Heuristic Optimization Techniques

Exercise 3

David Fankhauser, 1025876
Christoph Weiler 1029175
Gruppe 1

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1 Advanced Local Search Description

We implemented a *General Variable Neighbourhood Search* based on our four neighbourhoods from assignment 2, namely Ordering 1-Shift (*sho*), Shift Edges (*moe*), Max-Crossing Neighbourhood (*map*) and Min-Max-Crossing Ordering (*mmc*). For a neighbourhood description see report-2.

Our previous approach of computing the number of crossings was rather inefficient: To create a neighbour, we copied the old solution, made a change to generate a new neighbour and finally used delta evaluation to compute the number of crossings in a fast way. However, generating a neighbour by copying a solution is computational expensive. Hence, we only copy solutions, if a better neighbour was found which increased the performance by roughly 4 times.

In that way we were able to run Variable Neighbourhood Searches in the given time frame.

From theory we expected varying results, when using different orders for the same neighbourhoods. We were able to confirm this statement empirically. On each instance we experienced the best results when using a neighbourhood that shifts edges to another page and then improving the ordering (See Appendix for a graphical view).

2 Experimental Setup

We tested our program on our local computer because in this assignment we used cmake for crossplattform development and the boost library. The needed tools were not installed on Eowyn nor Behemoth therefore we decided to test our application on our computers. The test environment for the results are a Intel Core i7-2600K processor on Ubuntu 15.10. Our code is written in C++11 and it was compiled with gcc 5.2.1.

3 Results

For the evaluation we use the following keys:

- g = greedy construction heuristic
- sho = shift ordering neighbourhood
- moe = move edge neighbourhood
- map = Max crossing page neighbourhood
- mmc = Min-Max crossing ordering neighbourhood
- f = first-improvement step function
- r = random step function
- vns = Variable Neighbourhood Search

3.1 Results of VNS applied with two neighbourhoods

	g+vns[sho+f,moe+f]		g+vns[mmc+f,map+f]	
Instance	Obj	Time	Obj	Time
automatic-1.txt	9	4.35 ms	19	6.99 ms
automatic-2.txt	0	14.18 ms	3	23.29 ms
automatic-3.txt	49	100.55 ms	78	40.93 ms
automatic-4.txt	7	154.01 ms	36	8.42 ms
automatic-5.txt	10	109.48 ms	12	22.82 ms
automatic-6.txt	7456783	900000.00 ms	6327391	175168.00 ms
automatic-7.txt	21999	900000.00 ms	23545	5587.51 ms
automatic-8.txt	596130	900000.00 ms	402355	181285.00 ms
automatic-9.txt	814918	900000.00 ms	601204	900000.00 ms
automatic-10.txt	28523	900000.00 ms	27215	27286.30 ms

3.2 Results of VNS with all neighbourhoods with randomized step functions

A VNS search on the instances 6-10 is still quite exhaustive. Therefore we treat these instances seperately with a lower number of runs.

	g+vns[mmc+r,map+r,sho+r,moe+r]					
Instance	Best Obj	Mean Obj	Std Dev Obj	Mean Time	Std Dev Time	Runs
automatic-1.txt	9	11.32	1.61	621.60 ms	85.31 ms	50
automatic-2.txt	0	0.26	0.66	1478.52 ms	122.67 ms	50
automatic-3.txt	42	48.74	3.35	6015.53 ms	936.27 ms	50
automatic-4.txt	0	2.60	1.89	3216.76 ms	364.00 ms	50
automatic-5.txt	2	4.64	1.35	3503.22 ms	369.22 ms	50

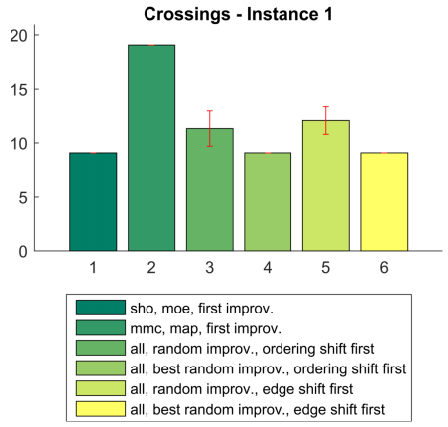
	g+vns[map+r,mmc+r,moe+r,sho+r]					
Instance	Best Obj	Mean Obj	Std Dev Obj	Mean Time	Std Dev Time	Runs
automatic-1.txt	9	12.06	1.26	597.11 ms	74.62 ms	50
automatic-2.txt	0	0.34	0.68	1492.39 ms	142.34 ms	50
automatic-3.txt	40	50.80	3.36	4819.61 ms	686.03 ms	50
automatic-4.txt	0	3.80	2.16	3660.42 ms	506.85 ms	50
automatic-5.txt	3	4.82	1.19	3336.54 ms	428.98 ms	50

