	4.55064
500100	788	60255ms	0	49272.9	4.89305
500240	795	60871ms	0	51819.9	5.14598
500660	796	60971ms	0	53258.0	5.28878
500480	782	60854ms	0	48616.3	4.8279
500060	806	61074ms	0	47531.5	4.72015
500380	802	61302ms	0	49866.5	4.95203
500200	808	61242ms	0	49985.5	4.96385
500380	792	61098ms	0	44419.1	4.41111
500380	802	58061ms	0	45351.2	4.50366
1000040	1610	120533ms	0	35737.8	3.54893
1000420	1624	120785ms	0	33487.8	3.32549
1000200	1618	120814ms	0	40382.1	4.01021
1000380	1647	121552ms	0	29694.6	2.94882
1000300	1603	121399ms	0	37876.9	3.76134
1000340	1620	121455ms	0	32979.1	3.27504
1000660	1606	121931ms	0	31032.8	3.08169
1000200	1613	122383ms	0	28940.7	2.87394
1000400	1608	122508ms	0	30615.6	3.04028
1000440	1600	123519ms	0	34954.5	3.47117
1000020	1599	117839ms	0	33290.0	3.30582
5000040	8115	597027ms	0	19010.2	1.88782
5000560	8091	598618ms	0	20850.4	2.07055
5000300	8033	592347ms	0	19696.5	1.95595
5000780	8062	594861ms	0	19814.8	1.96767
5000440	8025	550604ms	0	20063.8	1.99239
5000280	8067	523008ms	0	22236.8	2.20819
5000340	8080	519997ms	0	18450.9	1.83221
5000380	8057	518472ms	0	21403.4	2.12546
5000040	8080	520758ms	0	20535.4	2.03927
5000020	8104	522512ms	0	23058.9	2.28982
5000420	8054	555623ms	0	20188.9	2.00481

Table 25: specialized: wl_2000_1

4 Comparison

The algorithms were compared on all instances of the wareshouse allocation problem. Every instance was solved 11 times for 8 different amounts of evaluation calls, starting from 1000 and ending by 5000000 calls. These three algorithms were run in parallel.

In the following subsections are presented plots comparing these three algorithms in terms of quality of solution as a function of number of evaluation calls.

The plots contains box plot for each batch. Boxplots belonging to individual algorithms have connected means to better visualize, when each algorithm gets better than the others.

On y axis are plotted only fitness function values excluding constraint violations for infeasible solutions. Algorithms find valid solutions really quickly, so for plotted evaluation call limits, the common fitness function and fitness function considering violations have the same value.

What those charts do not include is runtime of algorithms, which will be described in conclusion.

4.1 wl_16_1

On this instance, the local search algorithm outperforms both basic evolution algorithm and mine specialized memetic algorithm with evolution algorithm being better than the memetic one. This can be caused by the greedy initialization, or that the local search is more likely to shift to more promising areas due to more random trials, while the other two algorithms try to combine already found solutions and the pure randomization isn't so frequent. Quite interesting is, that the memetic algorithm struggles against the evolutionary one. This is probably caused by evaluation calls "wasted" on local search, so it does not perform as many population generations. However, as opposed to the other two, the memetic algorithm decreases monotically while tightening the confidence bounds, so even though the found solution is not as good, it is unlikely, that it will get stuck in some worse. That cannot be said about the two other as their confidence bounds are huge and not with improving trend.

