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Modified greedy Delaunay graph-based method for TSP initialization

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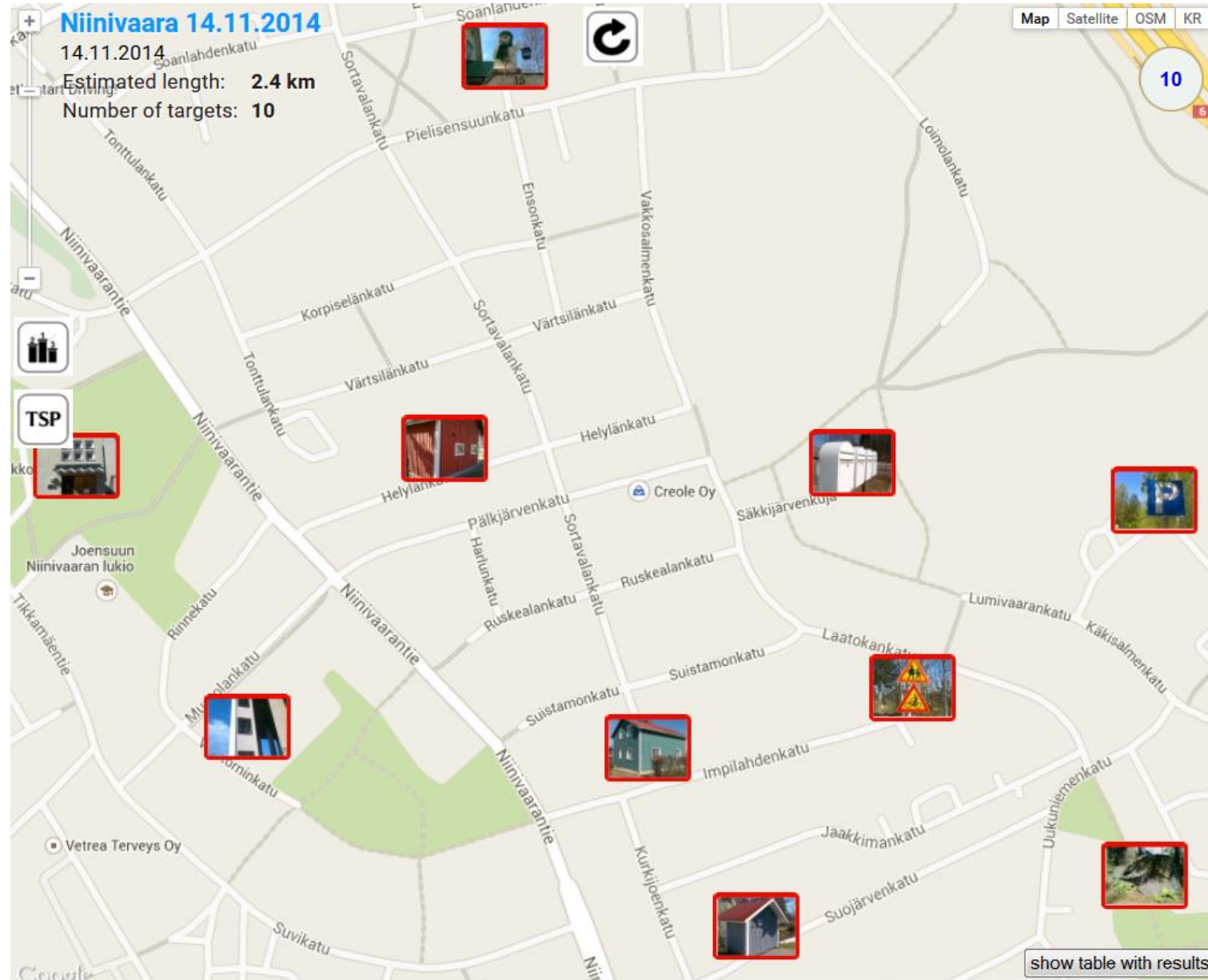


