THE AMERICAN UNIVERSITY IN CAIRO
الجامعة الأمريكية بالقاهرة

CSCE330401/ Digital Design II

A Simple Simulated-Annealing Cell Placement Tool

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1. Introduction:

   We developed a simulated annealing cell placement tool that minimizes the total wire length used in connecting the cells in a grid using the half-perimeter of the smallest bounding box containing all pins for a net and depends on the cooling effect.

   Our work on Git Hub:

   https://github.com/YaraYahia17/DDII_Project

2. Algorithm:

   We create an initial random placement. Then mark the current temperature as the initial one and while is it still greater than the final one, we swap cells and calculate the change in the wire length. If it is a negative change, we accept the new wire length as the final one and if not, we reject with probability $(1 - e^{-\Delta L/T})$ and schedule temp.

3. Implementation:

The algorithm is divided into three steps. First, it parses a text file that contains the number of cells, number of connections, grid size (to create the 2d array) , and a line for each net that describes the number of cells in the net and which cells are there. Secondly, we created a 2d array initially empty that represents the initial grid then we implemented a random function that loop over a list of the cells and put them in random locations in the 2d array. Then, we started calculating the wire length using the half-perimeter of the smallest bounding box containing all pins for each net (HPWL). We did that by selecting the net's cells and getting the difference of the minimum and maximum x and between the minimum and maximum y then adding them to get the initial total wire length. Third, we started doing the simulated annealing algorithm and scheduling. As long as the initial temperature calculated by (500*initial cost) is greater than the final temperature, as the temperature decreases by (0.95*current temperature) each time the number of swaps per temperature ends. We first picked any two cells and swapped these cells. Then, calculate the total wire length again, if it is less than the previous wire length, then

we pick it as the best solution. If no, we reject with probability calculated in the code by the difference in the wire length and current temperature. After getting the best total wire length by iterating over the nets, we place the new cell locations on the grid. Then present the final cell placement on the 2d array.
We tried reducing the algorithm complexity by mapping the cells to the nets they appeared at and then when swapping any two cells, it check the map first and instead of going for the whole new grid to calculate the wire length. It go over the cells of the nets associated to the swapped cells to calculate the wire length again.

- Swapping with empty cells: get random column and row and for two cells and swap
- Plotting graphs: used matplotlib in python to plot the 2 d graph for the relationship between TWL and temperature when it changes. For the relationship between TWL and cooling rate, we did it manually on excel with changing the cooling factor every time in the code.
- Binary representation: by looping over the final placement grid,, we printed 1 for the filled grid and zero for the empty

4. Cooling rate: temperature starts with 500* initial cost and then it reduced by 0.95 every 10*number of cells
5. Results:

   We ran the three different test files. In each run it successfully changed the cell placement and reduced the wire length.

   For the TLW and temperature graph, we start with a high temperature and a large total wire length and as the temperature decreases the total wire length decreases.

   For the TWLand cooling rate, the TWL is highly affected by the cooling grate as it decreases whenever the cooling factor increases.

D0:
initial placement
23 21 -- 1 2 10 11 --
15 -- 0 -- 17 16 3 13
9 22 12 -- 20 4 6 14
-- 18 7 5 8 19 -- --

wire length: 90

final placement:
20 22 -- 1 6 14 2 --
3 -- 8 -- 15 16 9 21

5 10 17 -- 12 23 7 13
-- 18 4 0 11 19 -- --

wire length: 42

D1:
initial placement
29 16 6 -- 20 9 1 15
11 5 12 31 10 33 32 24
13 34 35 26 3 23 0 2
14 25 8 -- 21 4 -- 22
7 -- 17 18 19 30 28 27

wire length: 178

final placement:
23 32 5 -- 35 17 9 14
16 30 27 4 24 31 15 3
20 28 22 19 21 34 25 6
11 10 33 -- 2 12 -- 1
13 -- 26 0 18 7 29 8