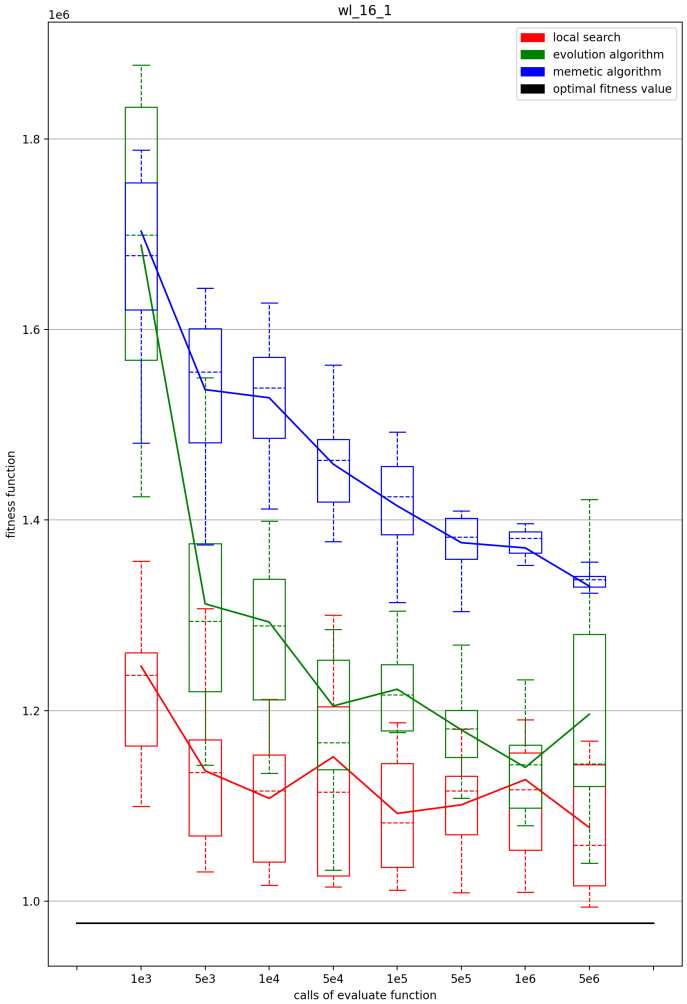

Figure 1: Comparison of algorithms on wl_16_1 instance

4.2 wl_25_2

This instance is easy, so all algorithms find really good solutions quickly. The memetic algorithm always finds the same solution and that will probably be caused by the greedily initialized candidate, which will get him stuck in some local optima and the mutation pressure isn't as great as in local search. On the other hand, the evolutionary algorithm oscilates quite a bit, so the best solution isn't guranteed to be reached every time. Local search finds really good solution after approximately 1000 random trials and then is not able to improve further. Also, the evolutionary algorithm needs a lot of evaluations to combine the population so the solutions are good. The random initialization obviously creates really bad solutions.

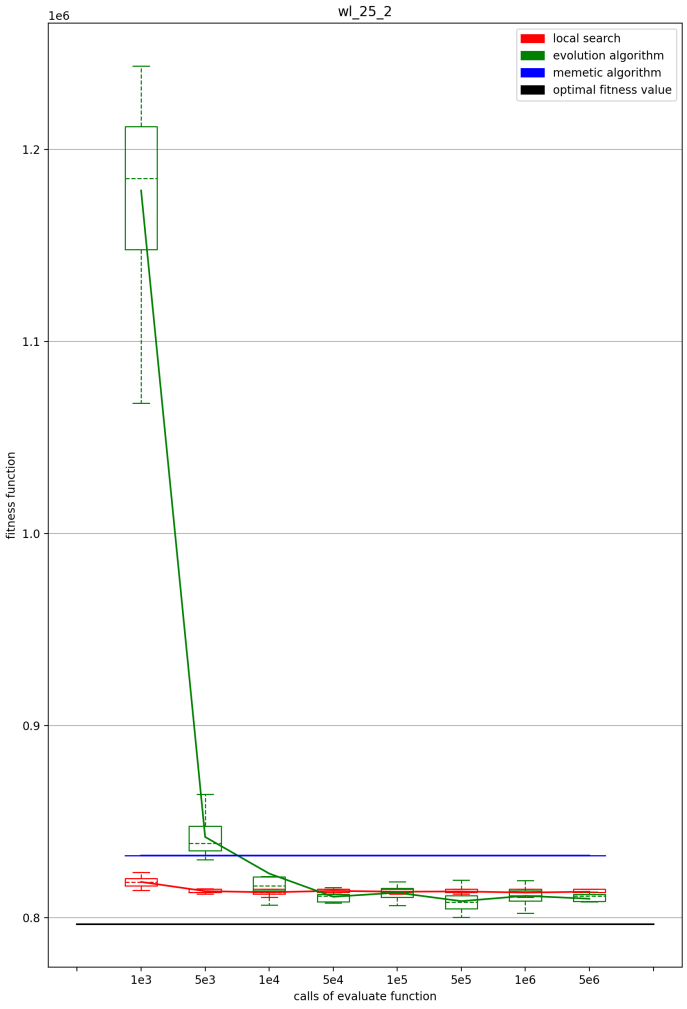

Figure 2: Comparison of algorithms on wl_25_2 instance

4.3 wl_50_1

Situation on this instance is almost exactly the same as in previous instance. It is really easy, so the power of the memetic algorithm doesn't show in comparison. Maybe, it would be suitable to perform local search also before the breeding phase in the memetic algorithm, so there would be possibility to get to another areas and not get stuck.