Joensuu

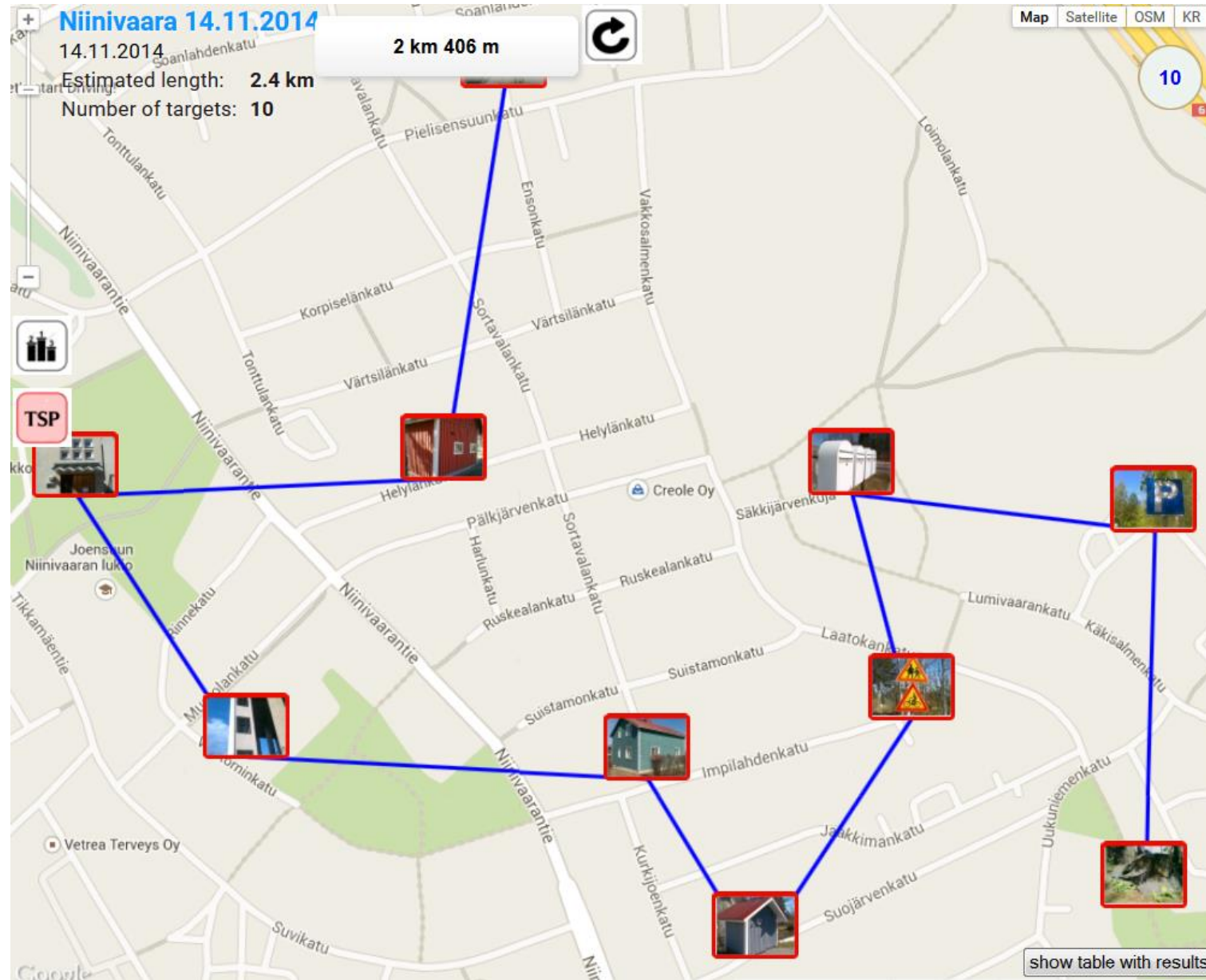


Travelling salesman problem (TSP)

Small-scale (open-loop) TSP

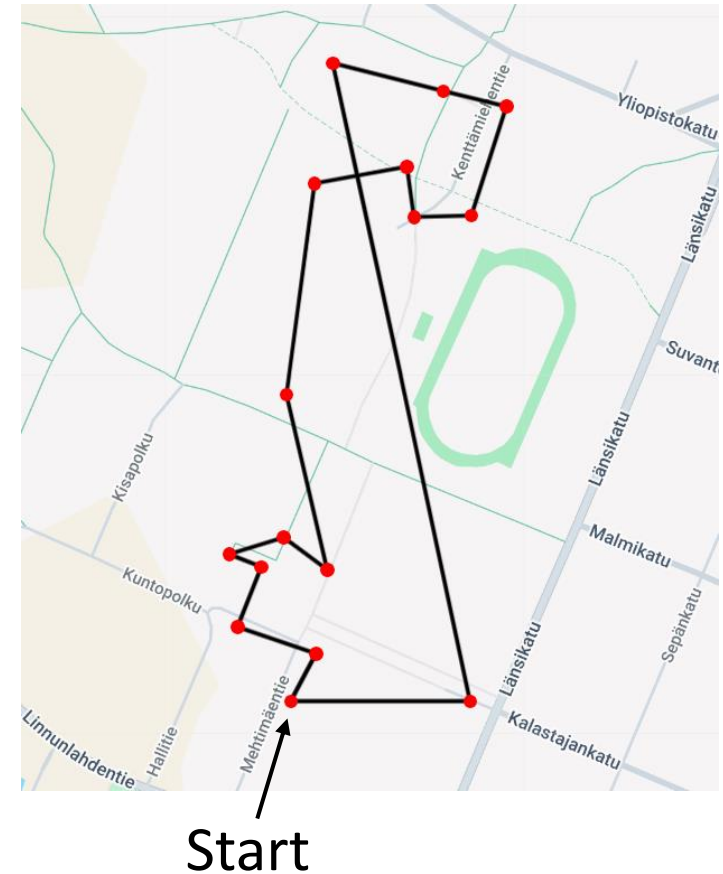


Solution



Simple initialization methods are slow

- Nearest neighbor approach:
 $O(N^2)$ steps
- Too much for bigger datasets
such as $N = 1 \text{ million}$

