Ant Colony Optimization Applied to Map Generalization

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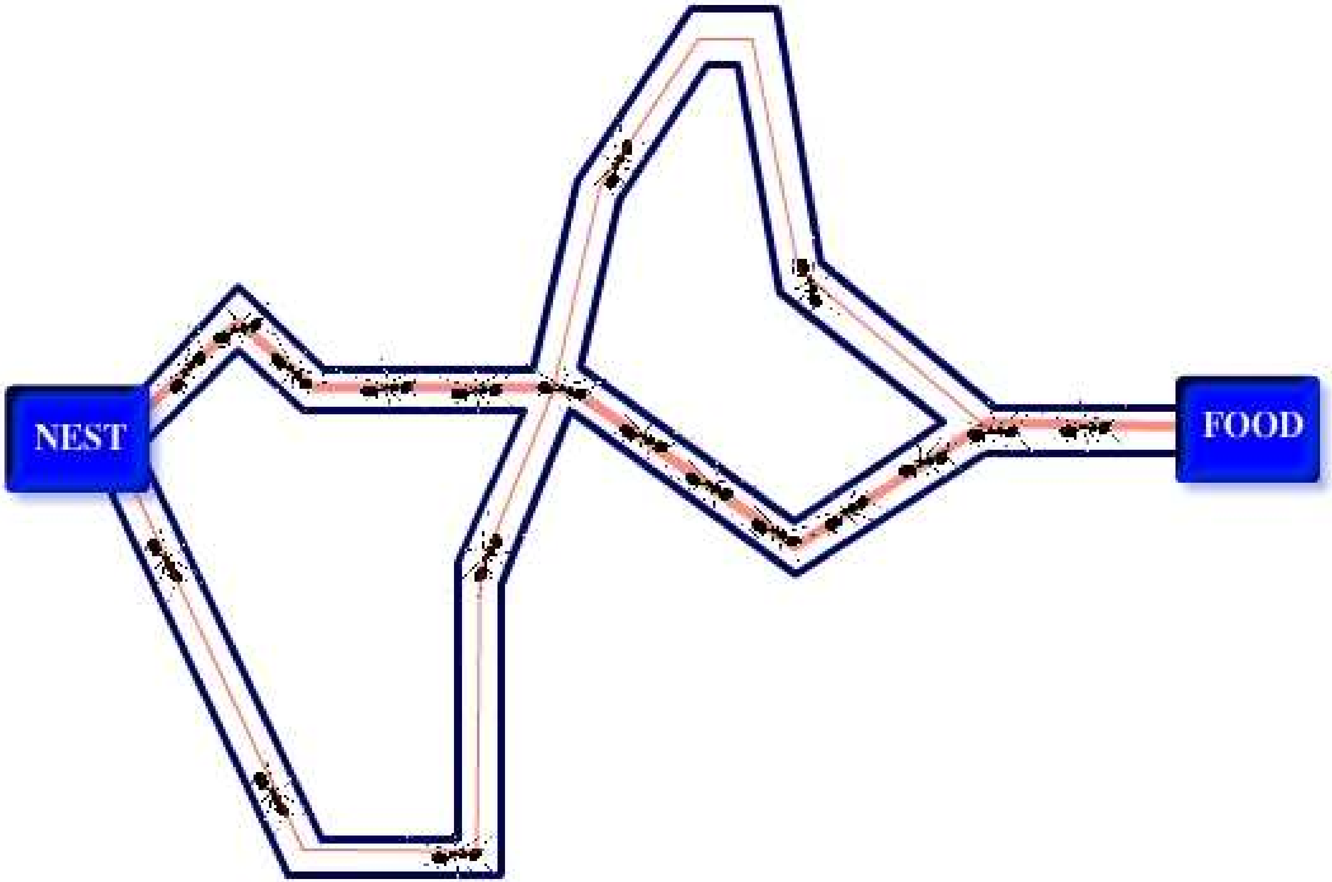
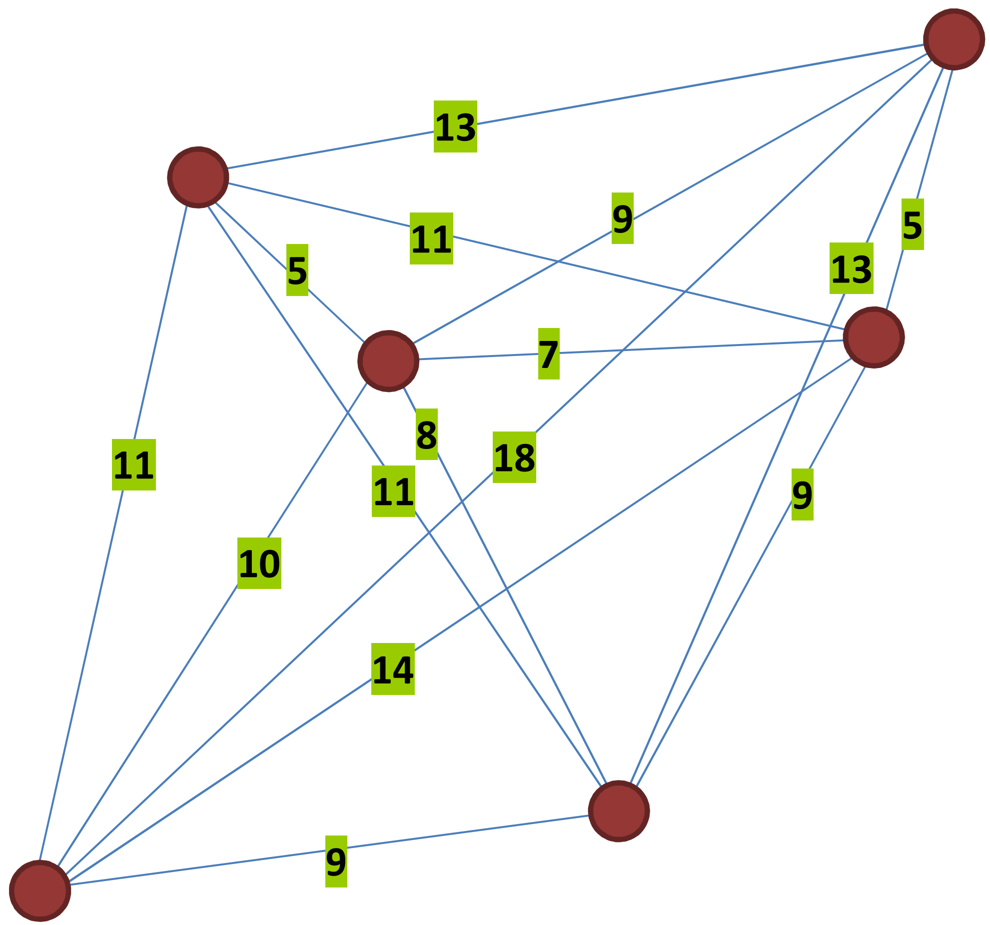
Background

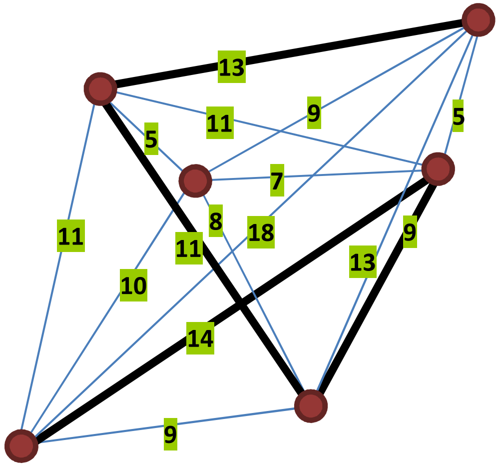
- PhD Project
- Simulated Annealing Work
- Ant Colony
  - Quality?
  - Speed?
  - Usability
  - Parallelization

What is Ant Colony Optimization?