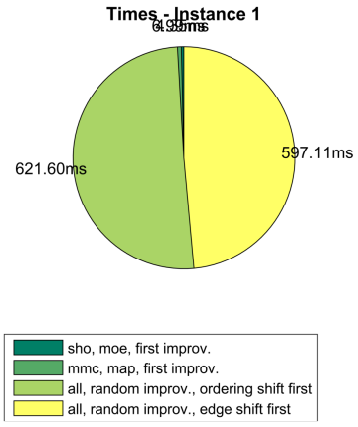
	g+vns[mmc+r,map+r]					
Instance	Best Obj	Mean Obj	Std Dev Obj	Mean Time	Std Dev Time	Runs
automatic-6.txt	2092733	2194286.00	138977.55	900000.00 ms	0.00 ms	3
automatic-7.txt	24235	24578.00	246.73	34735.63 ms	7540.72 ms	3
automatic-8.txt	392710	394370.33	1225.99	487229.67 ms	57619.84 ms	3
automatic-9.txt	643847	671164.33	19356.36	849122.67 ms	35975.91 ms	3
automatic-10.txt	26732	26795.67	59.42	268704.67 ms	28534.18 ms	3

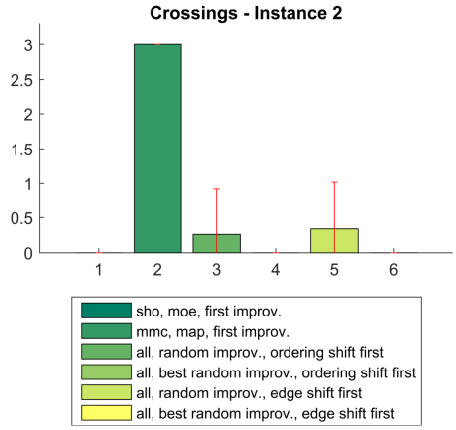
	g+vns[map+r,mmc+r,moe+r,sho+r]					
Instance	Best Obj	Mean Obj	Std Dev Obj	Mean Time	Std Dev Time	Runs
automatic-6.txt	2000002	2066923.33	53353.30	900000.00 ms	0.00 ms	3
automatic-7.txt	9934	10488.33	544.29	900000.00 ms	0.00 ms	3
automatic-8.txt	271187	273062.33	1555.14	900000.00 ms	0.00 ms	3
automatic-9.txt	394551	414834.00	14379.36	900000.00 ms	0.00 ms	3
automatic-10.txt	22182	22375.33	270.59	900000.00 ms	0.00 ms	3

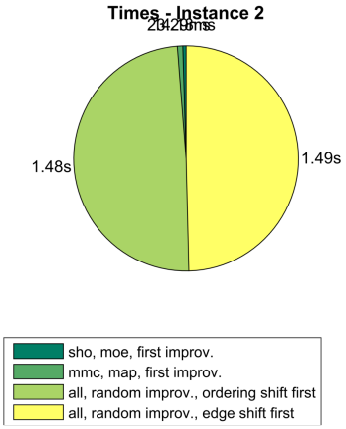
4 Appendix

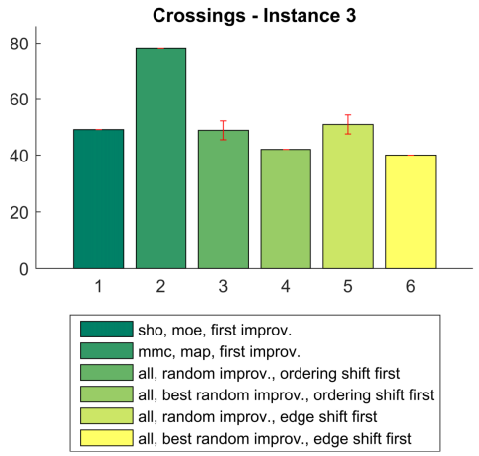
We also provide some additional figures for a better visual representation. The following ten figure show the mean objective function on the left side (including std-dev for randomized runs) and the run time in form of pie charts on the right side respectiveley..