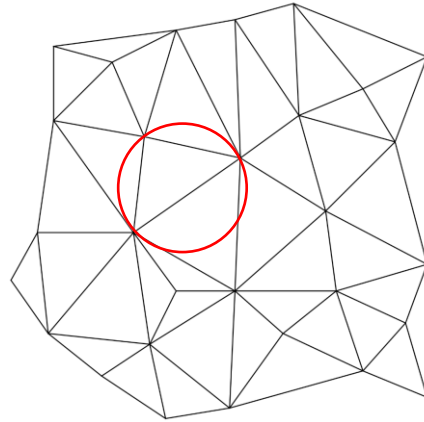


Delaunay graph

Dots-4345

$n = 29$

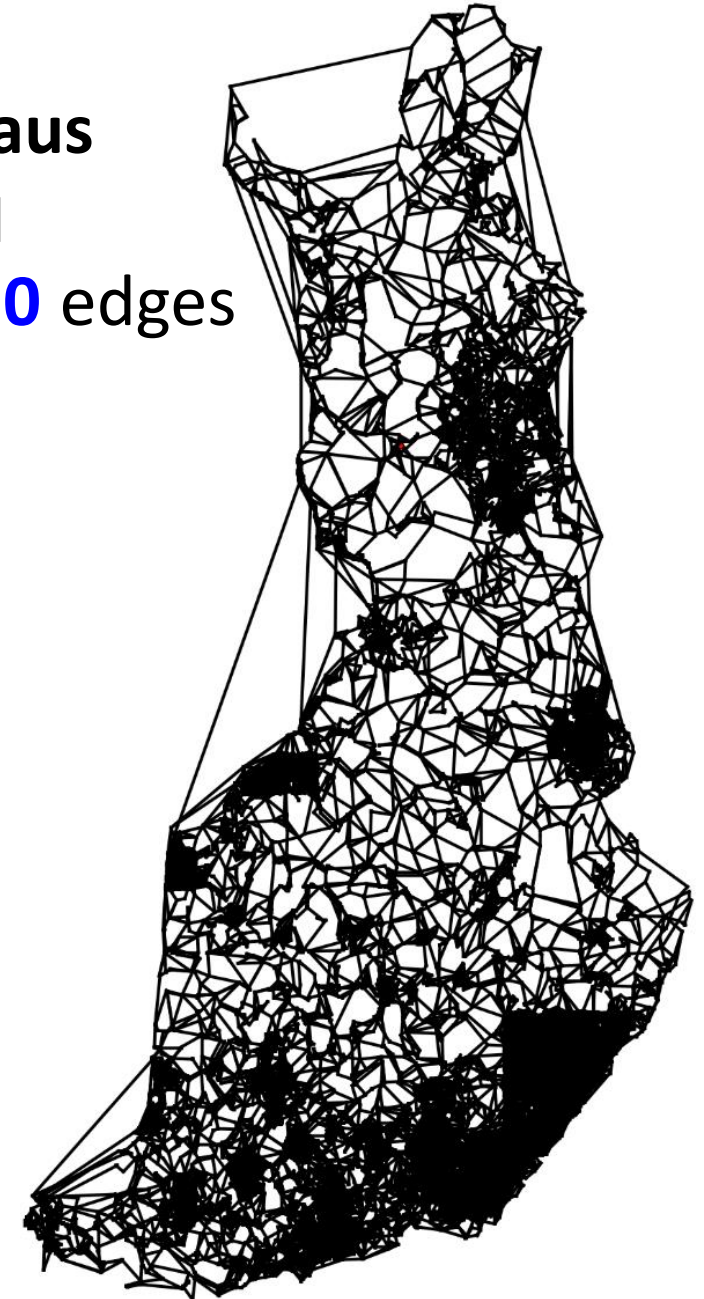
67 edges



Santa Claus

$n = 1.4\text{M}$

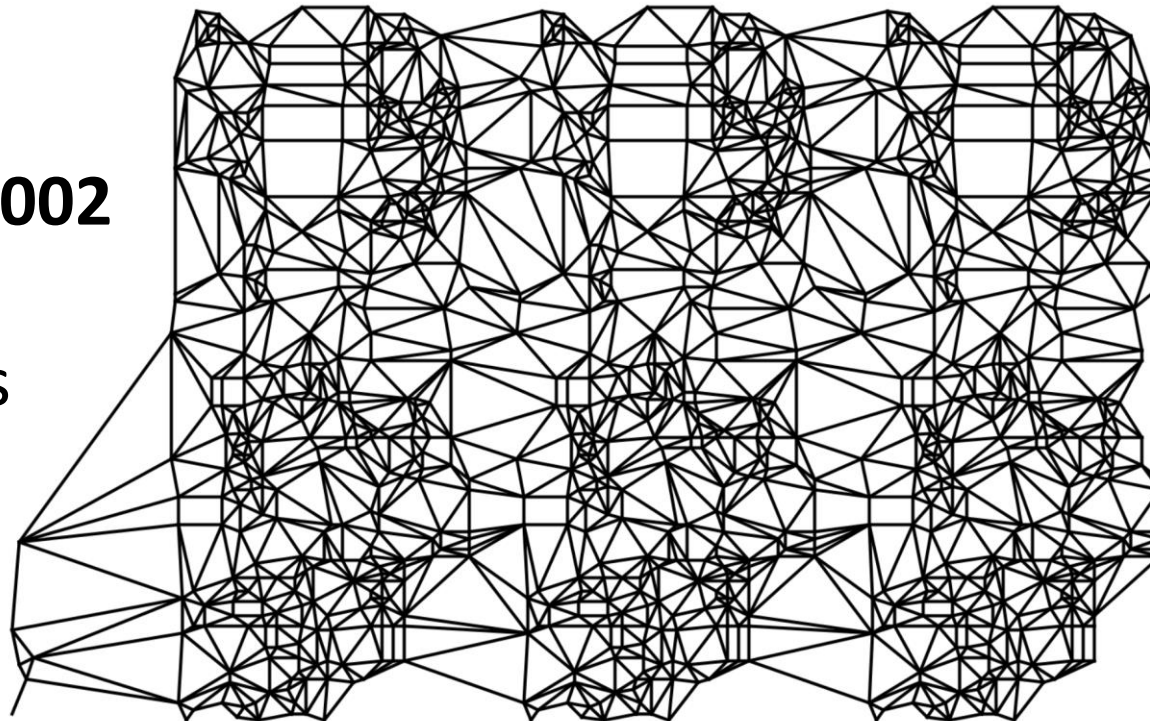
8,623,110 edges



TSPLIB-pr1002

$n = 1002$