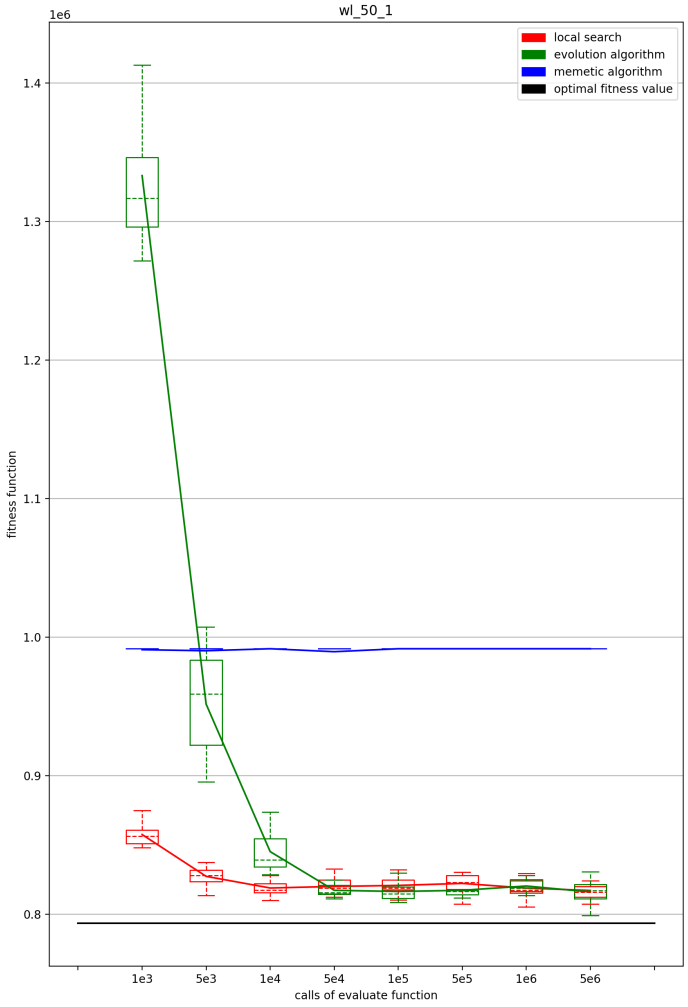

Figure 3: Comparison of algorithms on wl_50_1 instance

4.4 wl_100_4

This instance is where the situation changes. It is probably much harder and the local search simply does not have a chance to improve much from the greedy candidate. The evolution algorithm improves a bit, but it only gets stuck in a better solution. The best is the memetic one, possibly because it has more mutation power than the evolution algorithm and it is able to jump to more promising areas, where the evolution starts working again and starts finding better and better solutions.