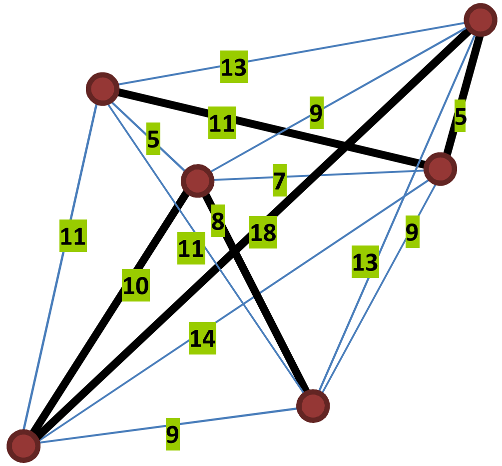


Travelling Salesman Problem

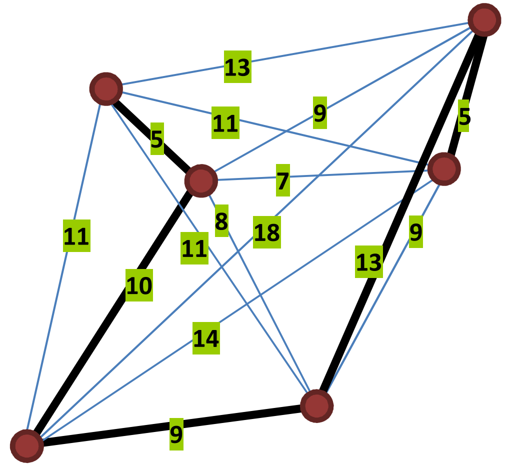




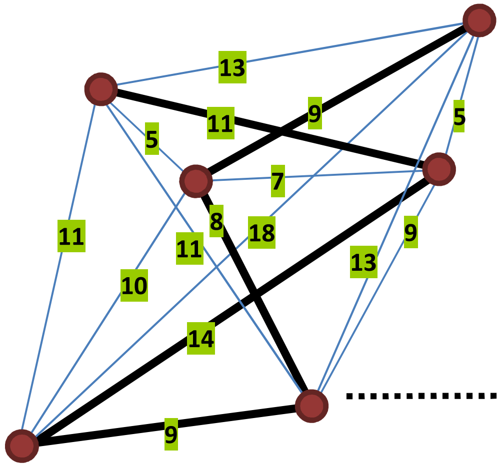
Tour length = 47



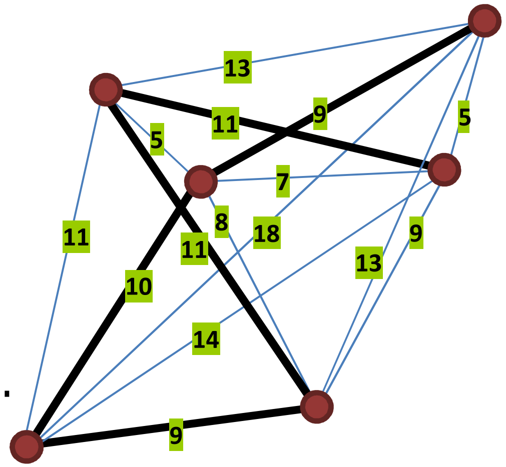
Tour length = 52



Tour length = 42

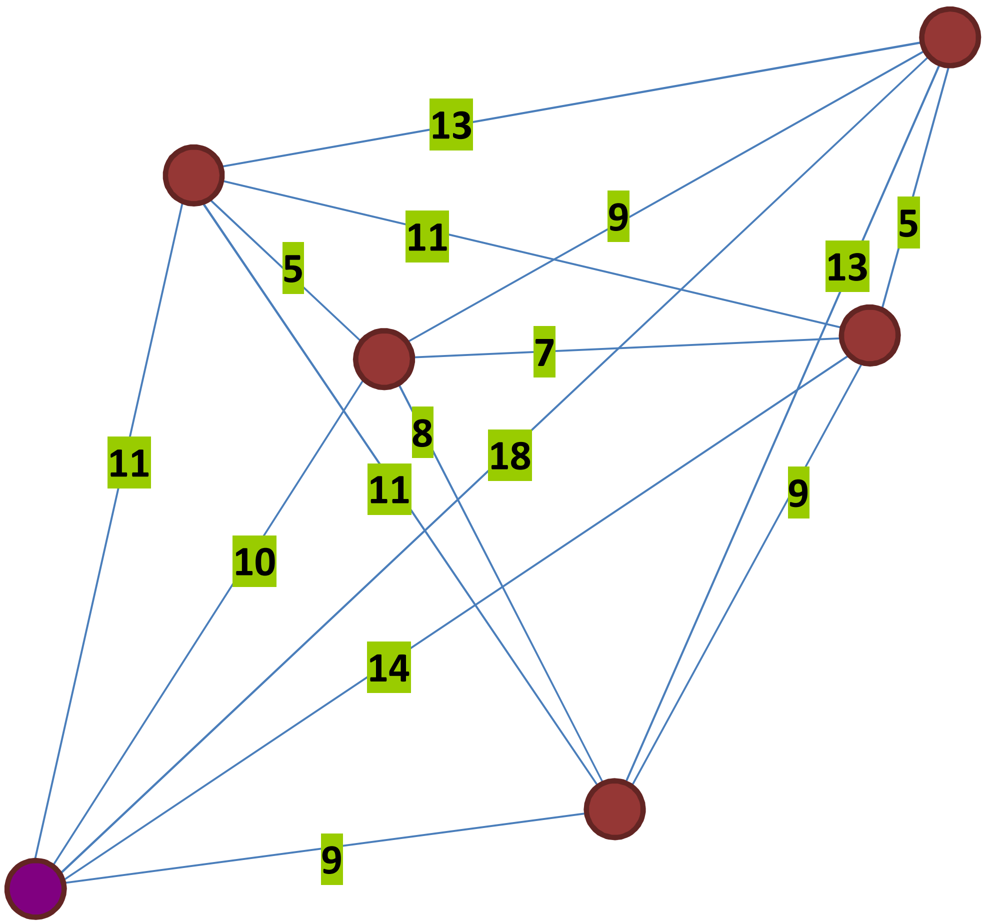


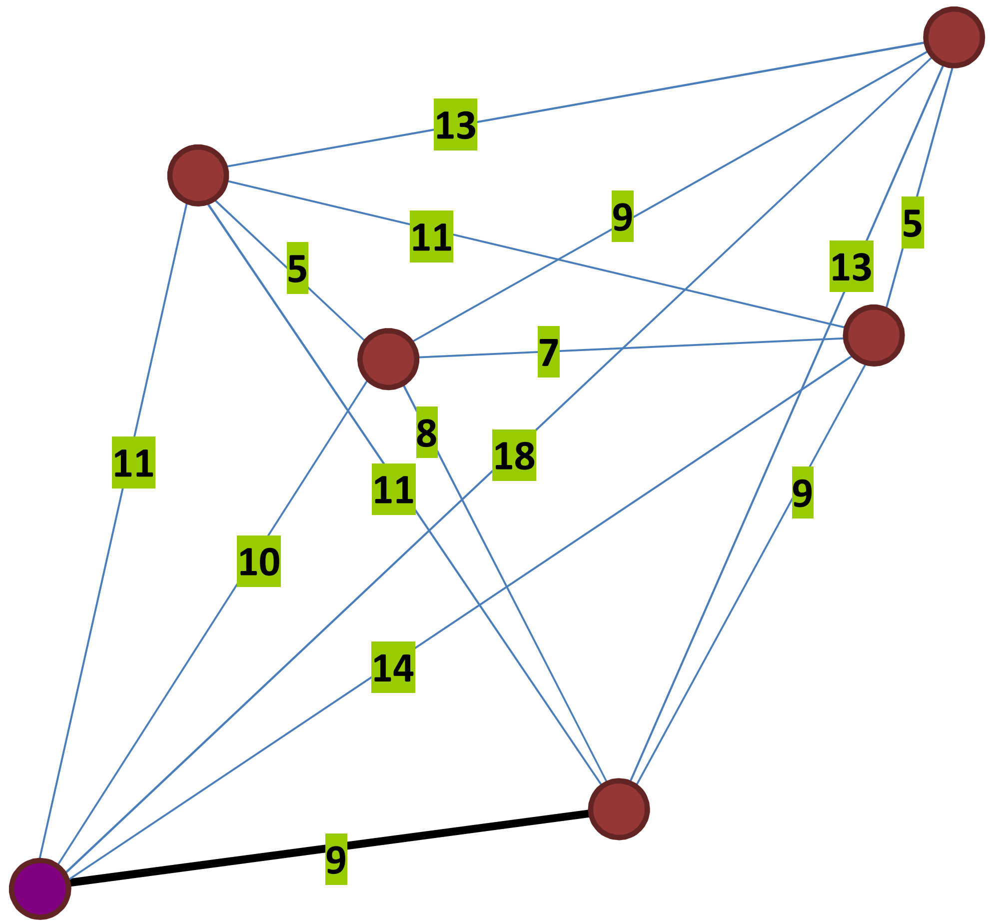
Tour length = 51



Tour length = 50

TSP - Greedy





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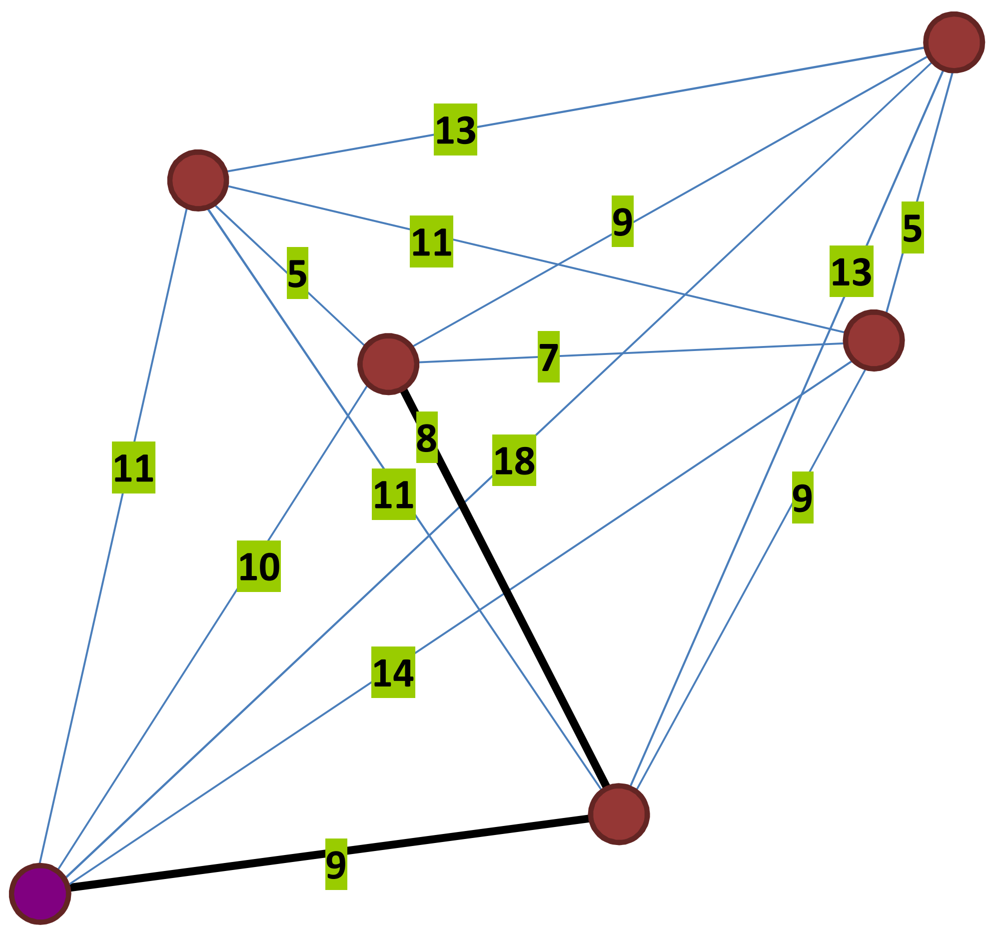
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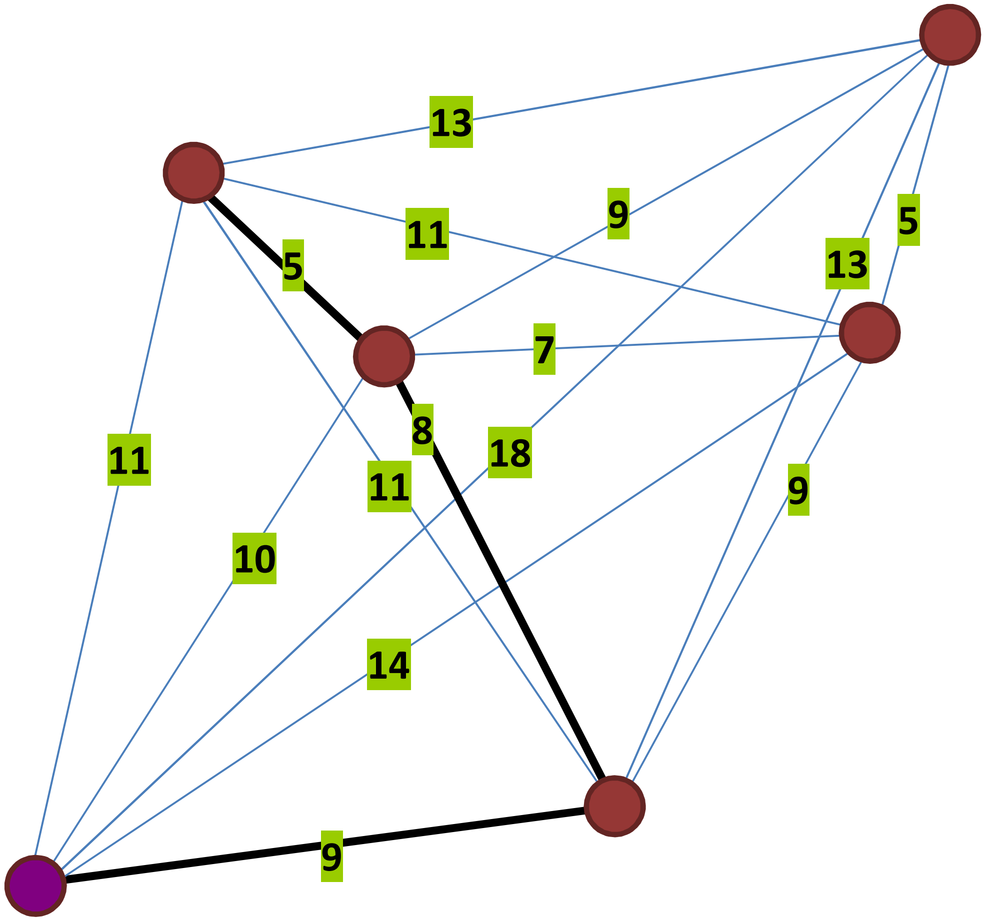
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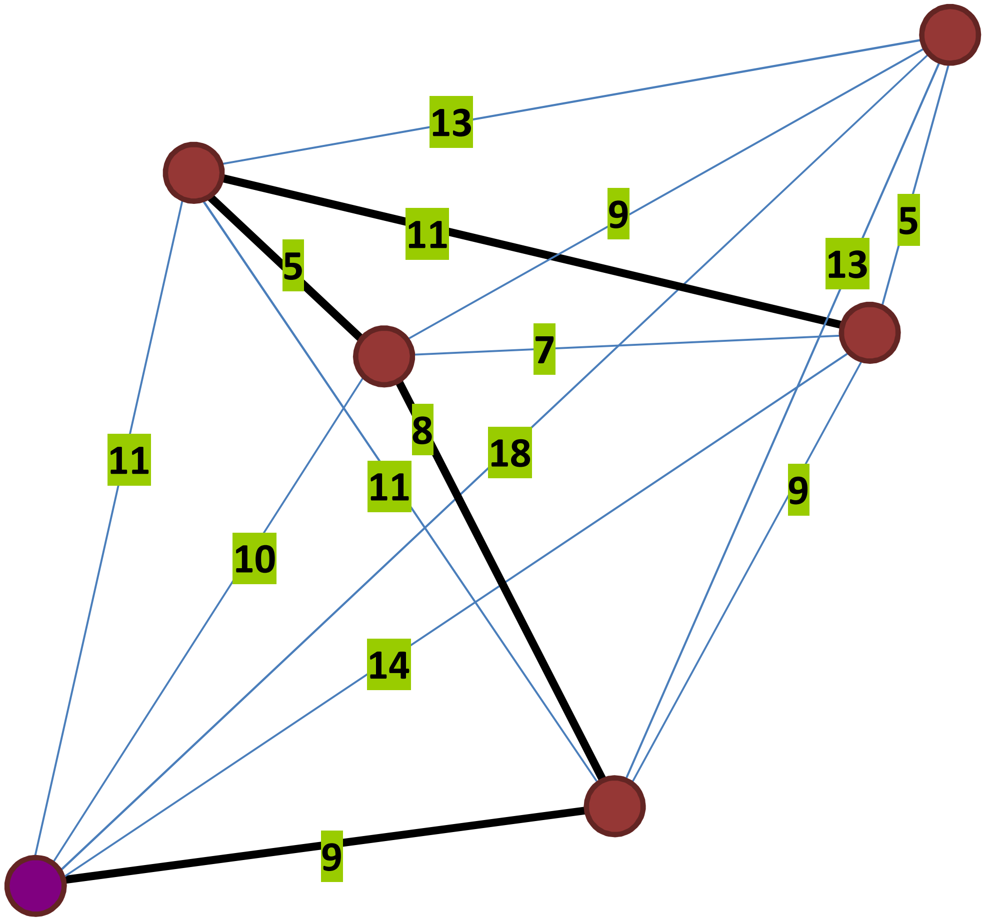
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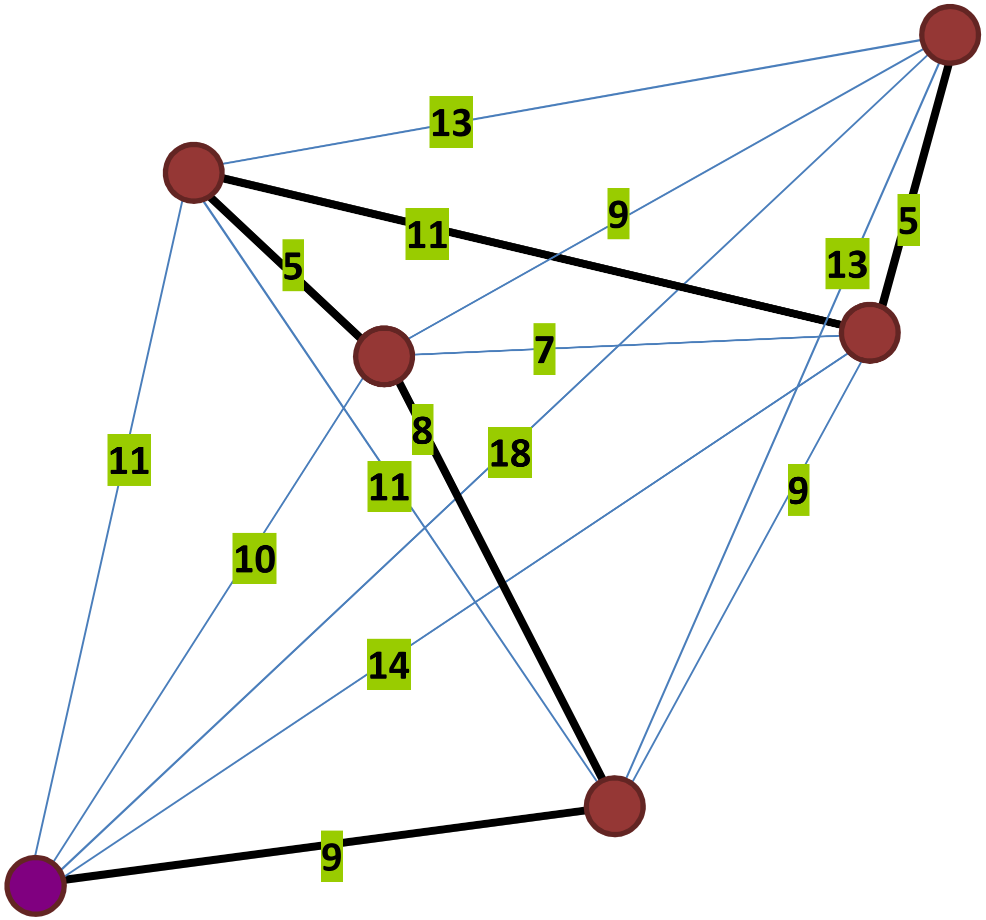
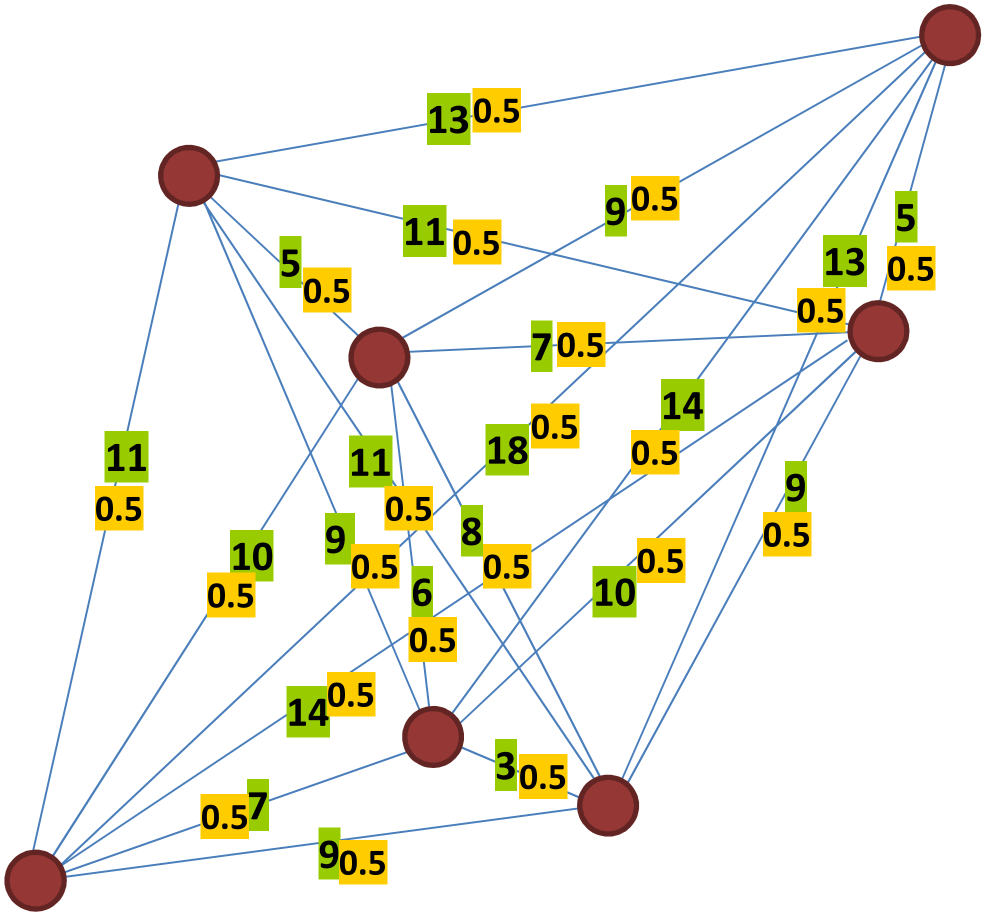