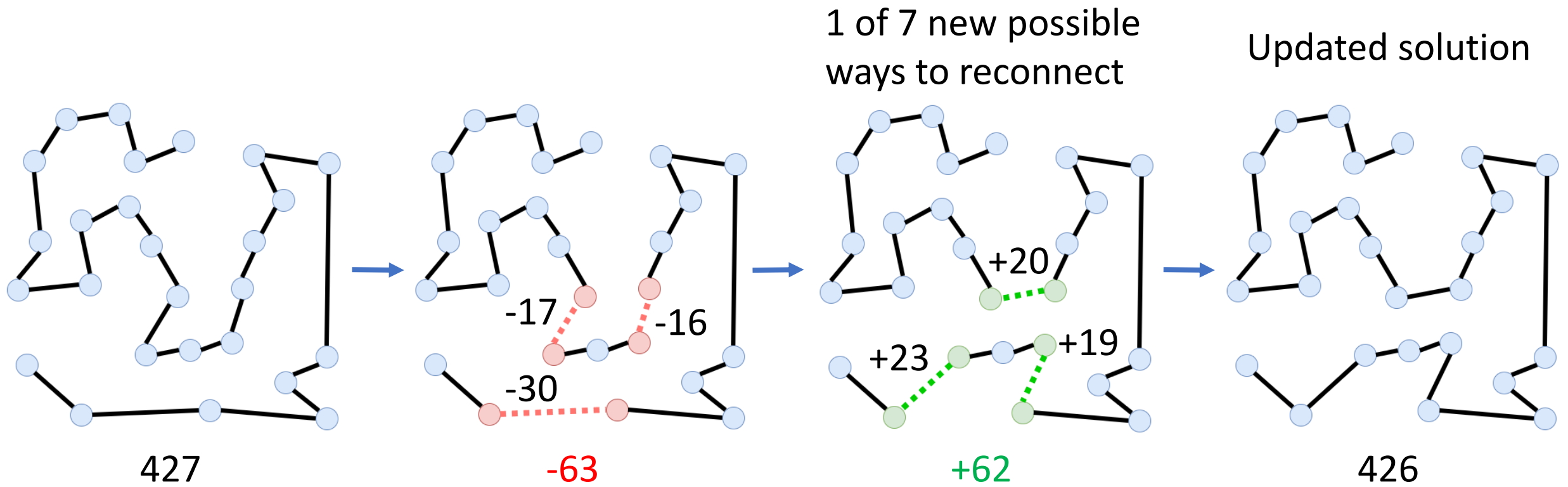
2838 edges



State-of-the-art

- **Lin-Kernighan heuristic (LKH)**: Local search method with **k-opt** operator with localized candidate selection
- **Initialization**: Any fast heuristic
- **Good initial**: Less operations and better final solution