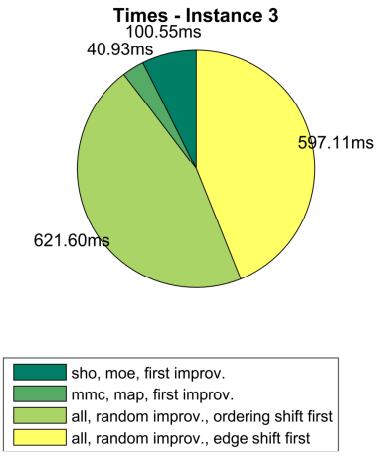

Crossings - Instance 1
20
15
10
5
0
1
2
3
4
5
6
sho, moe, first improv.
mmc, map, first improv.
all. random improv., ordering shift first
all. best random improv., ordering shift first
all. random improv., edge shift first
all. best random improv., edge shift first

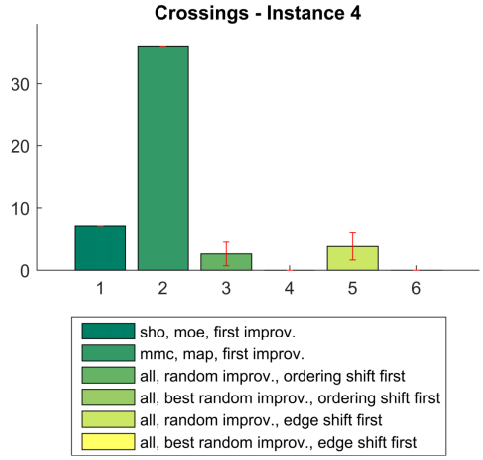

Times - Instance 1
621.60ms
597.11ms
sho, moe, first improv.
mmc, map, first improv.
all, random improv., ordering shift first
all, random improv., edge shift first

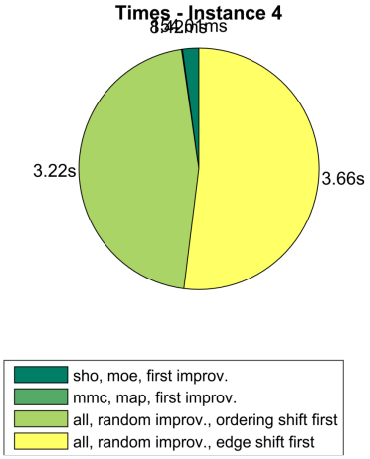

Crossings - Instance 2
3
2.5
2
1.5
1
0.5
0
1
2
3
4
5
6
sho, moe, first improv.
mmc, map, first improv.
all. random improv., ordering shift first
all. best random improv., ordering shift first
all. random improv., edge shift first
all. best random improv., edge shift first


Times - Instance 2
1.48s
1.49s
sho, moe, first improv.
mmc, map, first improv.
all, random improv., ordering shift first
all, random improv., edge shift first

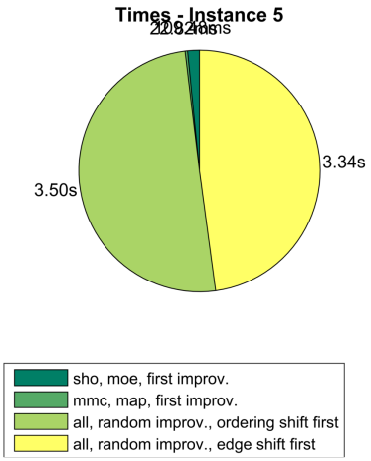

Crossings - Instance 3
80
60
40
20
0
1
2
3
4
5
6
sho, moe, first improv.
mmc, map, first improv.
all, random improv., ordering shift first
all, best random improv., ordering shift first
all, random improv., edge shift first
all, best random improv., edge shift first

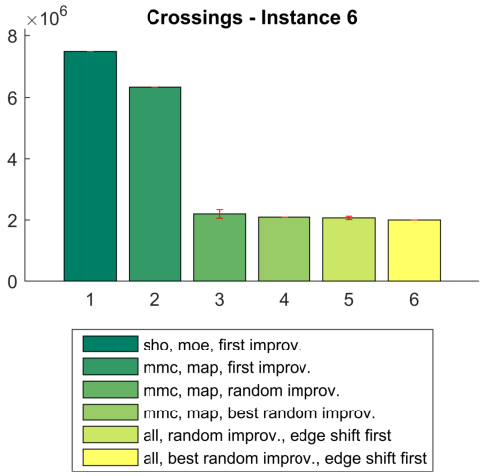

Times - Instance 3
100.55ms
40.93ms
597.11ms
621.60ms
sho, moe, first improv.
mmc, map, first improv.
all, random improv., ordering shift first
all, random improv., edge shift first