Tour length = 38

TCP – ACO Approach

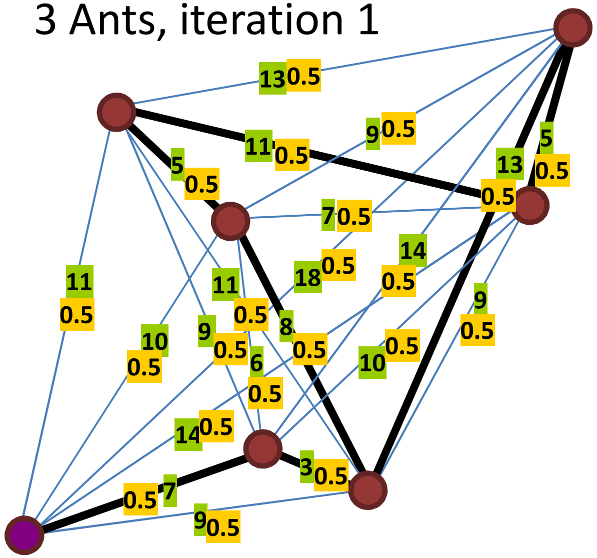
“best” is decided through a stochastic mechanism where the probability of selecting a particular city is governed by heuristic information (immediate benefit) and pheromone value (historical benefit).

```
while stop conditions not met /*start next iteration */

        for each ant
                start at random city
                while more cities to visit
                        travel to “best” available  city
                end while
                maintain record of this iterations shortest tour
        end for

        decay pheromone for all edges
        increase pheromone for edges belonging to this iterations shortest tour
        maintain record of overall shortest tour

end while
```

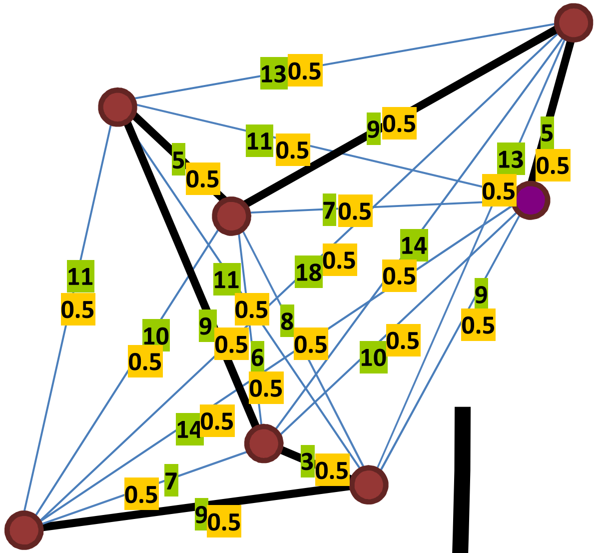


13 0.5
9 0.5
11 0.5
5 0.5
5 0.5
13
0.5
7 0.5
14 0.5
18 0.5
11 0.5
11 0.5
10 0.5
9 0.5
8 0.5
6 0.5
9 0.5
10 0.5
14 0.5
3 0.5
0.5 7
9 0.5