K-opt



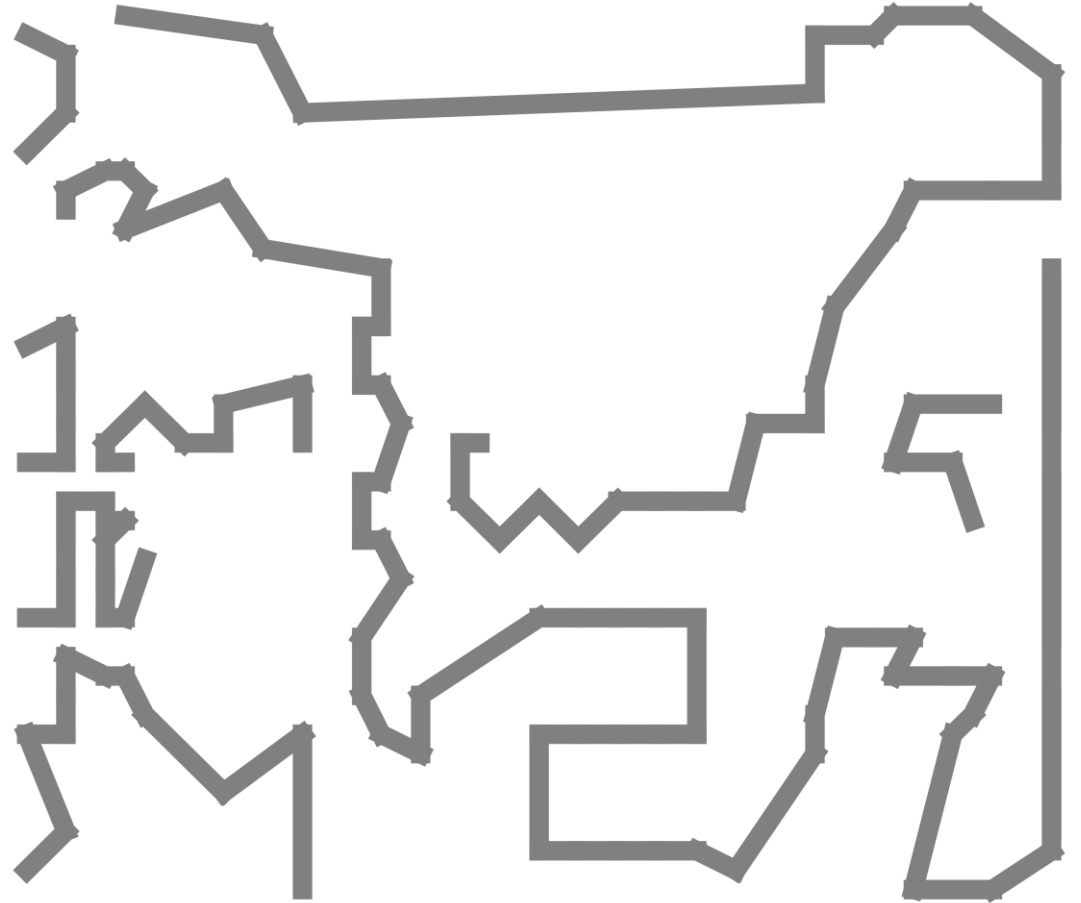
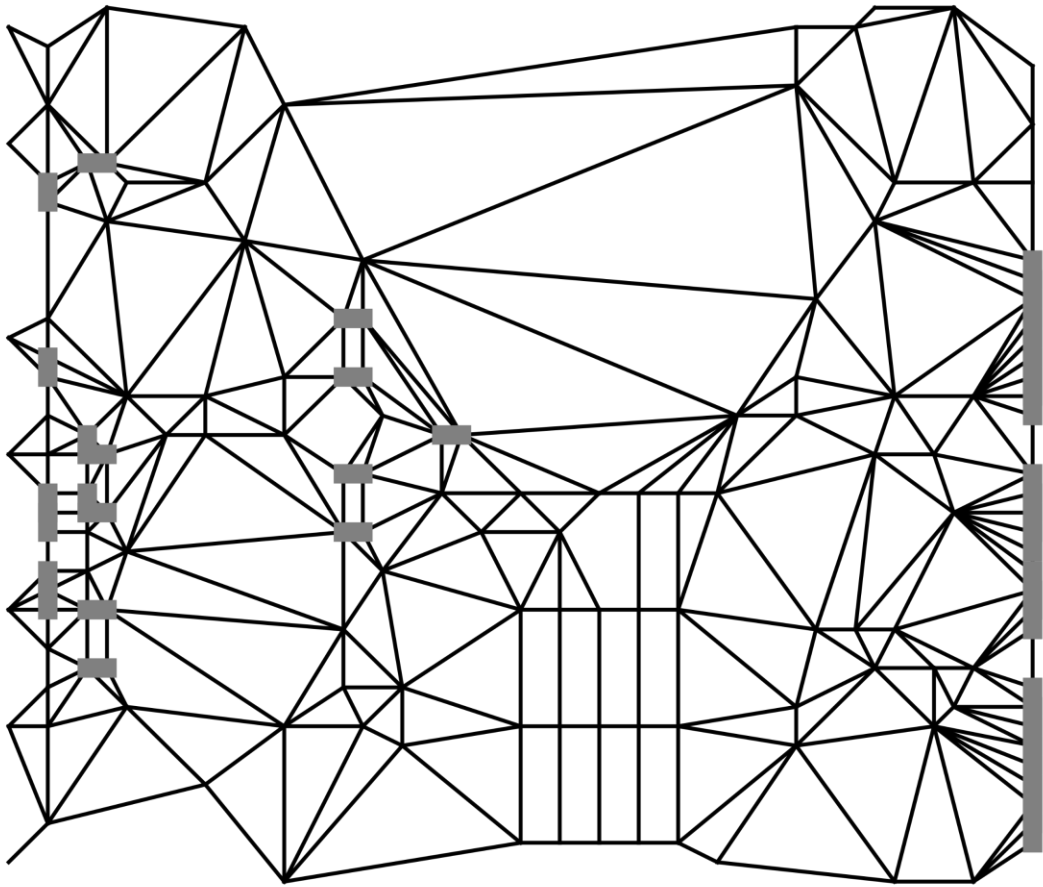
Initializations considered

- Nearest neighbor [3, 4]
- Nearest neighbor (fast) [2]
- Greedy graph [2]
- Kruskal-TSP [8]
- Moore [9]
- Sierpinski [10]
- Boruvka [11]
- Quick-Boruvka [7, 12]
- Christofides [13, 14]
- Walk [2]
- Delaunay shortest edge [15]
- Delaunay random edge [15]
- Delaunay greedy with fragment merge (new)