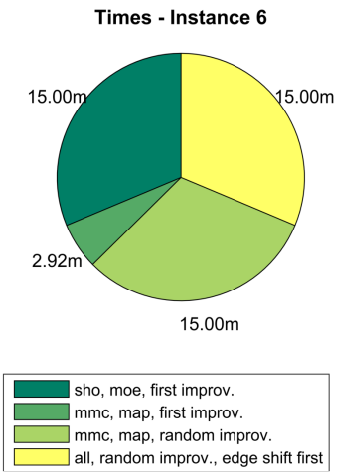

Crossings - Instance 4
30
20
10
0
1
2
3
4
5
6
sho, moe, first improv.
mmc, map, first improv.
all, random improv., ordering shift first
all, best random improv., ordering shift first
all, random improv., edge shift first
all, best random improv., edge shift first

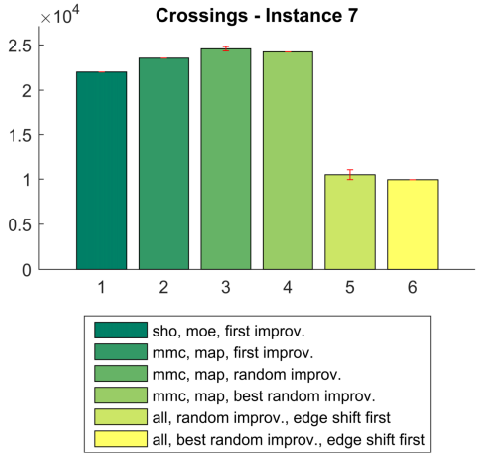

Times - Instance 4
3.22s
3.66s
sho, moe, first improv.
mmc, map, first improv.
all, random improv., ordering shift first
all, random improv., edge shift first

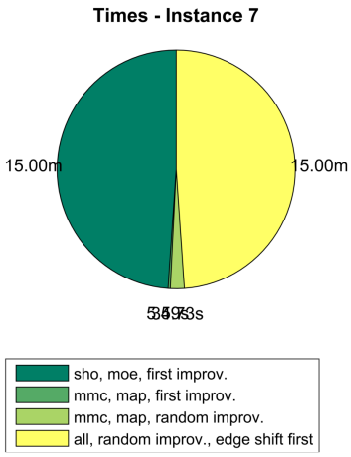

Crossings - Instance 5
12
10
8
6
4
2
0
1
2
3
4
5
6
sho, moe, first improv.
mmc, map, first improv.
all, random improv., ordering shift first
all, best random improv., ordering shift first
all, random improv., edge shift first
all, best random improv., edge shift first


Times - Instance 5
3.50s
3.34s
sho, moe, first improv.
mmc, map, first improv.
all, random improv., ordering shift first
all, random improv., edge shift first

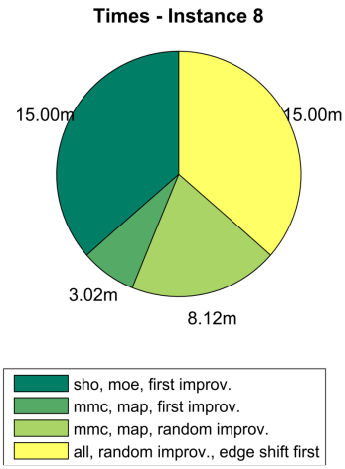

Crossings - Instance 6
×10^6
8
6
4
2
0
1
2
3
4
5
6
sho, moe, first improv.
mmc, map, first improv.
mmc, map, random improv.
mmc, map, best random improv.
all, random improv., edge shift first
all, best random improv., edge shift first