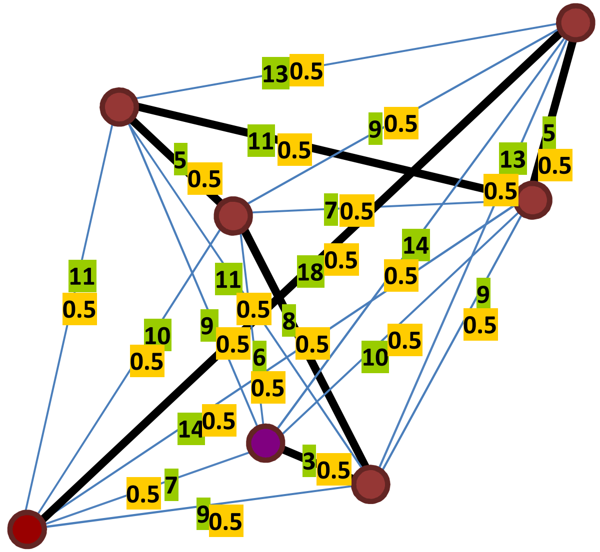
3 Ants, iteration 1



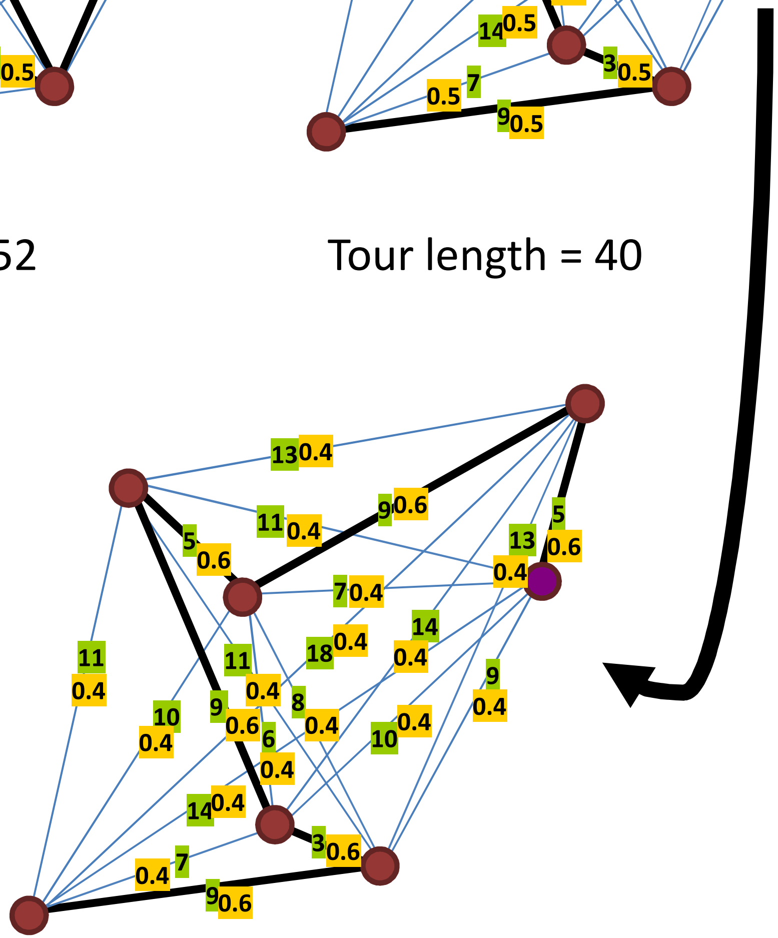
Tour length = 52



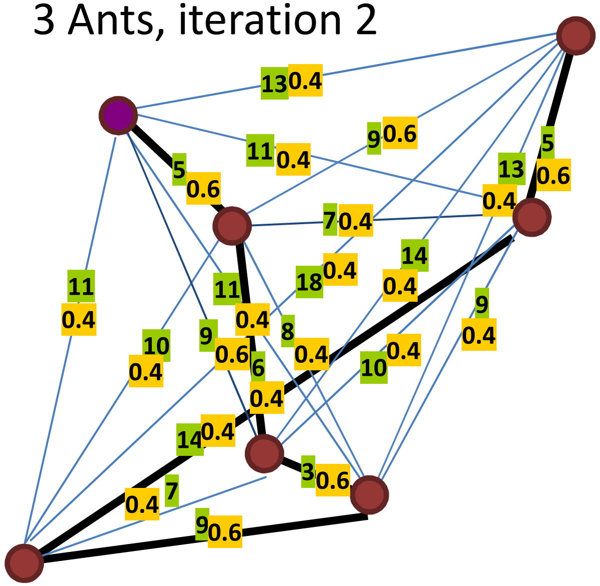
Tour length = 40



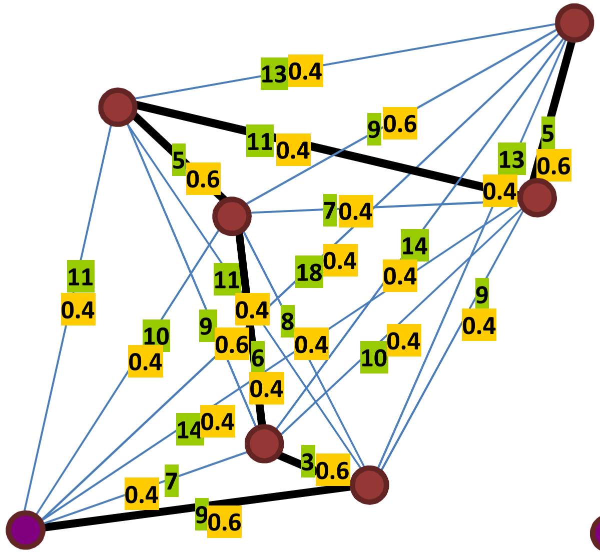
Tour length = 50



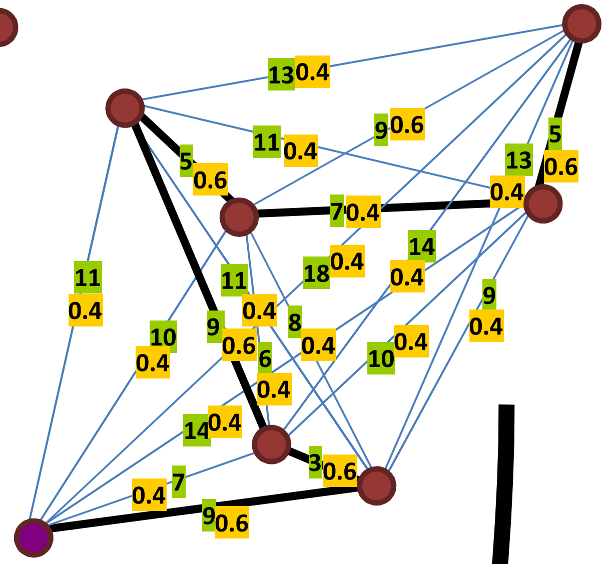
3 Ants, iteration 2



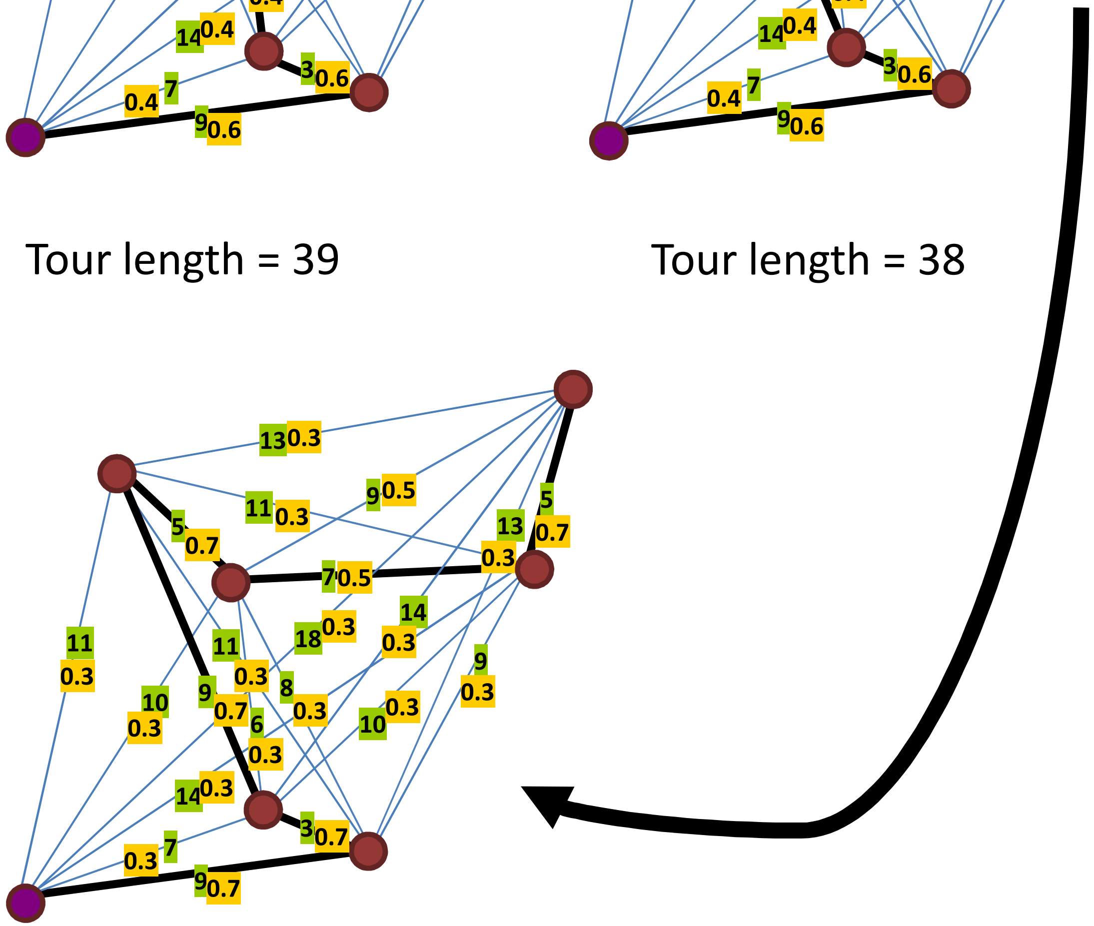
Tour length = 42



Tour length = 39



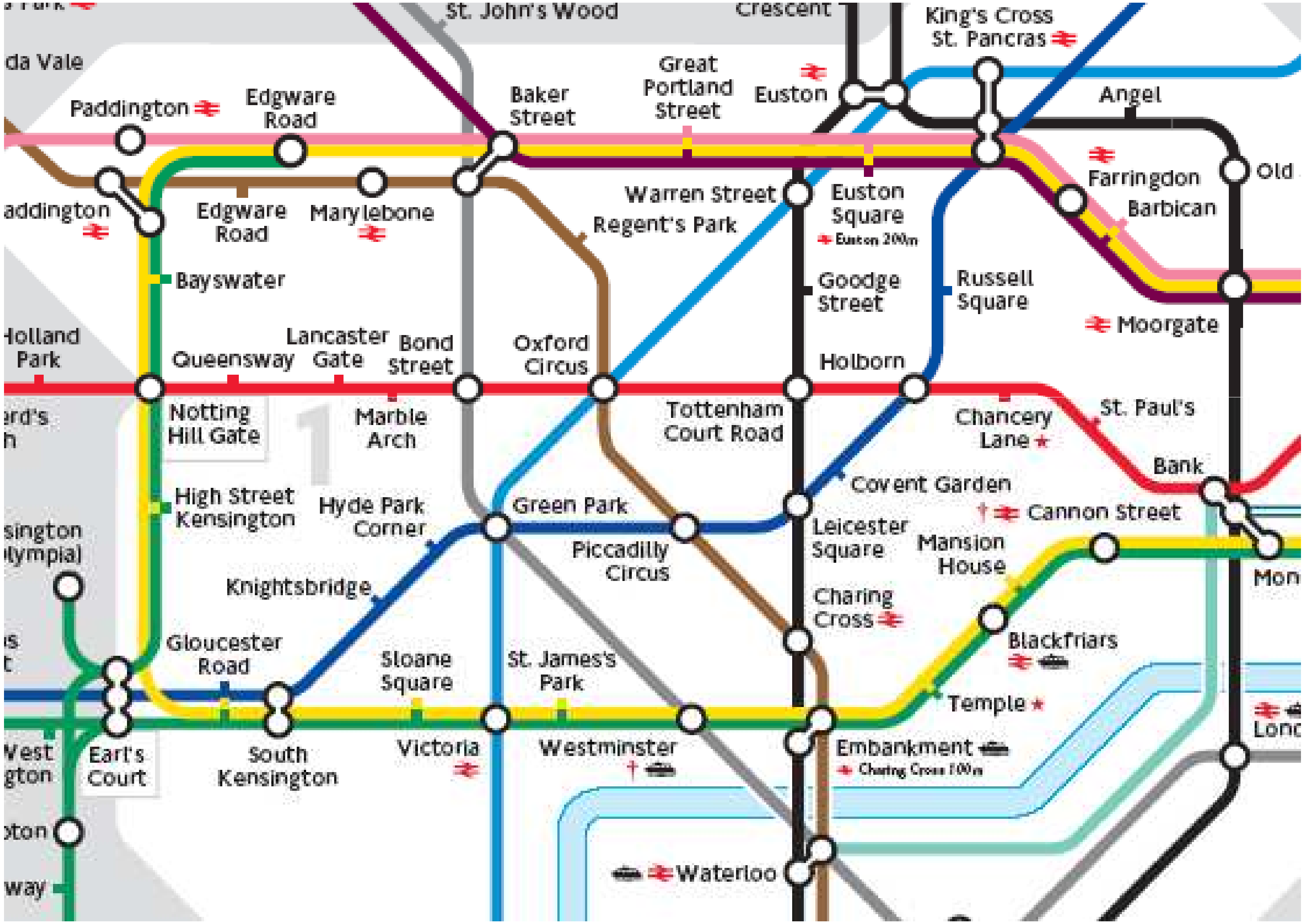
Tour length = 38



ACO and Map Generalization

- Schematic Maps
- River Symbolization

Schematic Maps



© Transport for London

Schematic Maps

- Silvania Avelar - Algorithm based on iterative improvement optimization / gradient descent

- Characteristics of schematic map

  - An abstract diagrammatic representation of a network

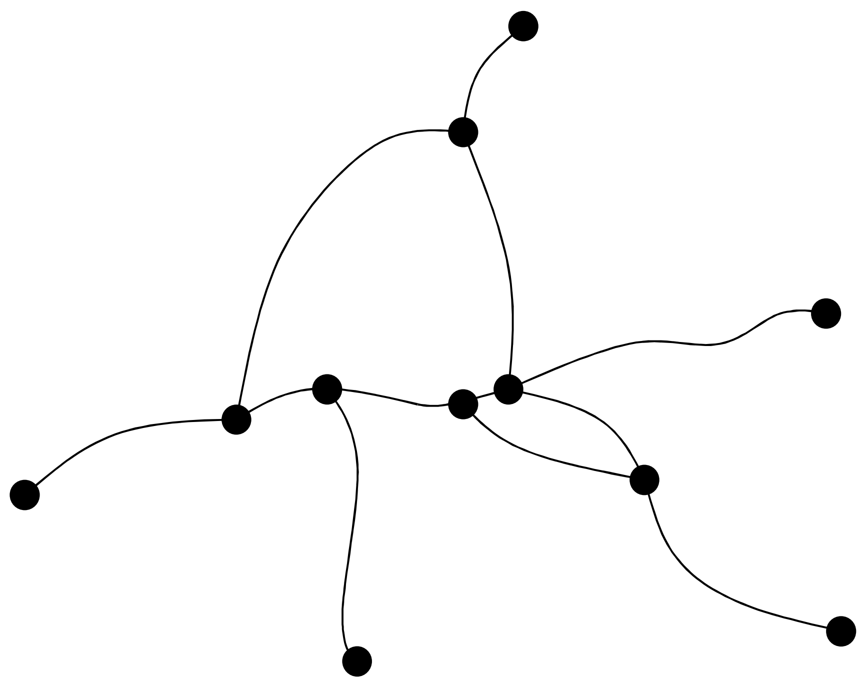
  - Topologically correct

  - Simplified lines

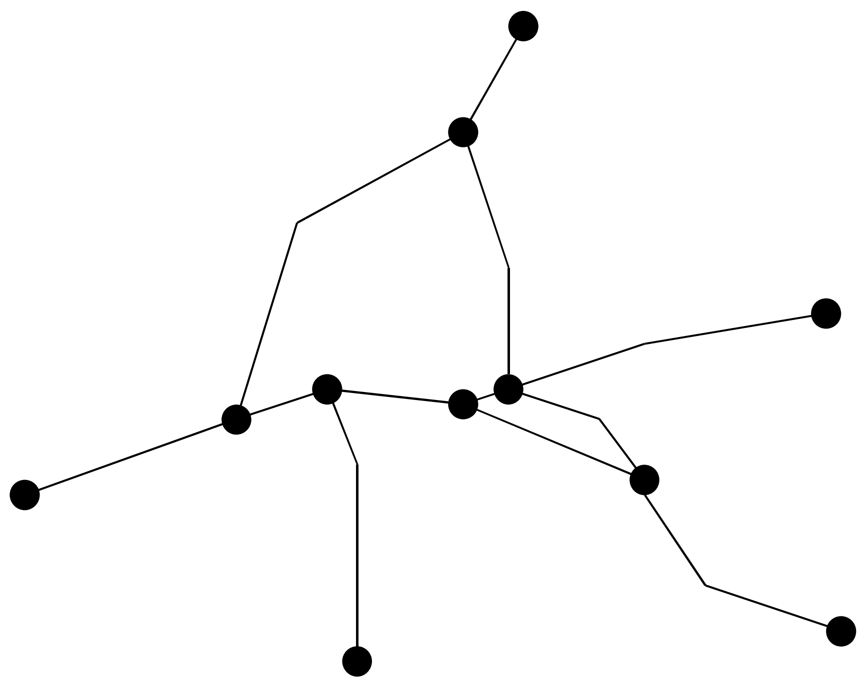
  - **Lines re-oriented so that they lie horizontal, vertical or diagonal**

  - **Scale in congested areas expanded at the expense of scale in areas of lesser node density**

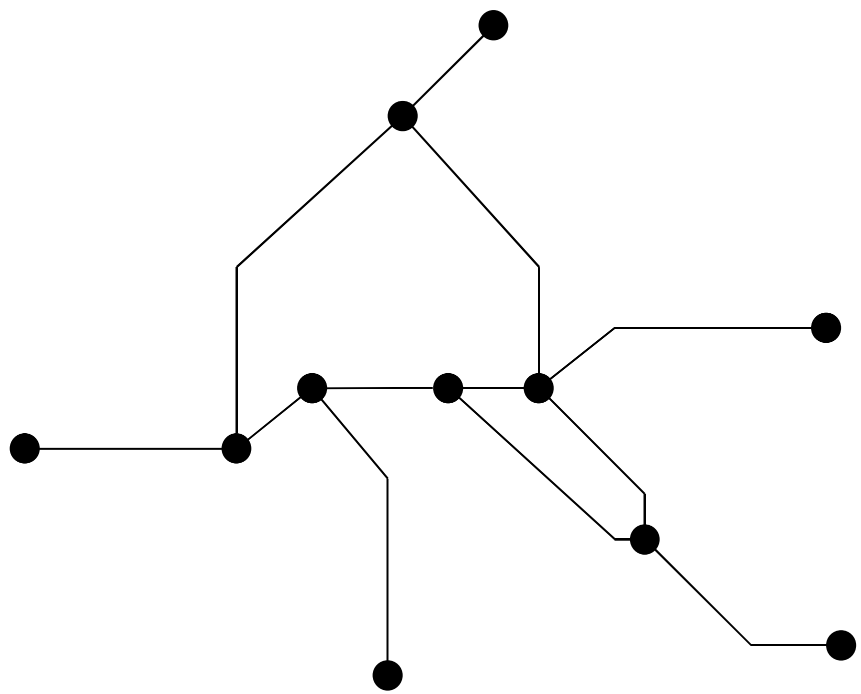
Example - Network



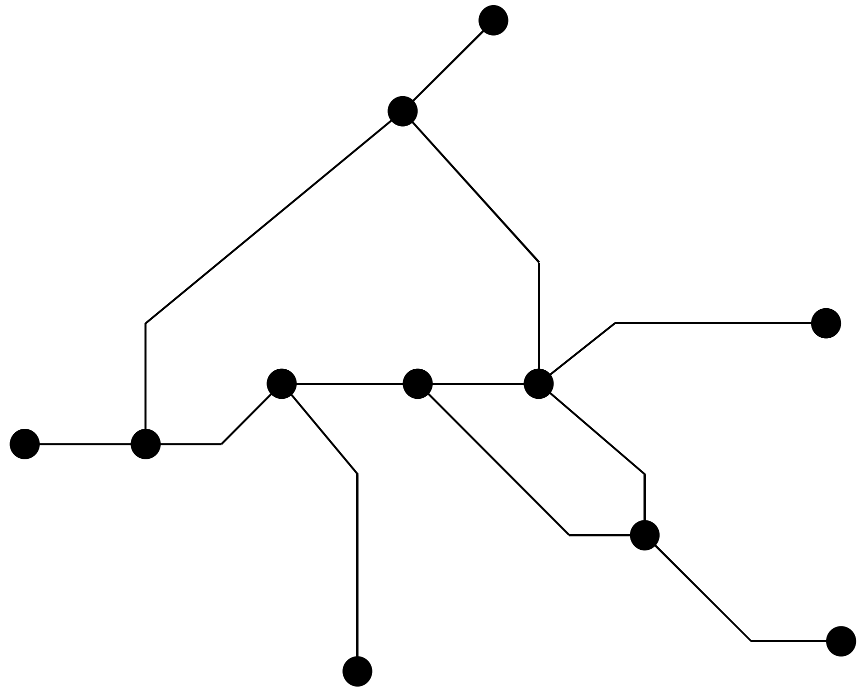
Example - Simplify

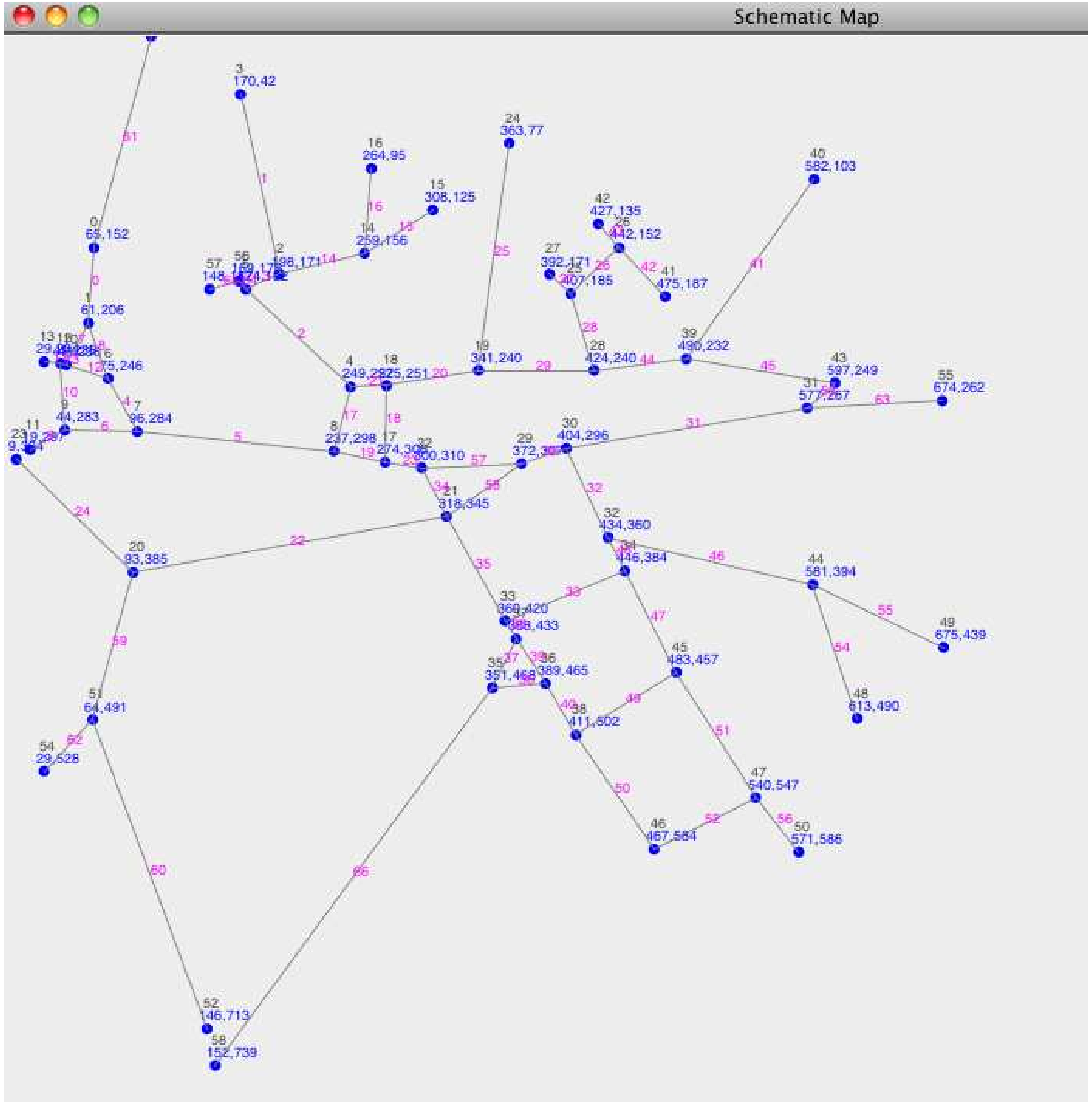


Example – Re-orientate



Example – Re-scale congested areas




Schematic Map
3
170,42
24
363,77
16
264,95
40
582,103
15
308,125
42
427,135
26
442,152
0
65,152
14
259,156
27
392,171
25
407,185
41
475,187
2
198,171
57
56
1
61,206
39
490,232
19
341,240
28
424,240
6
75,246
4
18
275,251
43
597,249
55
674,262
31
577,267
9
44,283
7
96,284
11
23
8
237,298
17
22
300,310
29
30
404,296
21
318,345
32
434,360
34
446,384
20
93,385
44
581,394
33
360,420
49
675,439
45
483,457
36
389,465
35
351,468
48
613,490
51
64,491
38
411,502
54
29,528
47
540,547
46
467,564
50
571,586
52
146,713
58
152,739