Graph-based

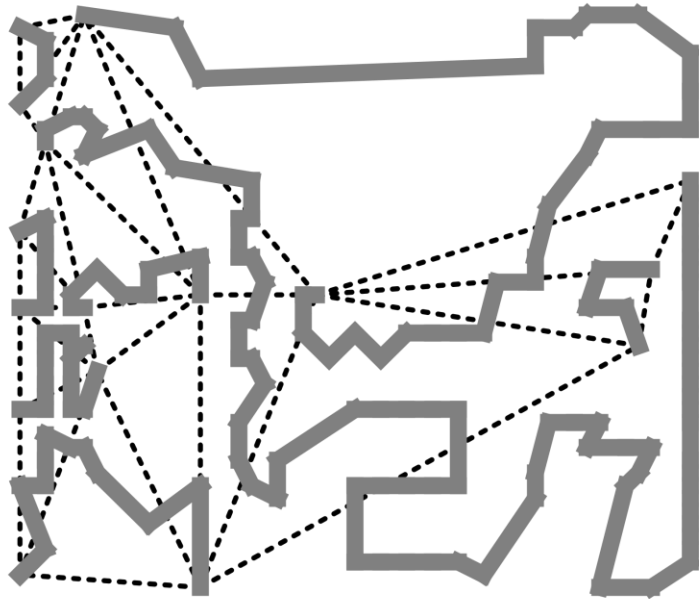
Too slow or
ineffective

Delaunay greedy FM: 1st phase



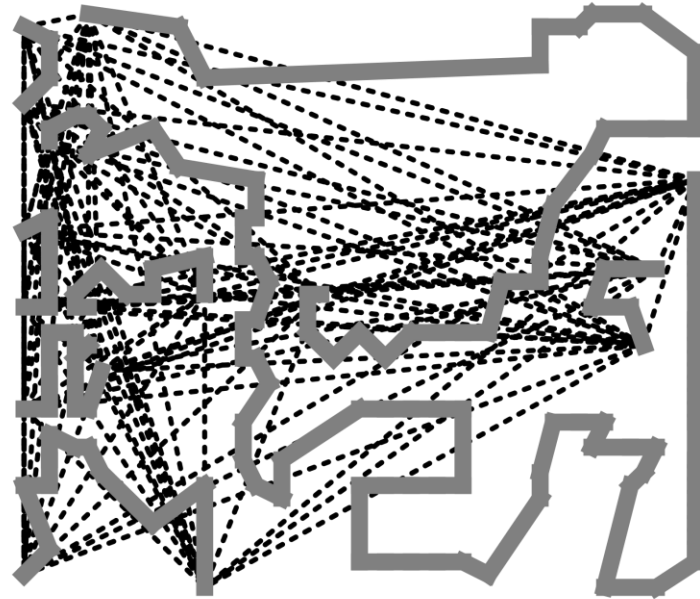
Fragment connection methods

Re-Delaunay



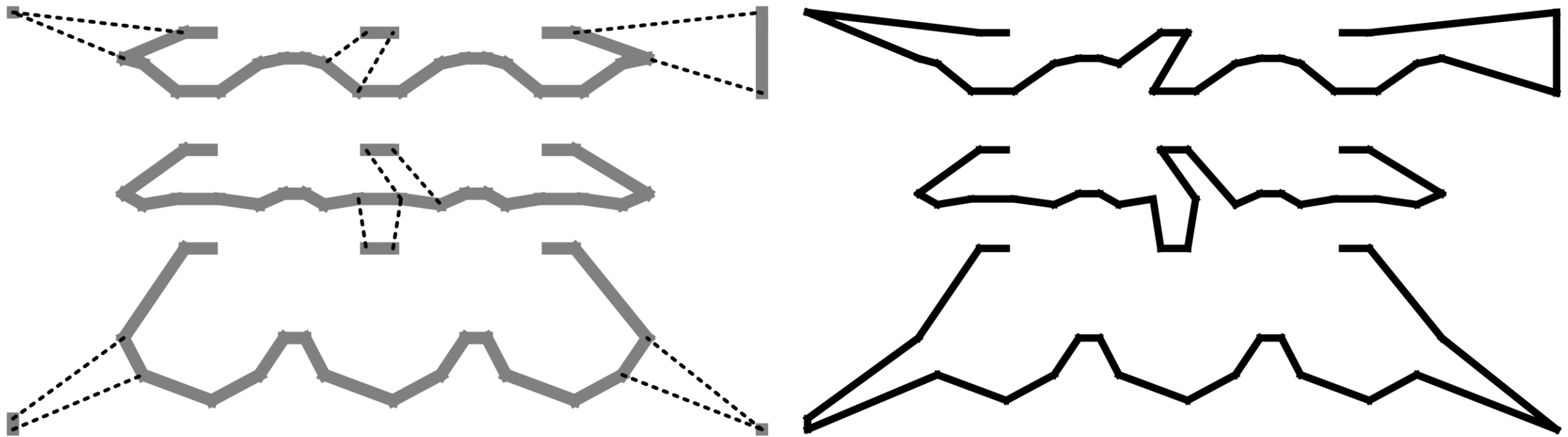
Edges 32

Full search



Edges 112

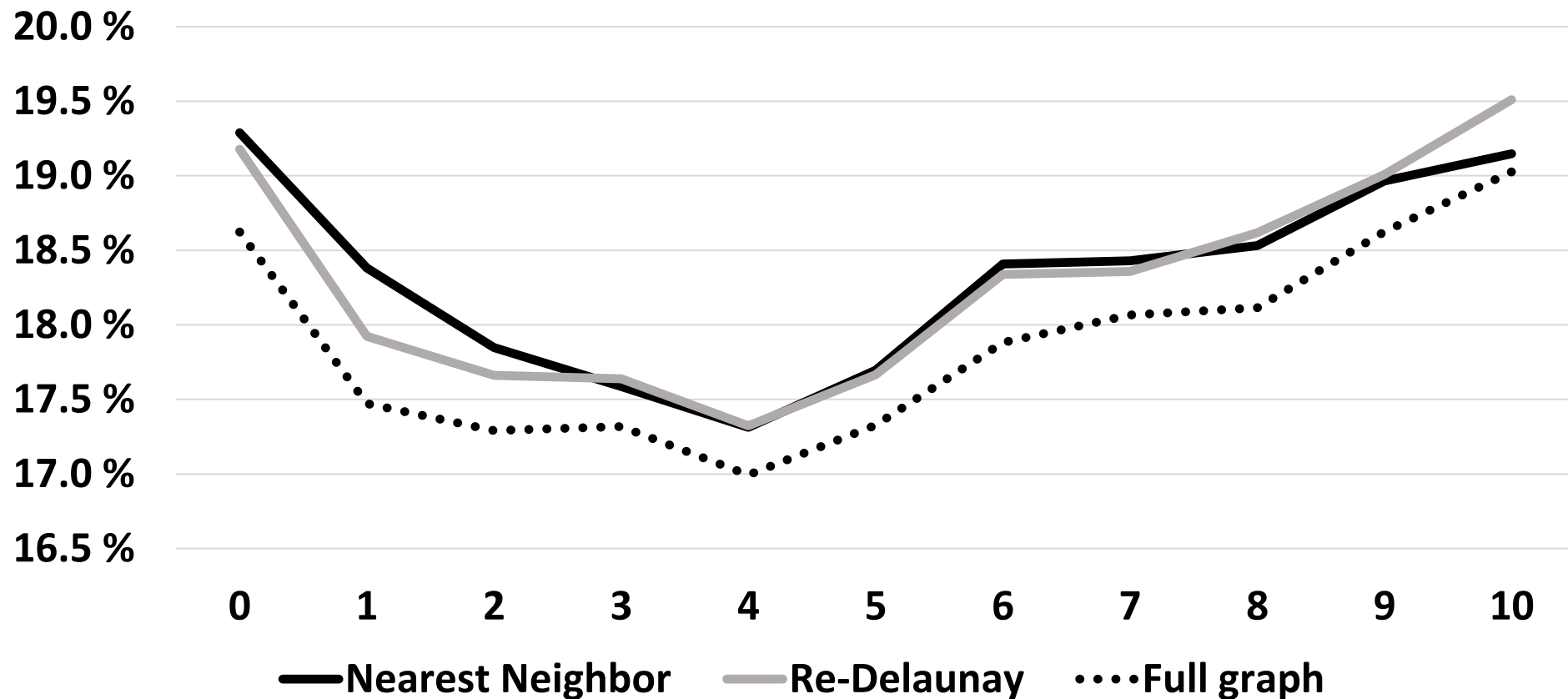
Fragment merging



Fragment merging values

TSPLIB results (78 instances)