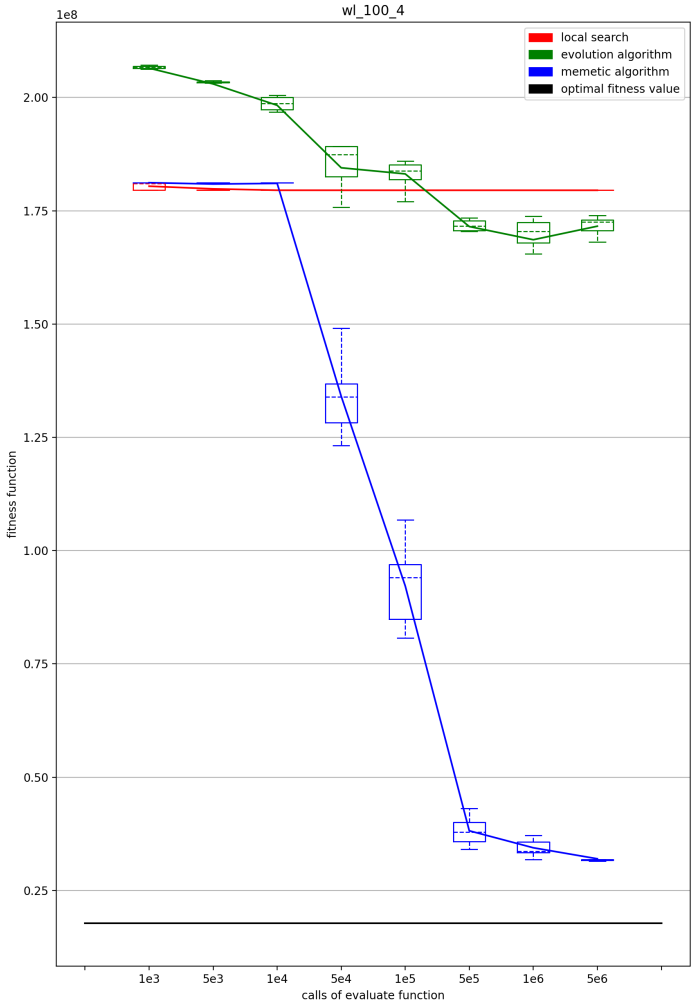

Figure 4: Comparison of algorithms on wl_100_4 instance

4.5 wl_200_1, wl_500_1, wl_1000_1, wl_2000_1

On the remaining 4 instances, the situation is almost the same.

On every number of evaluation calls evolution algorithm is much better than local search. Here, the search space is too large and the random mutation does not suffice to explore significant portion of it. It converges, but really slowly.

The evolution algorithm has a big jump in the first evaluation limits, but then it does not improve much. The population probably starts to stagnate and then the case is the same as with local search. It improves slightly, but it is not fast enough.

The memetic algorithm shows its power here. It starts really bad, because it wastes evaluation function calls on local search, but it improves gradually with increasing the limit and after approximately 100000 evaluations, it takes over both local search and evoluion algorithm. Also its confidence bounds are tight, so very similar solution is found almost every time. It cannot be seen very well from the plot, but the bsf solutions of evolution and memetic algorithms are quite far away.