ACO Algorithm – General Idea

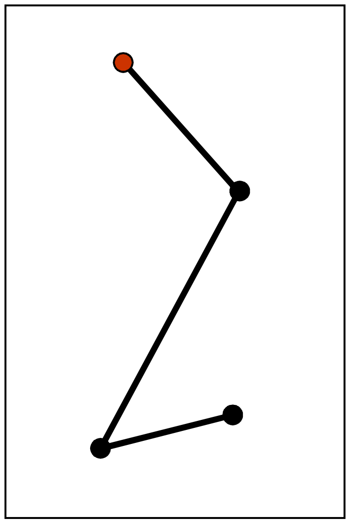
- Iterative Improvement
  - Initial state
  - Evaluate state
  - Modify state
  - Decision making process
  - Repeat until

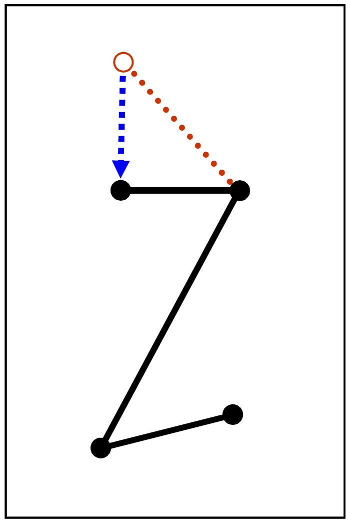
Initial State

- Initial data sets
  - Linear network
  - OS road centrelines (OSCAR)
  - Pre-generalized using ArcInfo Generalize

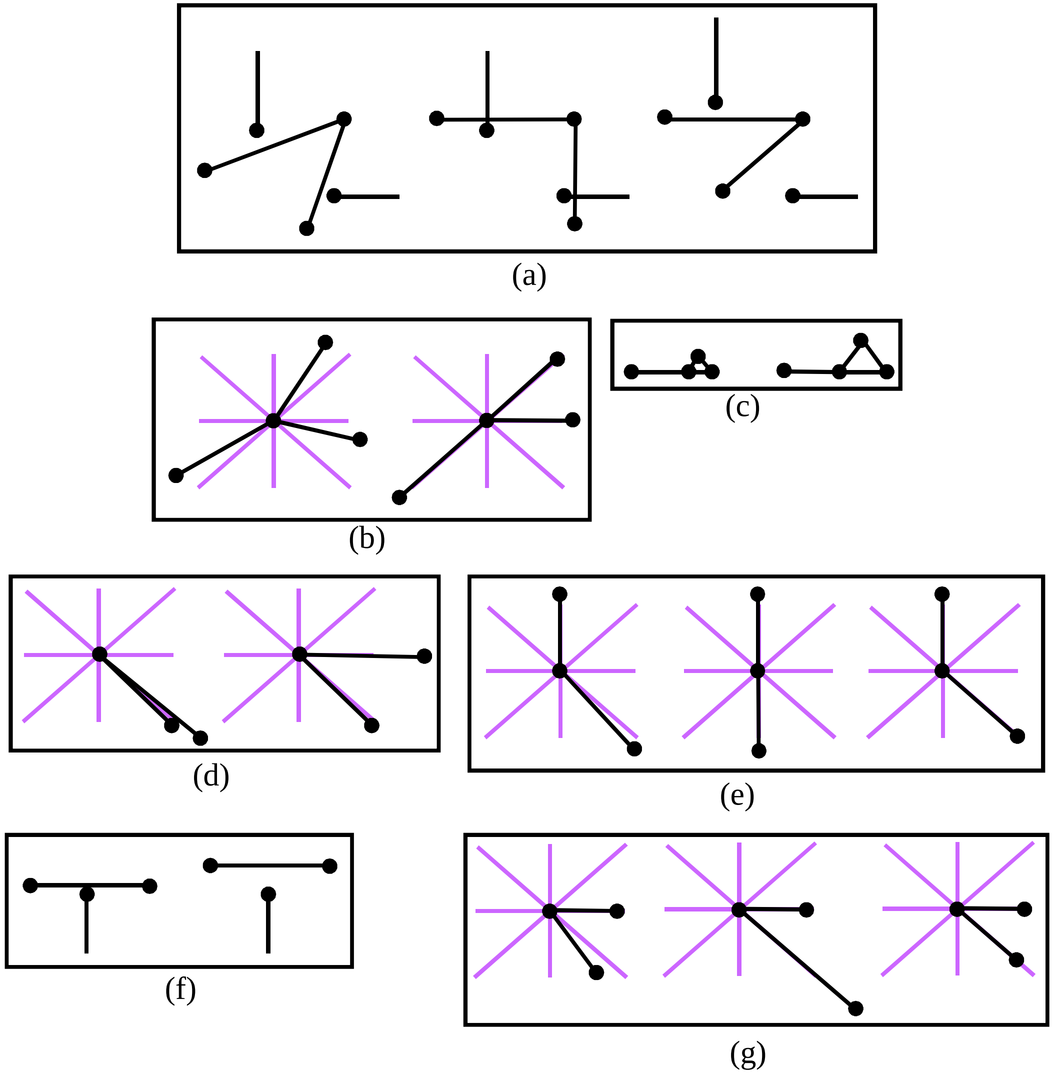
Modify State

- “Greedy” displacement
  - Pick a single vertex
  - Generate a displacement





Evaluate State - Constraints



(a) Topological

(b) Orientation

(c) Length

(d) Angle

(e) Rotation

(f) Clearance

(g) Displacement

Evaluate State - Cost

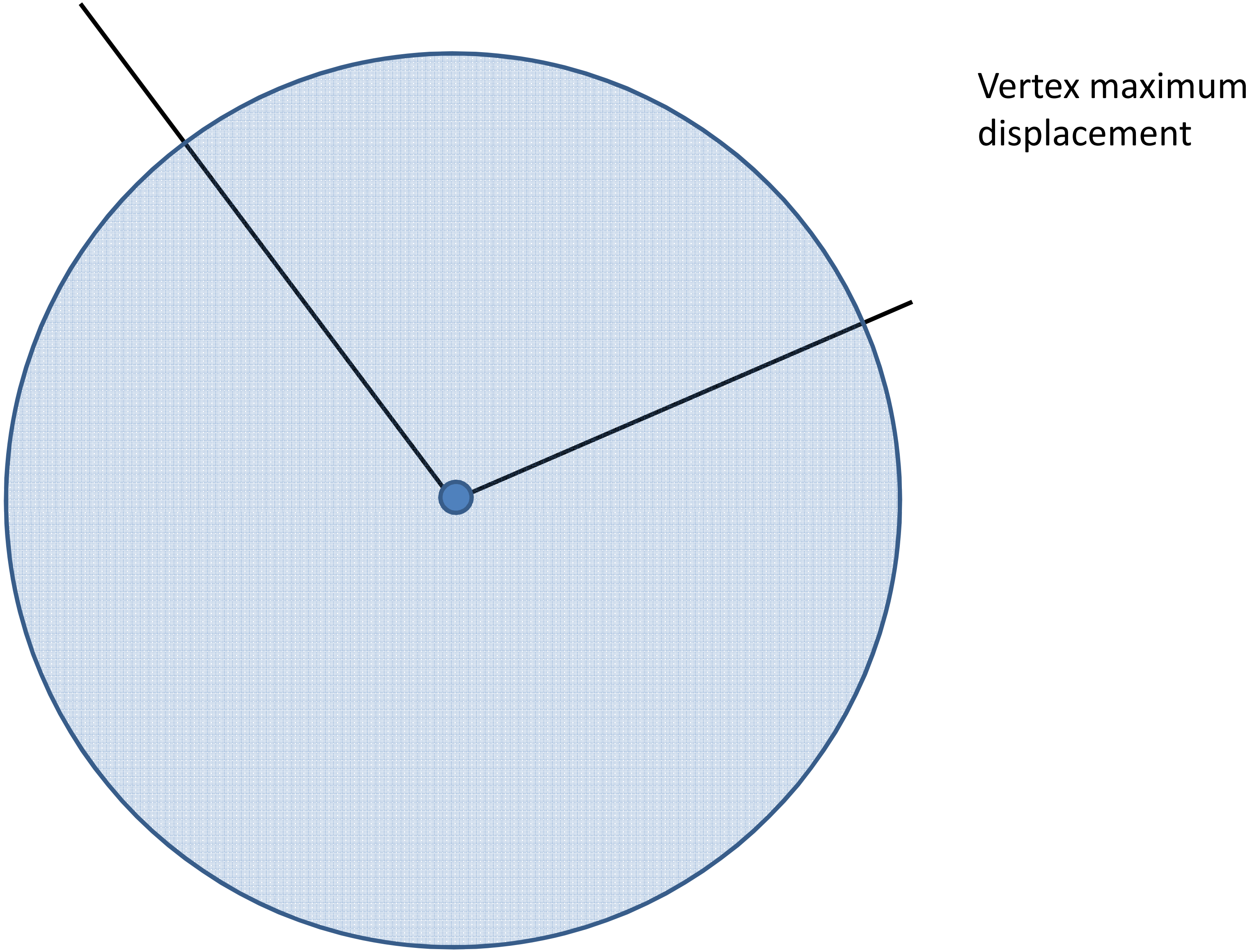
Cost =

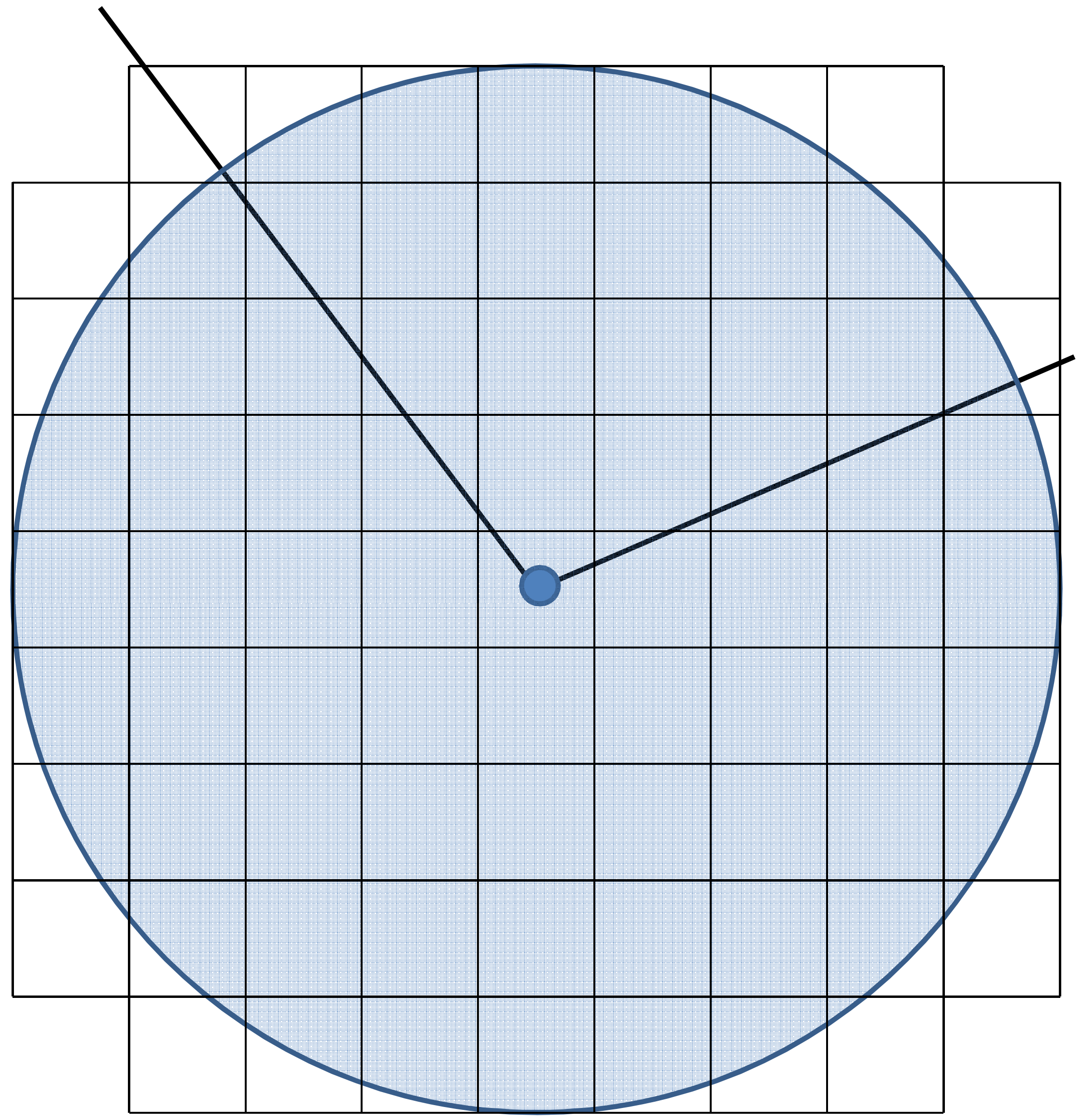
Topological x W1 + Orientation x W2 +
Length x W3 + Angle x W4 +
Rotation x W5 + Clearance x W6 +
Displacement x W7