Length (gap) with different merge values

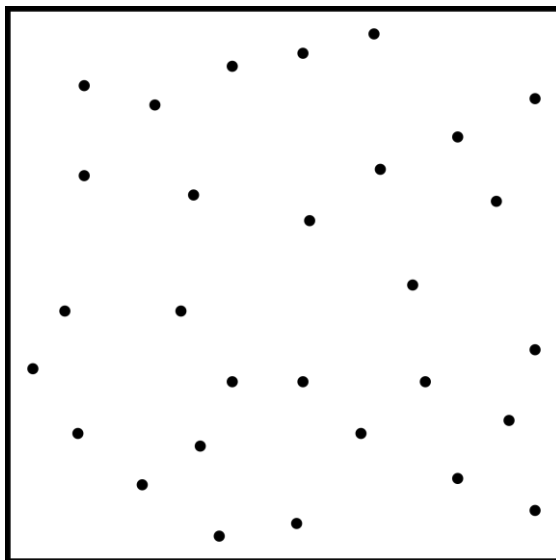


Results

Datasets

Dots-4345

$n = 29$



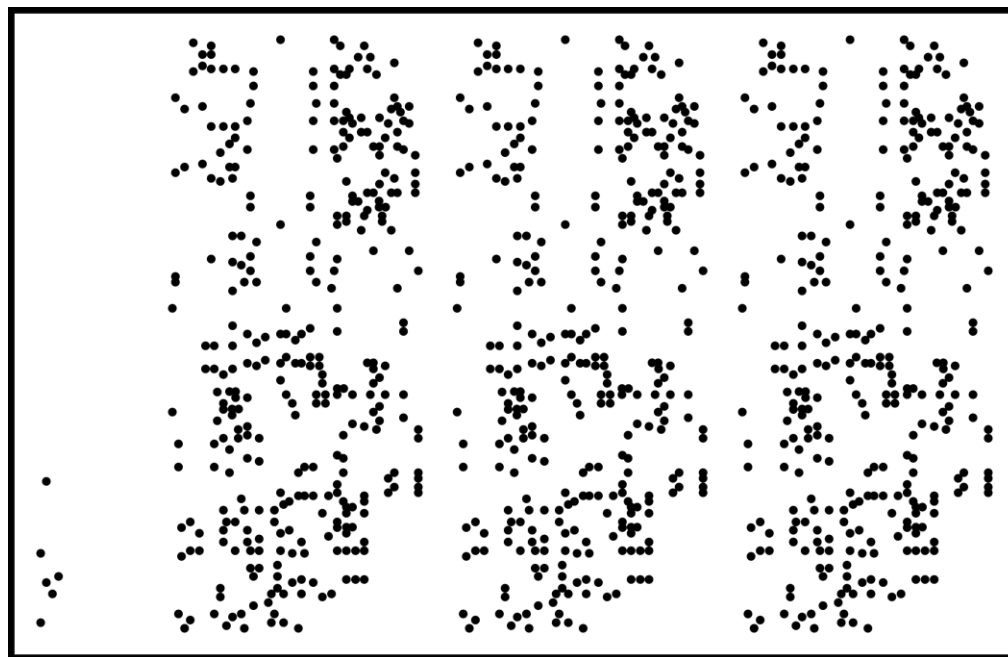
Santa Claus

$n = 1.4M$



TSPLIB-pr1002

$n = 1002$

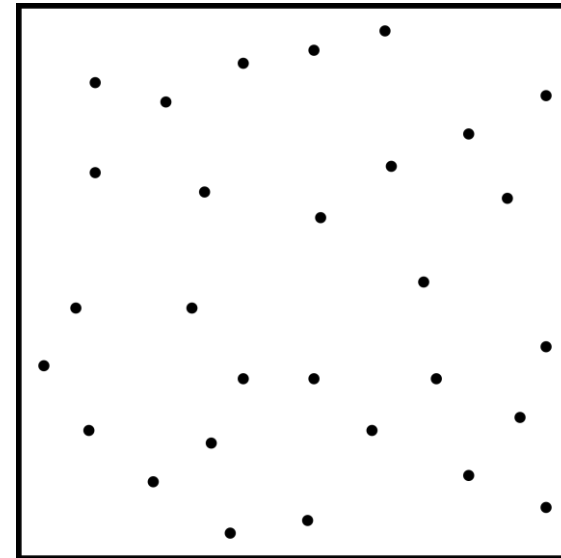


Results on Dots

Algorithm	Average gap
NN	9.25 %
Alpha = 0	
Boruvka	21.74 %
Quick-Boruvka	14.10 %
Greedy	19.72 %
NN (fast)	24.58 %
Walk	44.82 %
Delaunay greedy FM	2.18 %
LKH	0.32 %
Alpha = 100	
Boruvka	6.53 %
Quick-Boruvka	6.69 %
Greedy	6.56 %
NN (fast)	6.74 %
Walk	14.16 %
LKH	0.01 %

Dots-4345

$n = 29$



6449 instances

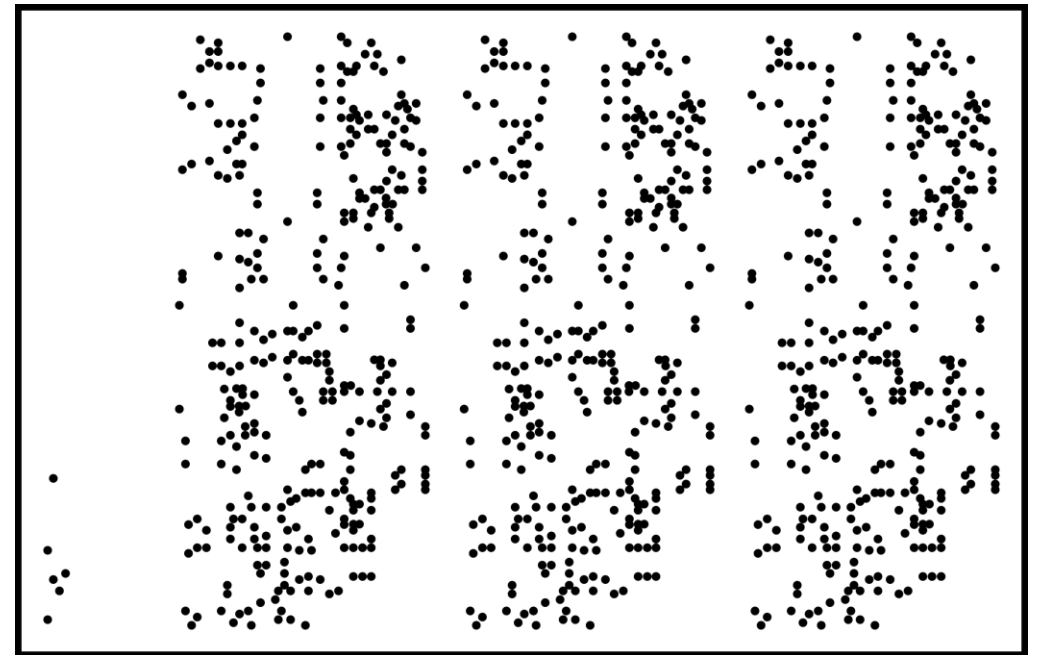
$n = 5-31$

Results on TSPLIB

Algorithm	Average gap	Time (ms)
NN	24.08 %	71
Alpha = 0		
Boruvka	20.01 %	151
Quick-Boruvka	22.22 %	148
Greedy	19.69 %	150
NN (fast)	35.67 %	149
Walk	140.23 %	148
Delaunay greedy FM	16.99 %	25
LKH	0.06 %	5440
Alpha = 100		
Boruvka	12.78 %	257