wire length: 72

D2:
initial placement
204 16 193 130 139 174 138 18 13 114 258 128 81 39 48 132 111 226 --
0
15 148 216 -- 208 117 71 97 102 154 127 107 147 249 66 -- 116 143 70
110
162 76 -- 254 121 123 -- 190 35 159 54 184 -- 1 227 47 177 105 -- 163
40 251 201 22 -- -- -- 206 99 20 77 -- 46 6 225 42 92 246 191 185
-- 129 25 115 44 -- 85 43 -- 170 172 157 4 9 58 198 -- -- 91 189
-- 222 235 -- 57 36 223 65 53 248 82 135 153 109 80 124 23 171 187
131
199 3 86 219 14 101 228 34 182 106 156 30 -- 100 221 118 133 104 180
195
26 173 -- -- 203 150 168 95 155 238 103 -- 243 240 55 -- 63 28 7 31

```
181 64 212 253 134 176 88 192 -- 11 61 120 183 21 45 87 78 8 255 215
72 73 -- -- 256 -- 149 161 247 49 252 137 144 19 122 158 230 68 231
209
83 -- 245 84 151 93 75 242 56 119 17 12 244 239 178 37 -- -- 108 29
237 126 38 -- 112 169 175 152 50 5 165 74 125 220 90 214 217 259 --
--
2 186 98 51 59 188 145 -- -- 197 69 234 -- 202 -- 62 140 196 136 166
200 194 179 207 241 257 167 233 229 211 96 113 210 52 141 -- 160 32
250 213
60 41 142 218 10 27 236 232 -- 24 205 -- 89 67 79 164 94 146 224 33

wire length:  3915

final placement:
232 88 164 59 121 75 225 254 118 92 25 222 41 140 256 247 149 35 --
102
85 110 6 -- 68 183 60 136 30 241 246 109 69 158 230 -- 113 50 179 167
73 147 -- 242 148 240 -- 252 160 47 123 133 -- 204 200 209 3 24 -- 42
161 49 80 55 -- -- -- 236 48 116 212 -- 99 226 162 165 26 38 186 19
-- 40 248 130 0 -- 83 210 -- 101 34 159 64 20 117 157 -- -- 98 184
-- 138 234 -- 16 180 67 53 201 193 32 96 115 235 7 153 245 39 71 199
137 145 81 36 218 65 181 251 259 74 169 228 -- 28 90 182 155 127 5 76
187 37 -- -- 21 84 79 202 203 56 82 -- 78 70 66 -- 135 185 10 249
23 197 4 258 58 152 95 139 -- 233 87 52 17 253 189 206 198 208 104 44
229 45 -- -- 192 -- 238 134 22 2 15 173 178 175 142 156 244 120 112
94
100 -- 224 103 146 227 51 170 205 237 126 1 154 150 174 89 -- -- 214
63
143 144 195 -- 29 220 119 77 57 257 215 129 13 12 171 243 108 18 --
--
62 177 132 72 168 176 43 -- -- 231 255 211 -- 191 -- 131 190 9 124
125
250 106 151 213 141 114 91 105 172 196 14 219 239 221 207 -- 8 61 46
107
111 128 166 163 11 216 27 194 -- 86 217 -- 93 188 33 54 122 97 31 223

wire length:  3976
```