Map Schematization – ACO Approach

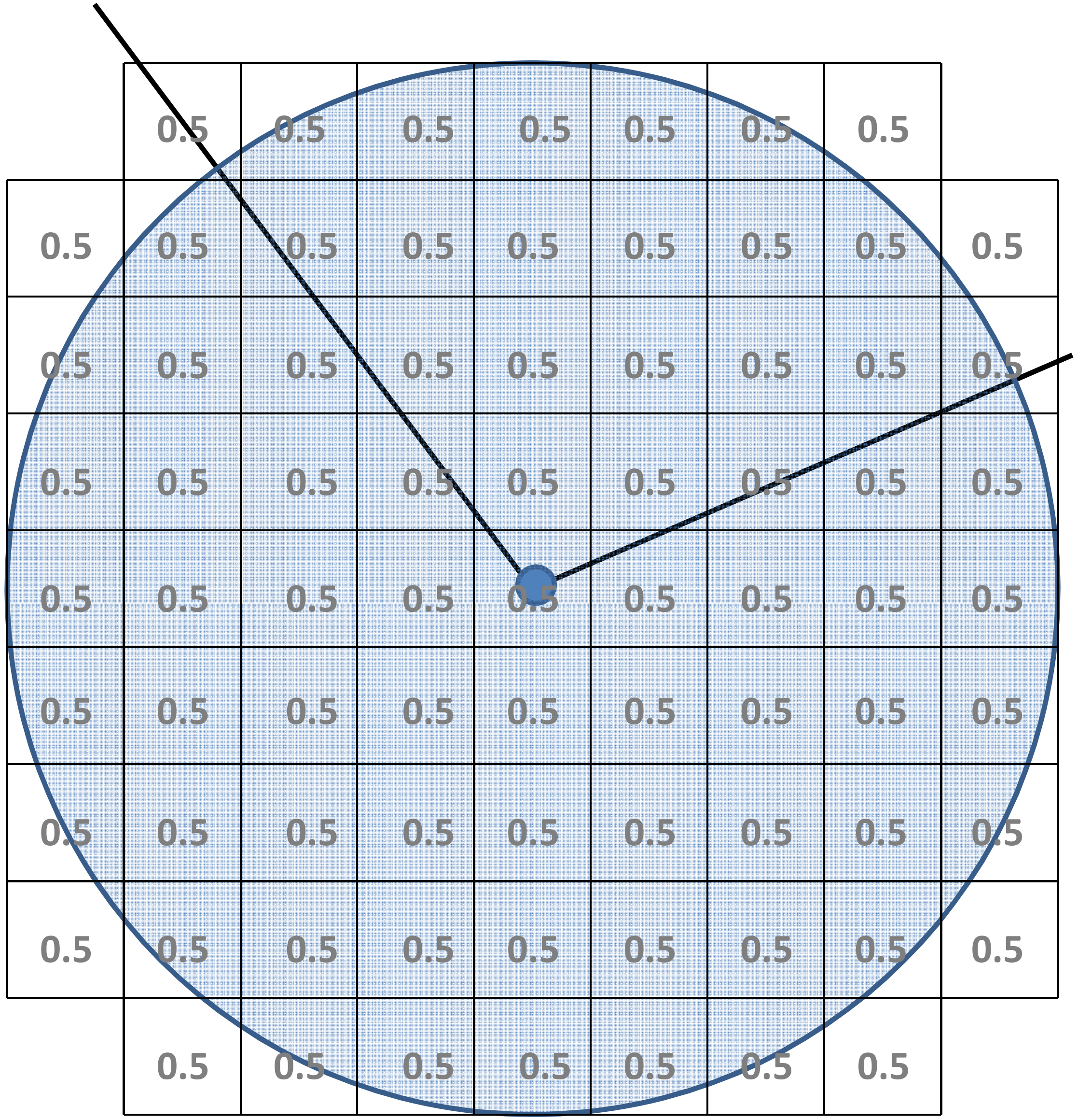
“best” is decided through a stochastic mechanism where the probability of moving to a particular location is governed by heuristic information (immediate benefit) and pheromone value (historical benefit).

```
while stop conditions not met  /*start next iteration */

        for each ant
                randomize vertex order
                for each vertex
                        perform “best” displacement
                end for
                maintain record of this iterations lowest cost schematic
        end for

        decay pheromone for all pheromone grid cells
        increase pheromone for grid cells corresponding to this iterations lowest cost schematic
        maintain record of overall lowest cost schematic
        reset network configuration

end while

perform local search?
```


Vertex maximum
displacement

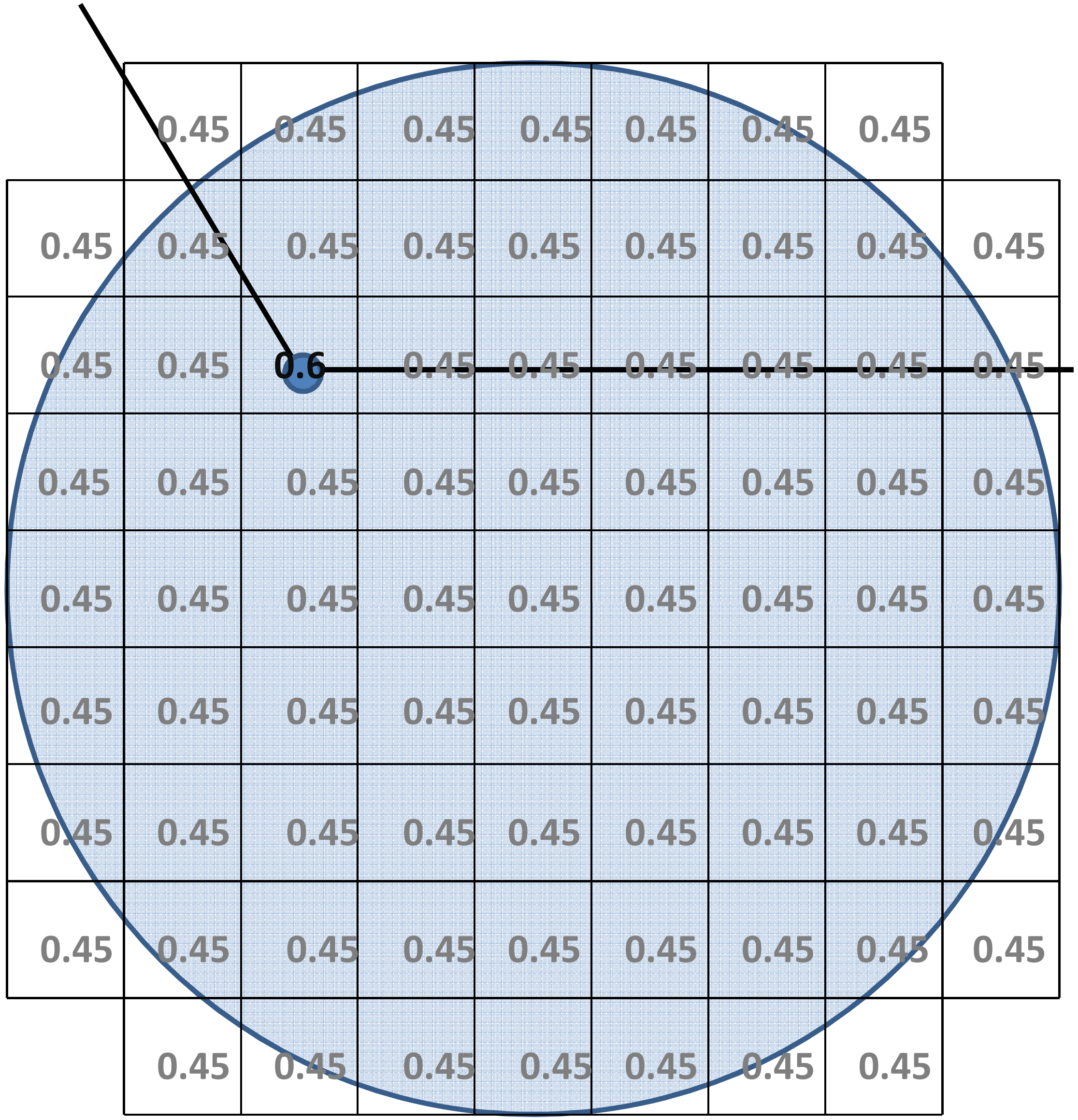


Pheremone Grid
(1 per vertex)