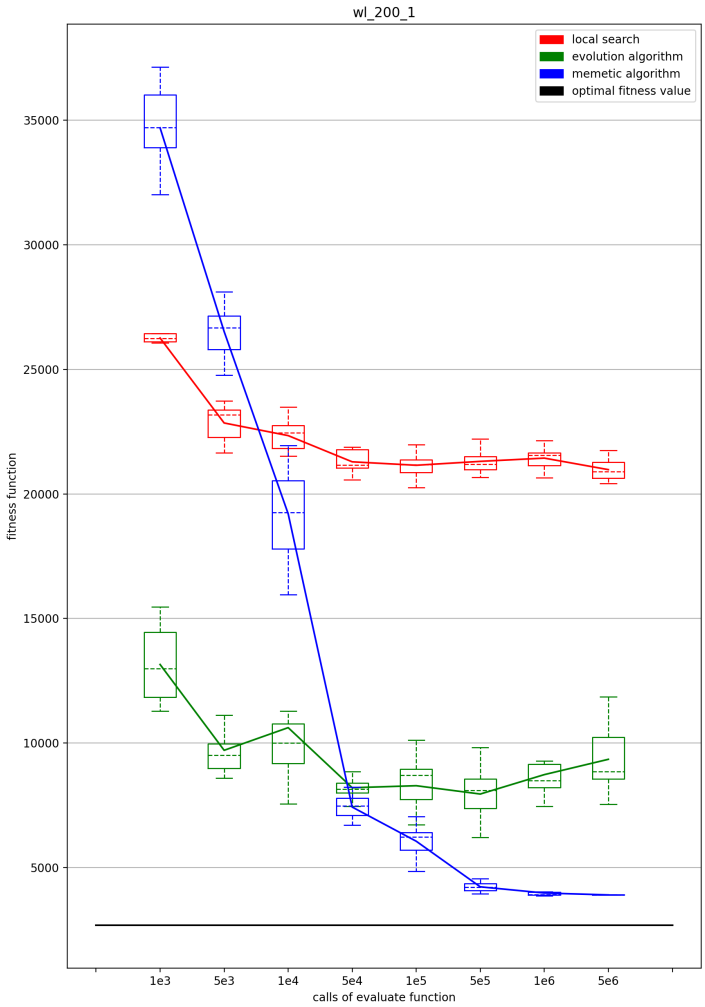

Figure 5: Comparison of algorithms on wl_200_1 instance

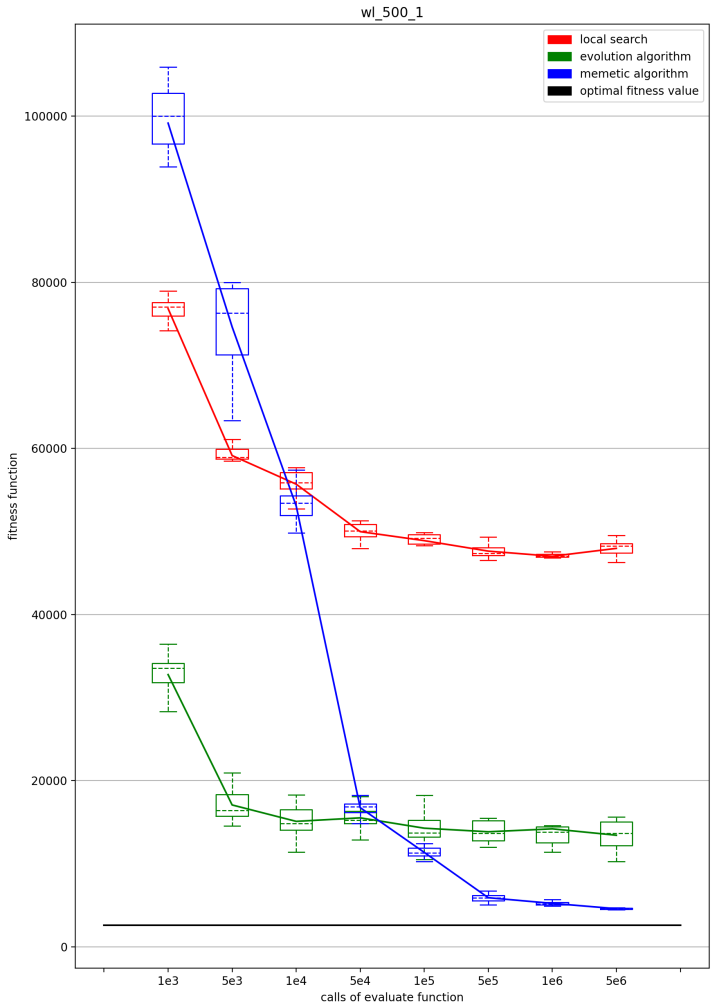

Figure 6: Comparison of algorithms on wl_500_1 instance

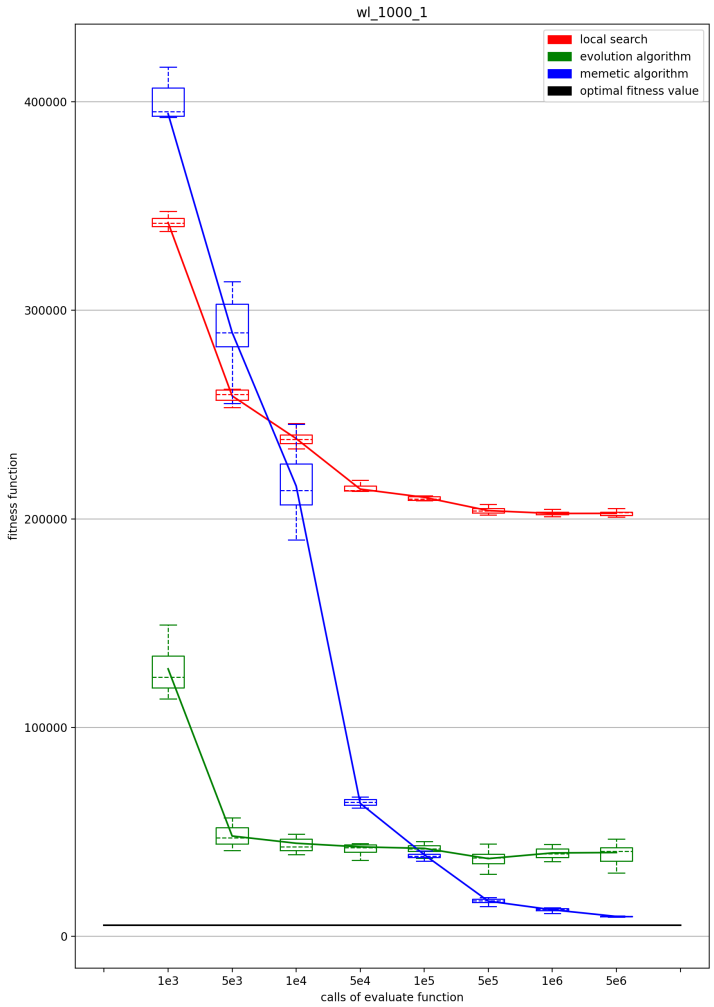

Figure 7: Comparison of algorithms on wl_1000_1 instance

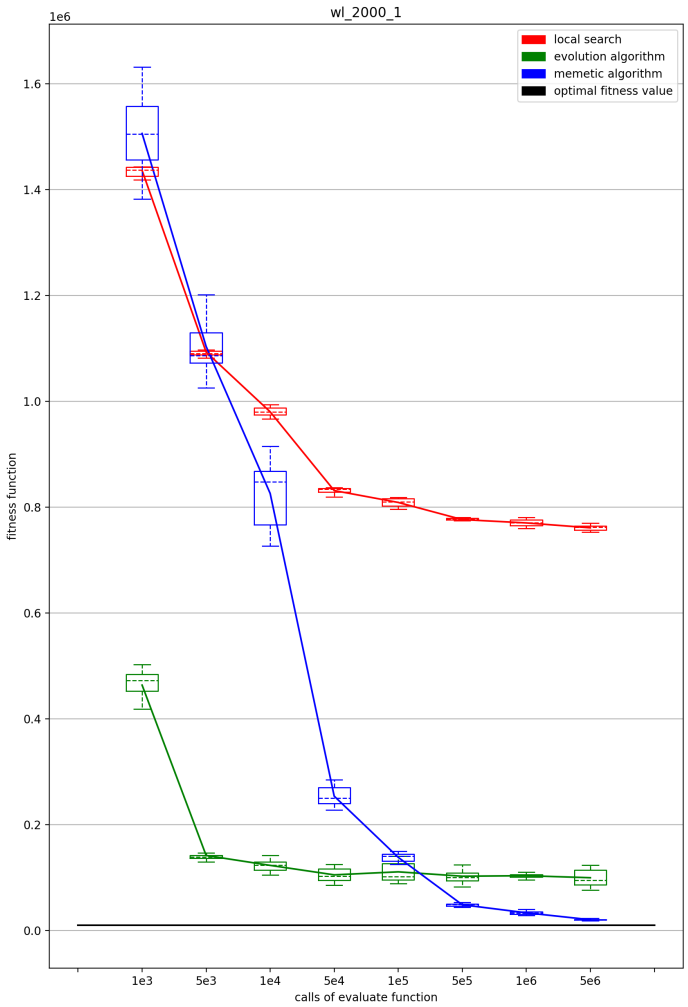

Figure 8: Comparison of algorithms on wl_2000_1 instance

5 Conclusion

In this report we compared simple local search, basic evolution algorithm and custom memetic algorith.

On simpler, smaller instances, the local search is better that the other two, because the search space is small enough and the algorithm has a chance to explore larger area and get to more promising solutions. On harder instances, this does not hold and the local search does not provide good results. Big advantage of local search is its speed.

The evolution algorithm needs more evaluations, but it eventually overcomes local search or at least gets on the same level. On bigger instances, it starts to struggle from stagnation of population and cannot further improve. Its huge disadvantage is, that it is by far the slowest from these three (time measured on the same number of evaluations).

The memetic algorithm quite struggles on smaller instances, as it cannot use the full potential of local search, but wastes a lot of evaluations on it, so it cannot breed as much. However, on large and hard instances, it is superior to both other algorithms. But, it needs more evaluations to overcome them, which is a big disadvatage. On the other hand, it is faster than evolution algorithm on the same number of evaluations. Also, it converges monotically while tightening interquartile range, so it is more likely to find similar solutions.

None of these algorithms struggles from being unable to find valid solution as it is usually quickly found in the first few iterations.