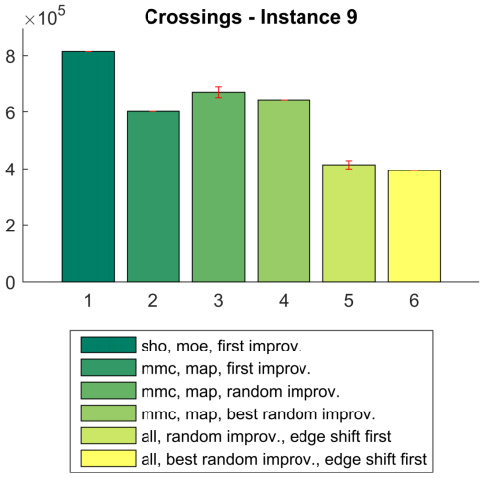

Times - Instance 6
15.00m
15.00m
2.92m
15.00m
sho, moe, first improv.
mmc, map, first improv.
mmc, map, random improv.
all, random improv., edge shift first

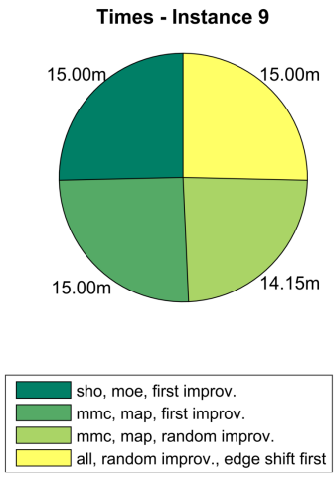

Crossings - Instance 7
×10^4
2.5
2
1.5
1
0.5
0
1
2
3
4
5
6
sho, moe, first improv.
mmc, map, first improv.
mmc, map, random improv.
mmc, map, best random improv.
all, random improv., edge shift first
all, best random improv., edge shift first

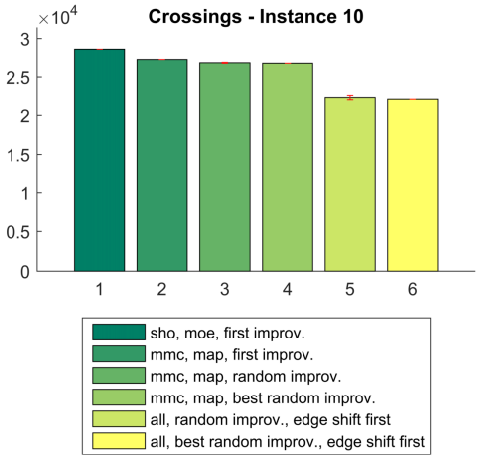

Times - Instance 7
15.00m
15.00m
sho, moe, first improv.
mmc, map, first improv.
mmc, map, random improv.
all, random improv., edge shift first

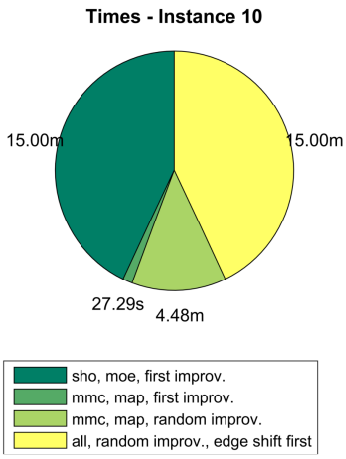

Crossings - Instance 8
×10^5
6
5
4
3
2
1
0
1
2
3
4
5
6
sho, moe, first improv.
mmc, map, first improv.
mmc, map, random improv.
mmc, map, best random improv.
all, random improv., edge shift first
all, best random improv., edge shift first


Times - Instance 8
15.00m
15.00m
3.02m
8.12m
sho, moe, first improv.
mmc, map, first improv.
mmc, map, random improv.
all, random improv., edge shift first


Crossings - Instance 9
×10^5
8
6
4
2
0
1
2
3
4
5
6
sho, moe, first improv.
mmc, map, first improv.
mmc, map, random improv.
mmc, map, best random improv.
all, random improv., edge shift first
all, best random improv., edge shift first


Times - Instance 9
15.00m
15.00m
15.00m
14.15m
sho, moe, first improv.
mmc, map, first improv.
mmc, map, random improv.
all, random improv., edge shift first


Crossings - Instance 10
×10^4
3
2.5
2
1.5
1
0.5
0
1
2
3
4
5
6
sho, moe, first improv.
mmc, map, first improv.
mmc, map, random improv.
mmc, map, best random improv.
all, random improv., edge shift first
all, best random improv., edge shift first


Times - Instance 10
15.00m
15.00m
27.29s
4.48m
sho, moe, first improv.
mmc, map, first improv.
mmc, map, random improv.
all, random improv., edge shift first