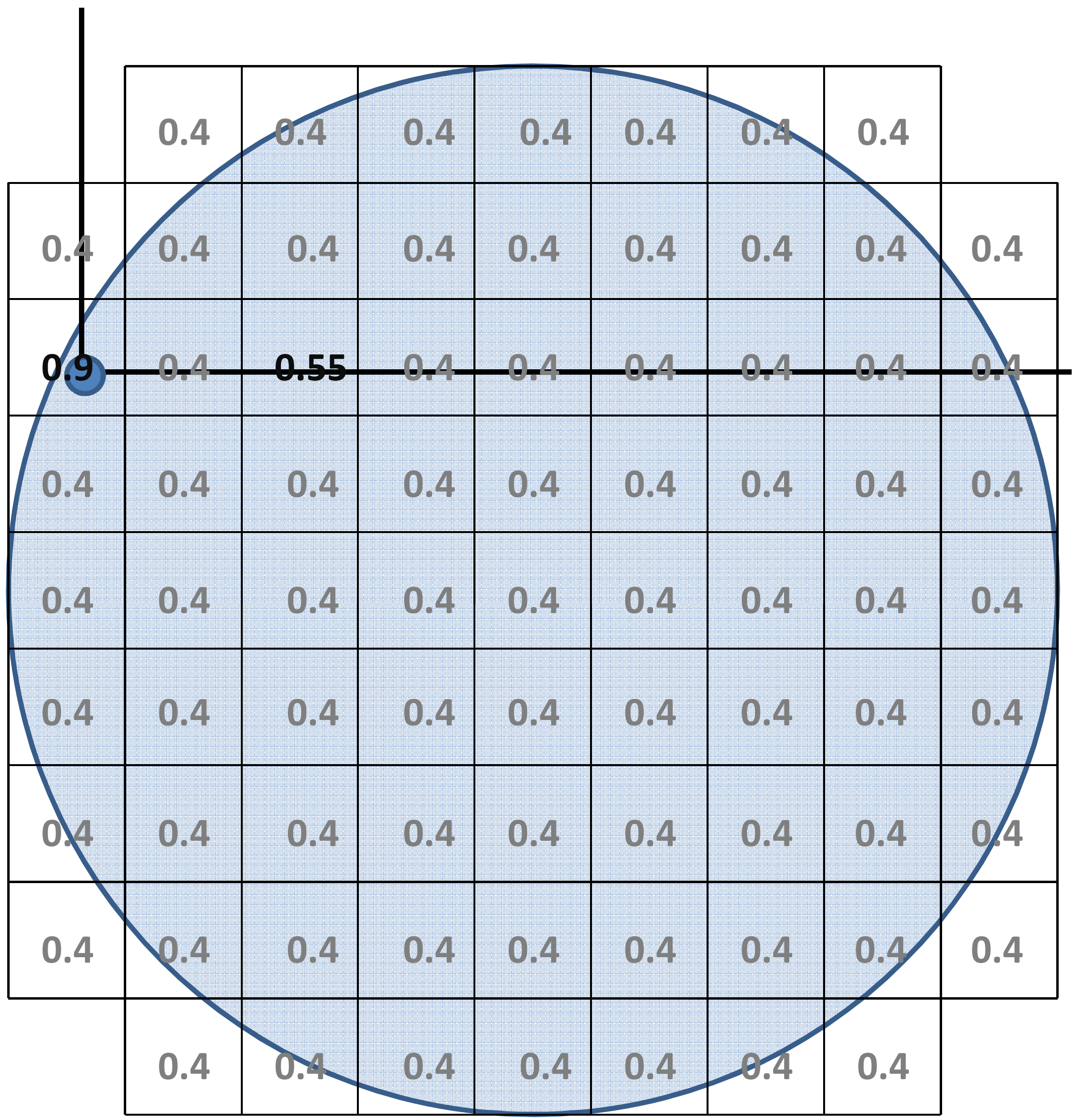


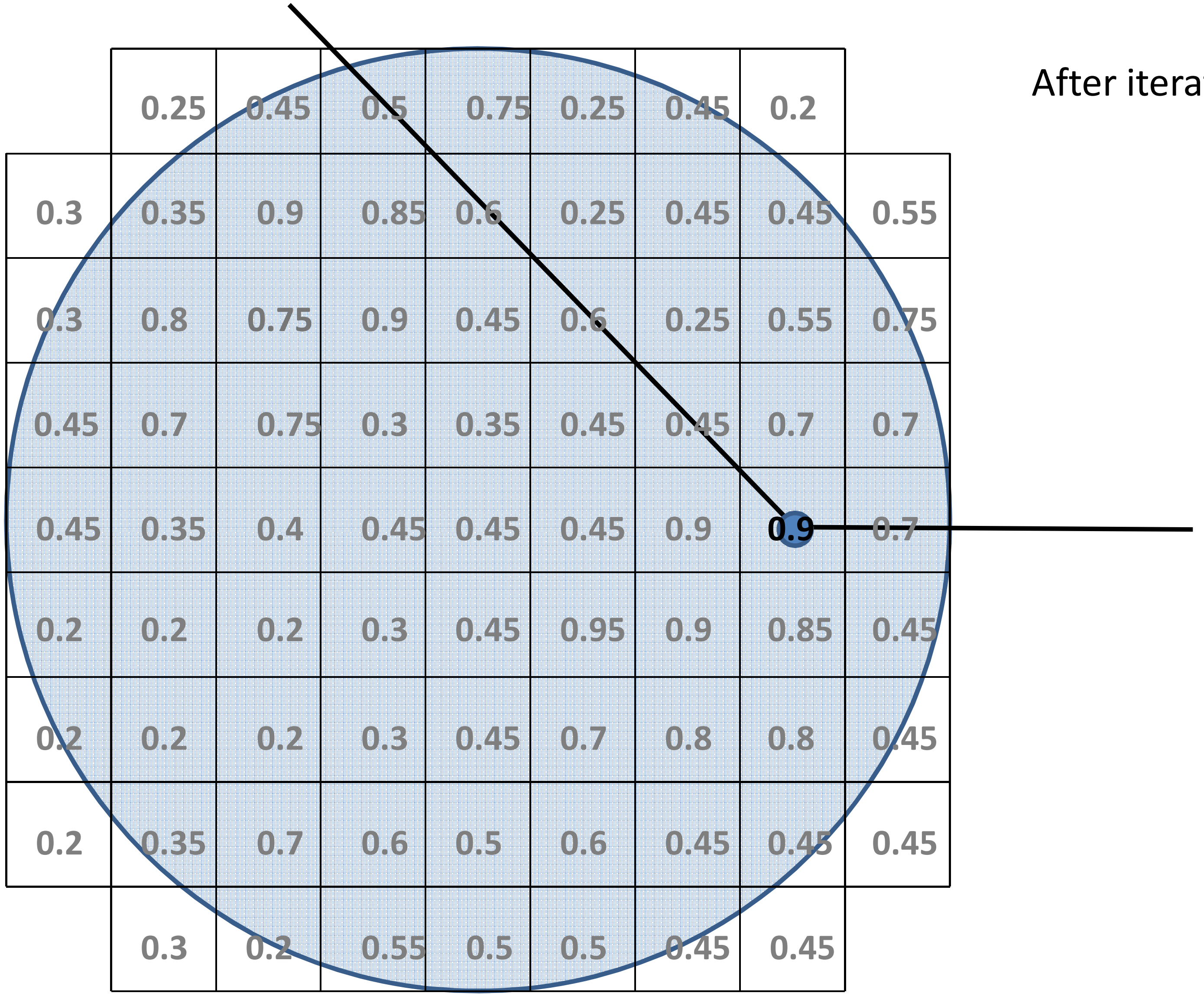
Initial pheremone values

After iteration 1

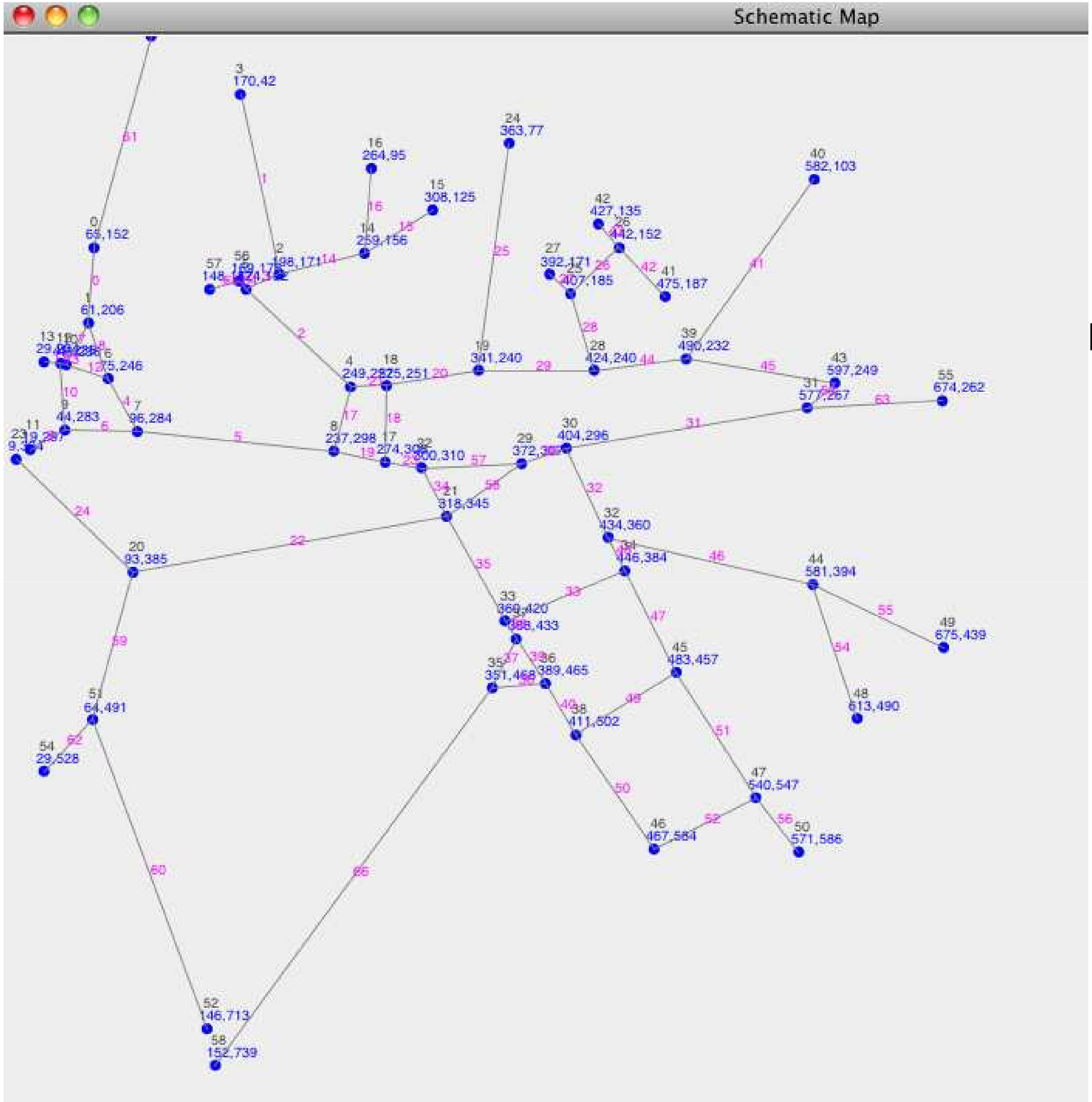


After iteration 2

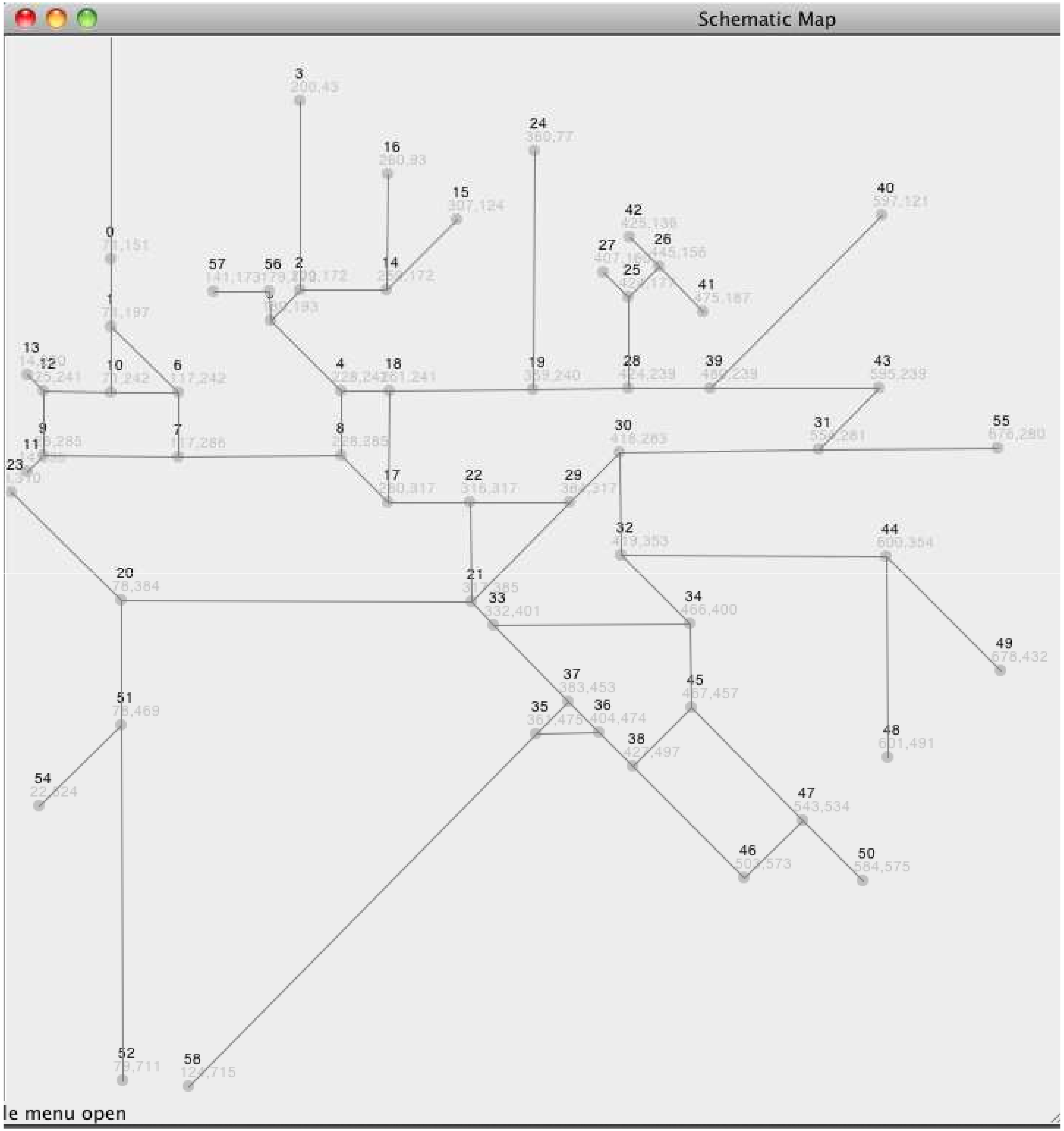




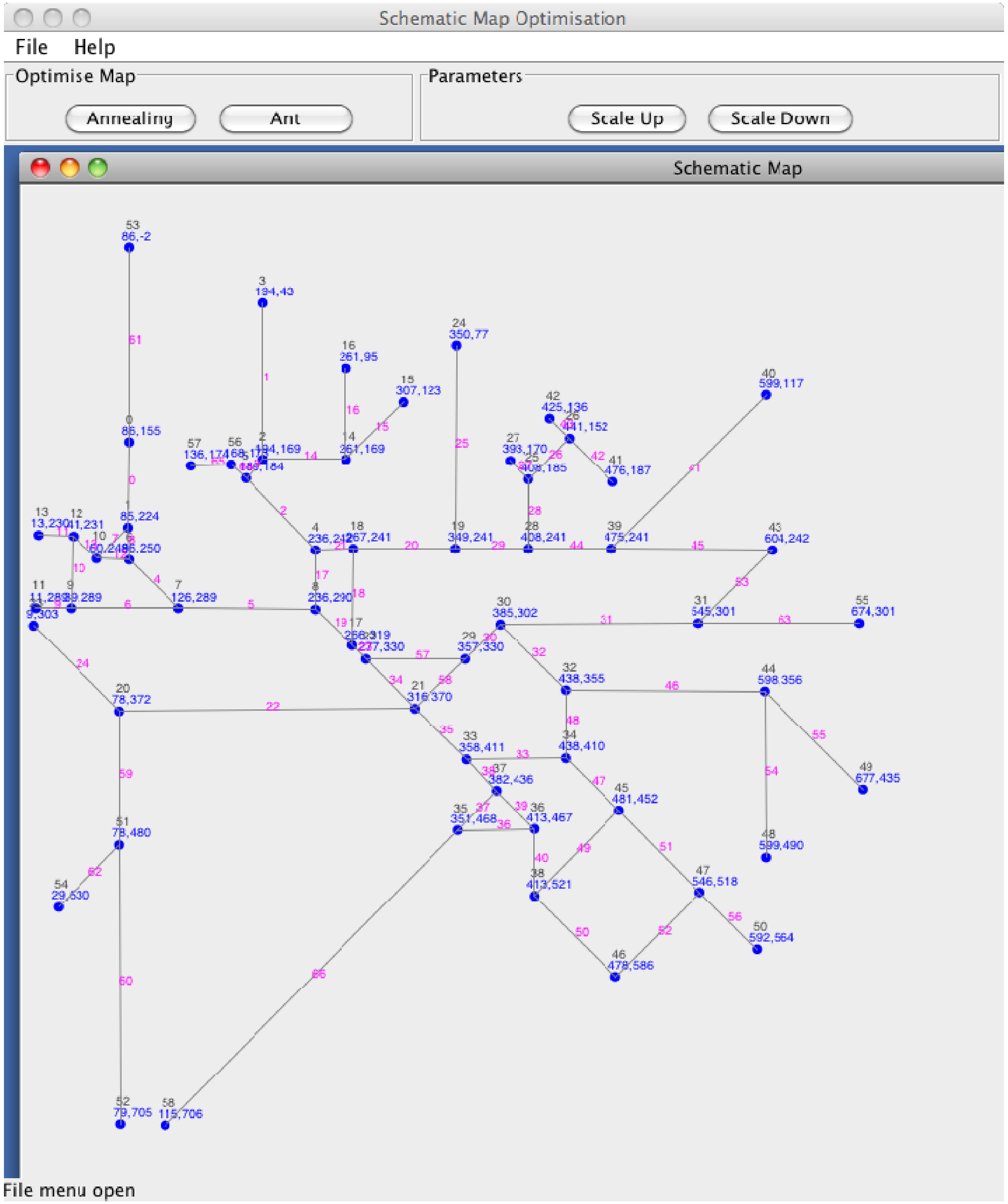
After iteration n



Initial cost =
650

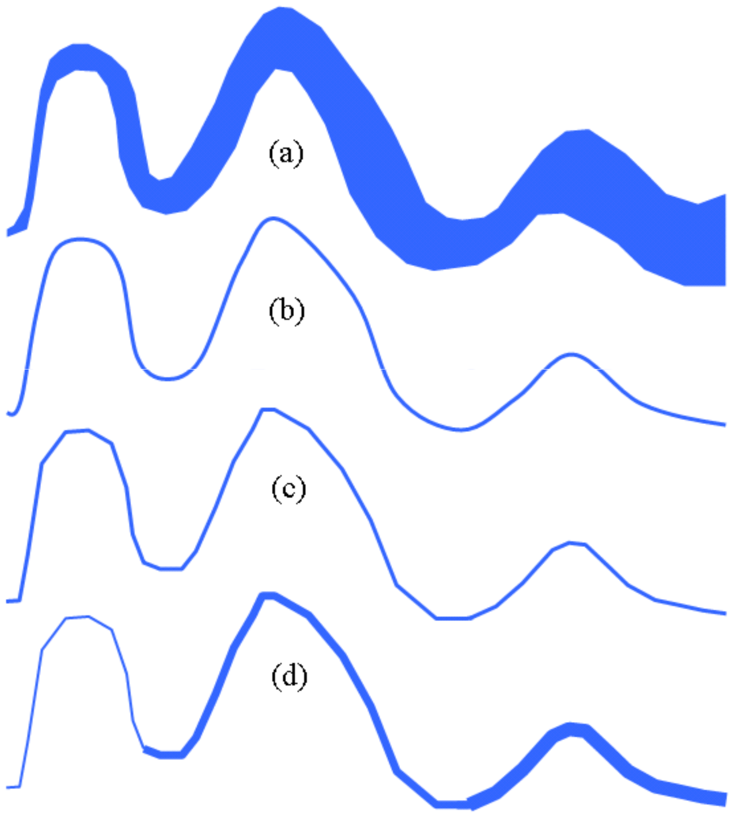


Best cost = 70
(80 seconds)



Best cost = 138
(> 600 second)