Quick-Boruvka	16.17 %	255
Greedy	12.64 %	259
NN (fast)	21.29 %	256
Walk	116.17 %	258
LKH	0.05 %	6370

TSPLIB-pr1002

$n = 1002$



78 instances

$n = 51-18,512$

Results on Santa

Algorithm	Length (km)	Time (s)
NN	-	>2h
Alpha = 0		
Boruvka	139 471	23.8
Quick-Boruvka	154 409	21.6
Greedy	132 460	23.9
NN (fast)	179 228	21.9
Walk	455 729	20.9
Delaunay greedy FM	139 270	16.6
LKH	109 454	3600.0
Alpha = 100		
Boruvka	128 798	495.2
Quick-Boruvka	144 222	506.0
Greedy	127 038	493.2
NN (fast)	158 508	488.1
Walk	468 314	501.1
LKH	109 360	3600.0



Santa Claus

$n = 1.4M$

Conclusions and future work

- Simple initialization takes $O(n^2)$ time, for Santa >2h
 - Best known: 108 417 km
 - With graph: 16-20 seconds (28.5 % gap)
 - LKH optimization: 1h (0.37 % gap)
 - New result: 8 minutes (0.28 % gap)
- New Delaunay-based variant introduced with decent results
- The effect of initialization on optimization