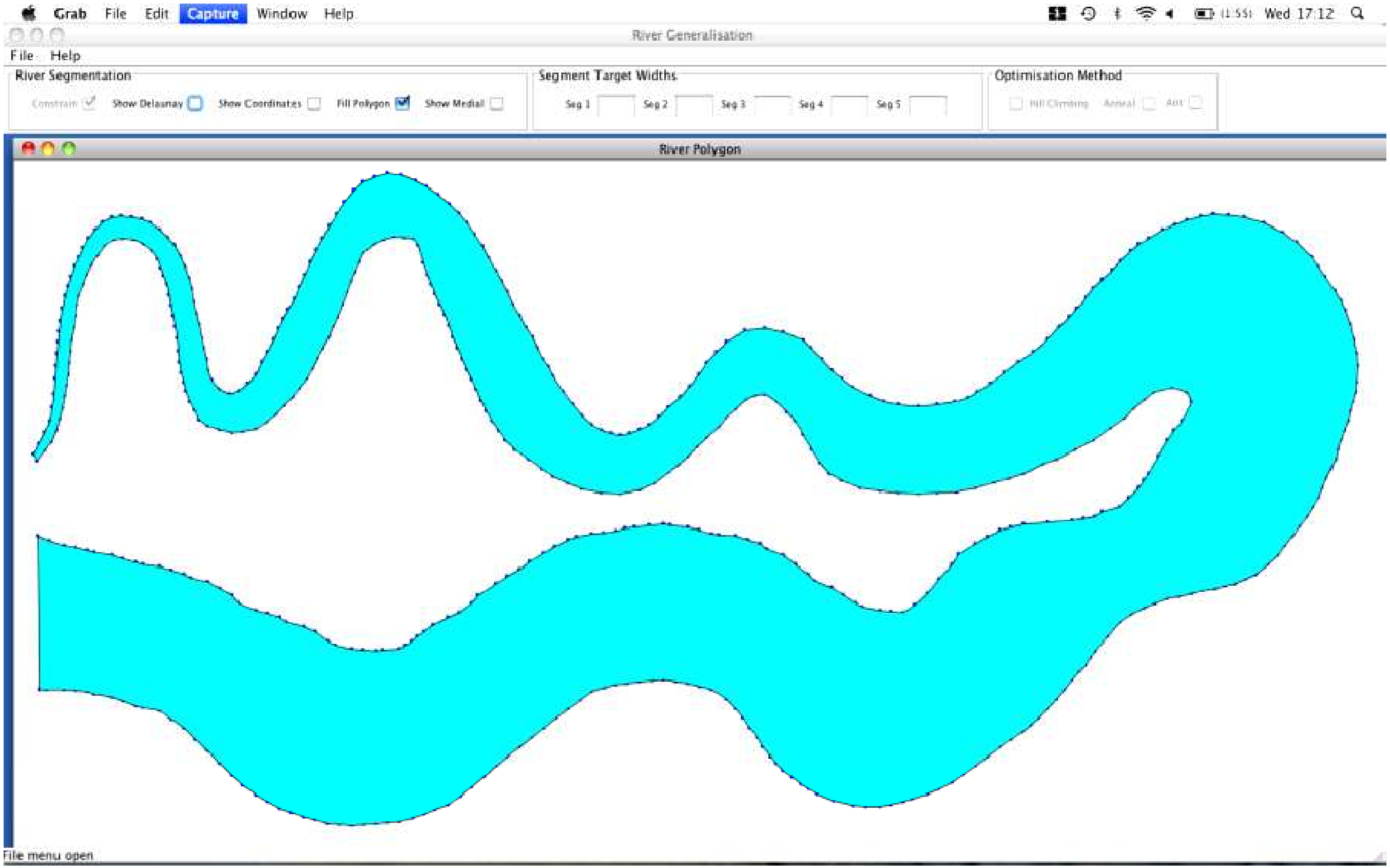
River Symbolization



“best” is decided through a stochastic mechanism where the probability of moving to a particular location is governed by heuristic information (immediate benefit) and pheromone value (historical benefit).

```
while stop conditions not met  /*start next iteration */

    for each ant
        randomize segment order
        for each segment
            perform “best” split(s)
        end for
        maintain record of this iterations lowest cost segmentation
    end for

    decay pheromone for all pheromone grid cells
    increase pheromone for grid cells corresponding to this iterations lowest cost
    schematic
    maintain record of overall lowest cost segmentation

    reset network configuration

end while
```

perform local search?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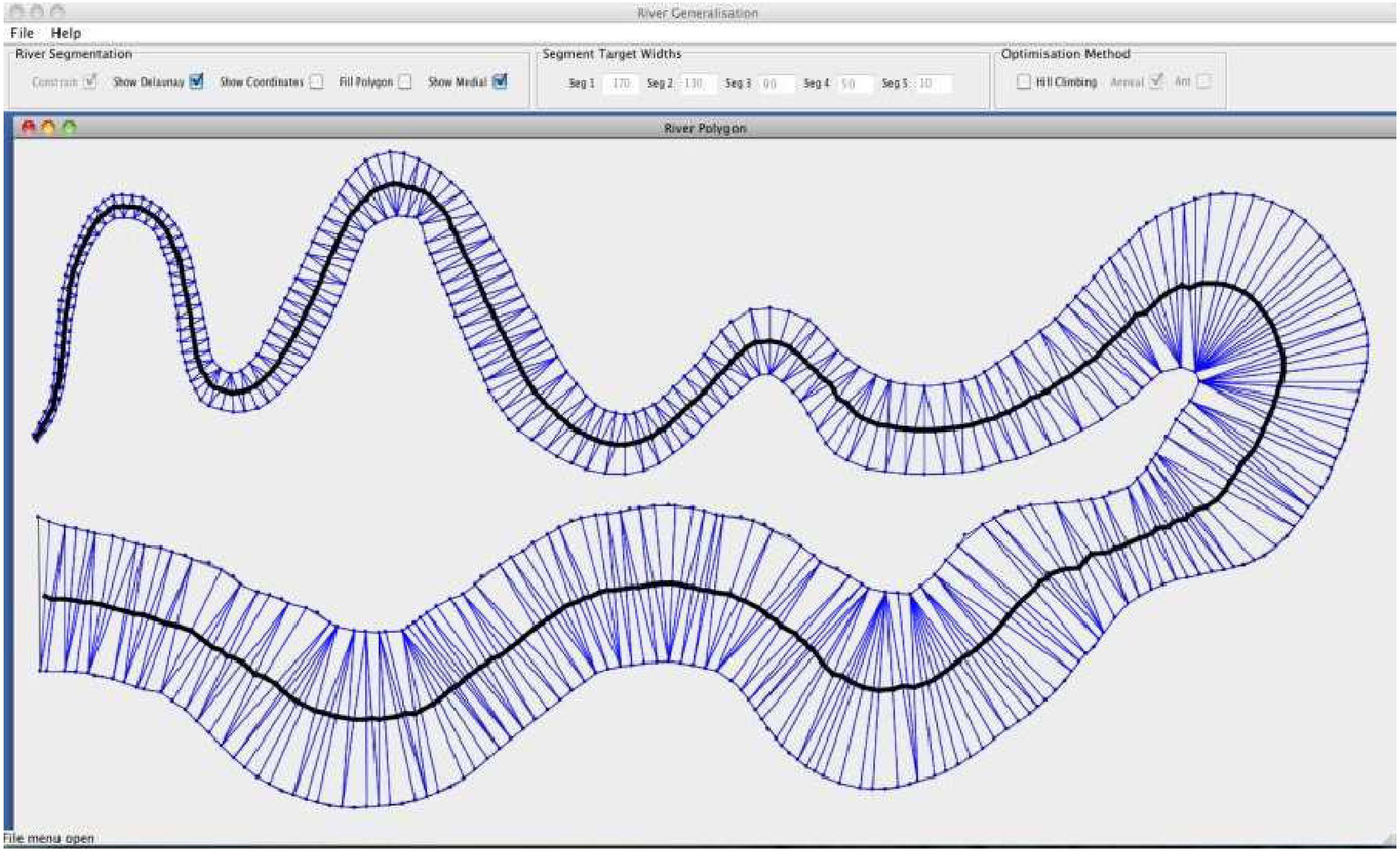
River Generalisation
File Help
River Segmentation
Constrain
Show Delaunay
Show Coordinates
Fill Polygon
Show Medial
Segment Target Widths
Seg 1
Seg 2
Seg 3
Seg 4
Seg 5
Optimisation Method
Hill Climbing
Anneal
Ant
River Polygon
File menu open


River Generalisation
File
Help
River Segmentation
Show Delaunay
Show Coordinates
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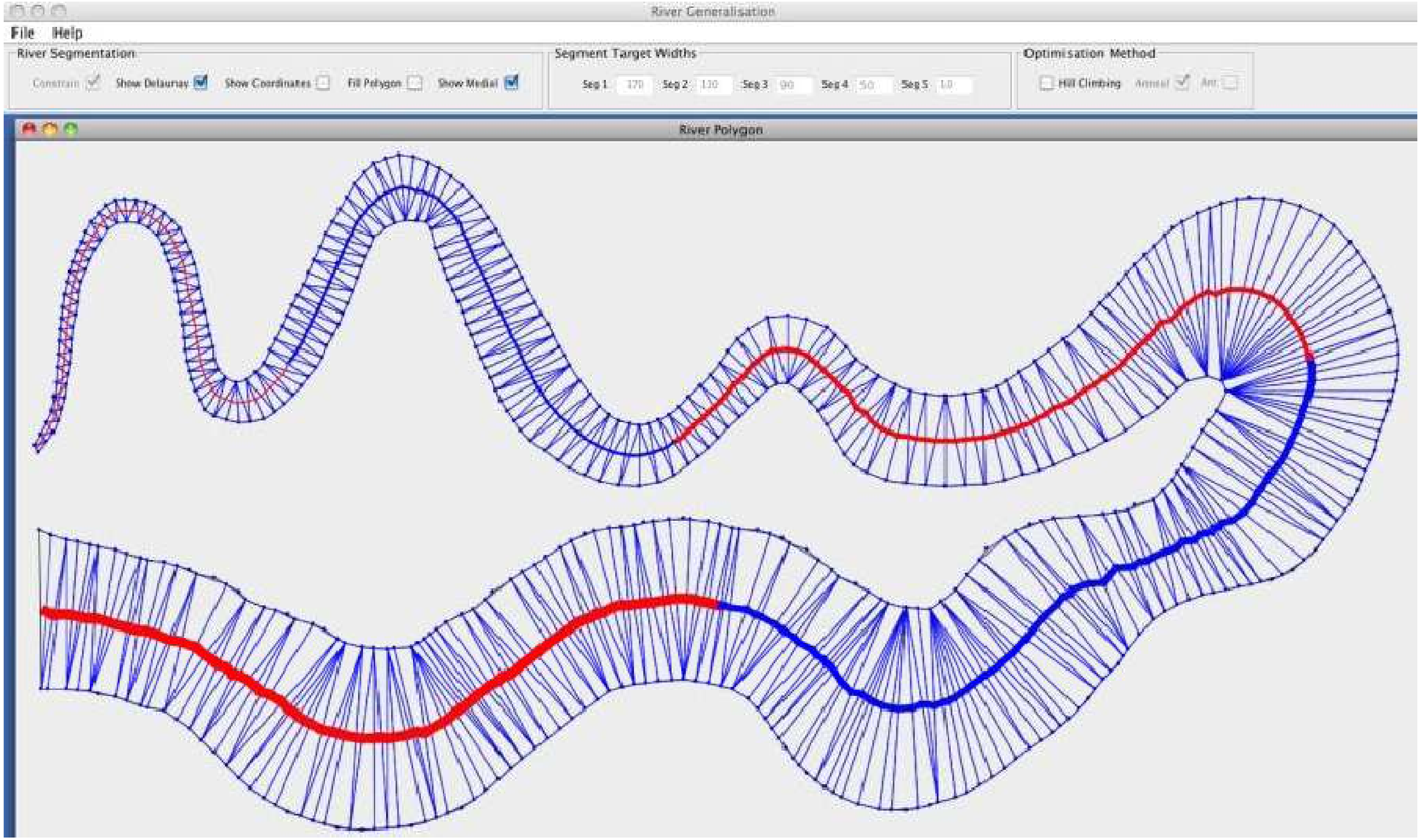
File menu open


River Generalisation
File Help
River Segmentation
Constrain
Show Delaunay
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Optimisation Method
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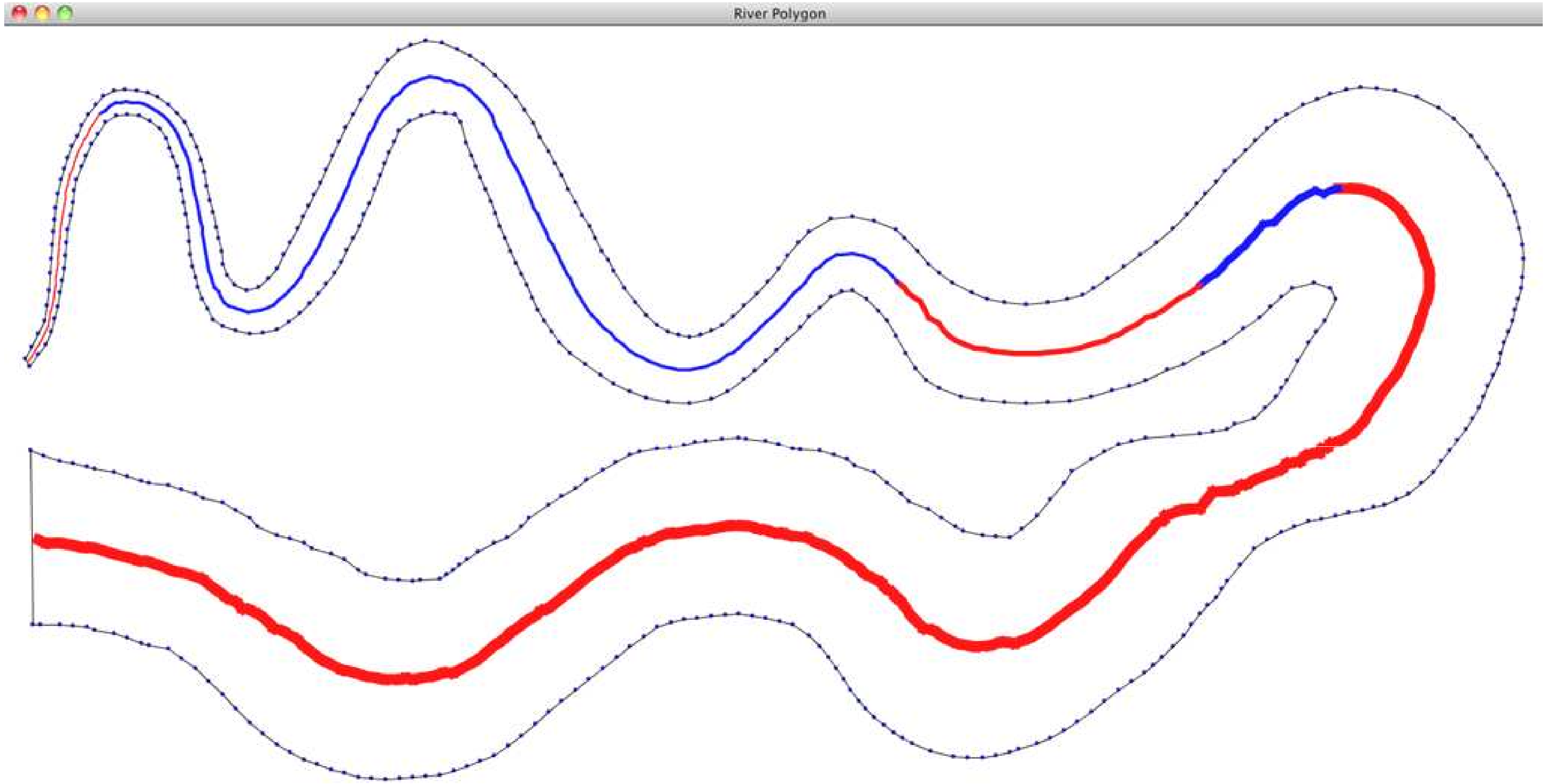
River Polygon


River Polygon

Conclusion

- Ant Colony Optimization – works
- Ant Colony Optimization – improves on SA?
  - Quality, speed, ease of use
- Future
  - More testing (including more realistic data)
  - Other map generalization problems
  - Parallelization