D3:

```
initial placement
176 -- 64 190 -- -- -- 120 -- 26 -- 110 -- 115 13 31 155 206 -- 132
-- -- 172 154 152
27 128 -- 175 185 118 196 -- -- -- -- 167 25 125 7 -- 82 105 -- --
153 -- 146 40 --
```

```
-- 139 -- 204 90 -- 22 8 198 -- 137 -- -- 200 116 17 149 -- 188 -- 24
117 68 -- 79
-- 51 -- 104 29 70 162 91 -- 15 23 163 202 159 4 -- 76 194 193 -- 135
49 80 184 81
-- 145 -- 208 -- 195 171 28 126 -- -- 59 -- 150 43 45 122 71 12 47 2
-- 89 -- 143
38 -- 158 -- 100 57 -- -- 209 183 -- 72 61 -- 165 54 134 -- 123 87
142 46 -- 92 --
-- 56 -- -- -- -- 86 -- -- -- -- -- -- 35 48 121 -- -- -- -- -- -- --
-- --
-- -- 74 -- 96 85 141 78 -- 127 62 -- 52 -- 69 11 -- 55 -- 161 10 --
-- -- 33
21 197 207 -- -- -- 77 6 -- 14 -- -- -- -- 211 -- 133 9 170 34 -- 174
-- 203 --
53 97 140 67 -- -- 109 -- 177 -- 50 94 63 18 -- 20 -- 107 -- 102 --
106 -- 147 --
212 -- 36 -- 148 84 19 -- -- -- -- -- -- 157 111 187 37 -- -- 65 191
-- 173 129 --
113 156 95 -- 60 -- -- -- 114 210 -- 93 -- 189 -- -- 73 -- 16 -- --
-- -- -- 169
-- -- 83 66 181 160 -- -- 99 -- 168 112 -- 144 199 138 101 -- 119 103
-- -- 98 205 166
41 -- 108 -- 179 88 1 -- 151 -- 39 -- 5 -- -- -- 42 3 -- 0 -- -- 178
-- 32
-- -- 124 164 186 130 131 201 30 75 192 -- 58 -- -- 136 -- 44 -- --
-- -- -- 180 182

wire length:  3714

final placement:
76 -- 184 13 -- -- -- 55 -- 62 -- 38 -- 88 132 28 43 108 -- 50 -- --
118 82 59
80 40 -- 128 212 89 22 -- -- -- -- 39 20 9 21 -- 12 8 -- -- 109 -- 25
26 --
-- 166 -- 3 199 -- 150 104 160 -- 129 -- -- 85 156 98 194 -- 102 --
84 182 42 -- 130
-- 146 -- 51 93 158 91 77 -- 206 34 183 18 81 176 -- 58 65 121 -- 49
11 155 16 7
-- 131 -- 67 -- 74 149 2 181 -- -- 73 -- 119 159 208 135 177 139 185
144 -- 197 -- 94
68 -- 133 -- 196 171 -- -- 78 14 -- 10 95 -- 52 190 72 -- 152 168 44
195 -- 115 --
-- 204 -- -- -- -- 157 -- -- -- -- -- -- 57 180 134 -- -- -- -- -- --
-- -- --
```

```
-- -- 188 -- 165 207 101 162 -- 127 203 -- 97 -- 202 0 -- 15 -- 33
170 -- -- -- 106
187 210 17 -- -- -- 142 31 -- 60 -- -- -- -- 126 -- 114 54 63 140 --
200 -- 37 --
189 116 92 46 -- -- 193 -- 173 -- 75 136 111 5 -- 138 -- 122 -- 148
-- 167 -- 191 --
205 -- 201 -- 123 172 45 -- -- -- -- -- -- 141 169 186 1 -- -- 117
175 -- 147 99 --
124 209 30 -- 179 -- -- -- 143 70 -- 69 -- 164 -- -- 23 -- 83 -- --
-- -- -- 105
-- -- 145 48 151 113 -- -- 29 -- 56 163 -- 112 66 153 32 -- 125 137
-- -- 4 100 41
27 -- 107 -- 198 19 161 -- 61 -- 154 -- 192 -- -- -- 87 47 -- 24 --
-- 178 -- 211
-- -- 90 86 174 35 71 120 6 64 110 -- 36 -- -- 79 -- 53 -- -- -- --
-- 103 96

wire length:  3605
```

TWL and temperature:

D0:

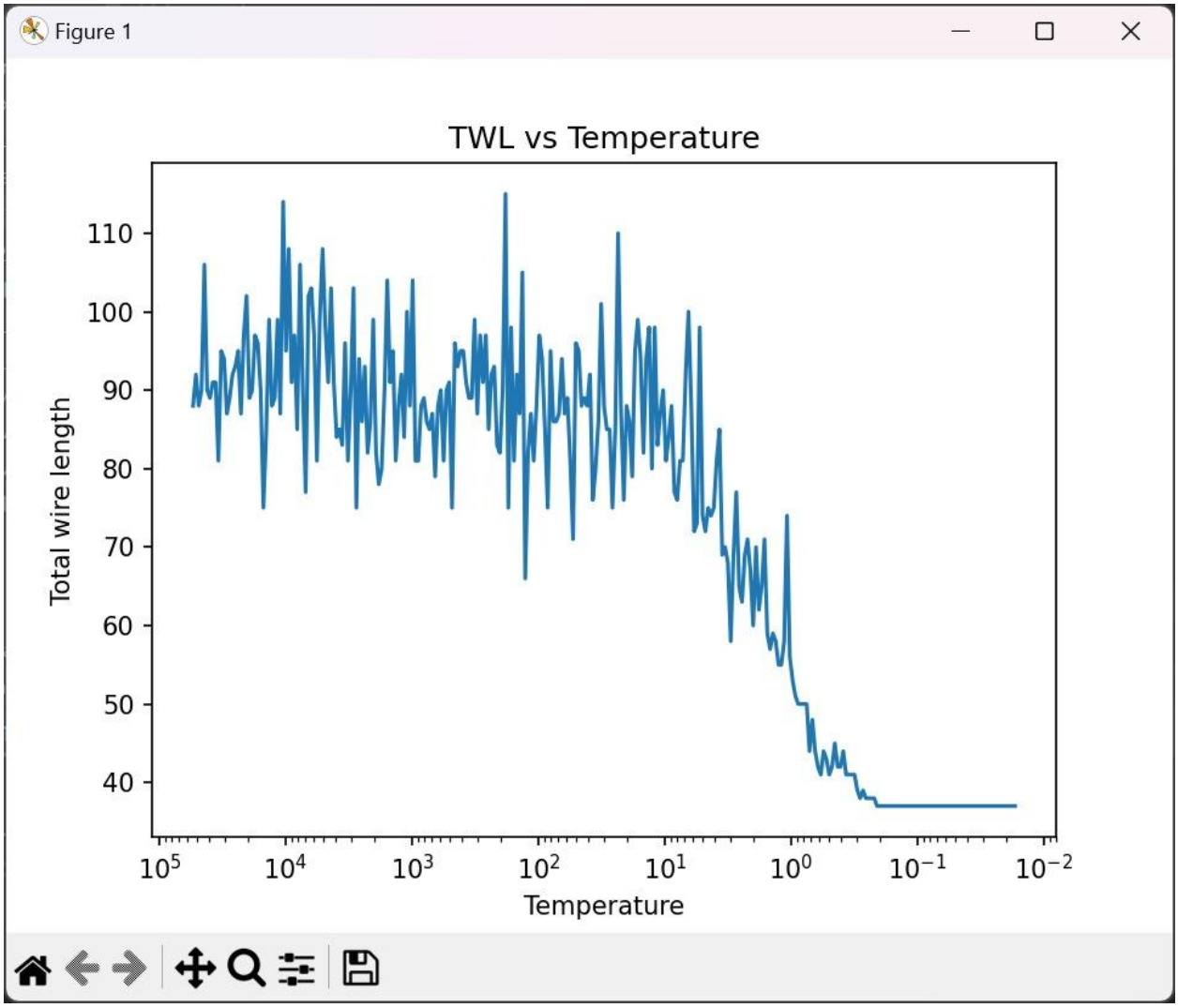


Figure 1
TWL vs Temperature
Total wire length
110
100
90
80
70
60
50
40
10^5
10^4
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
Temperature

D1:

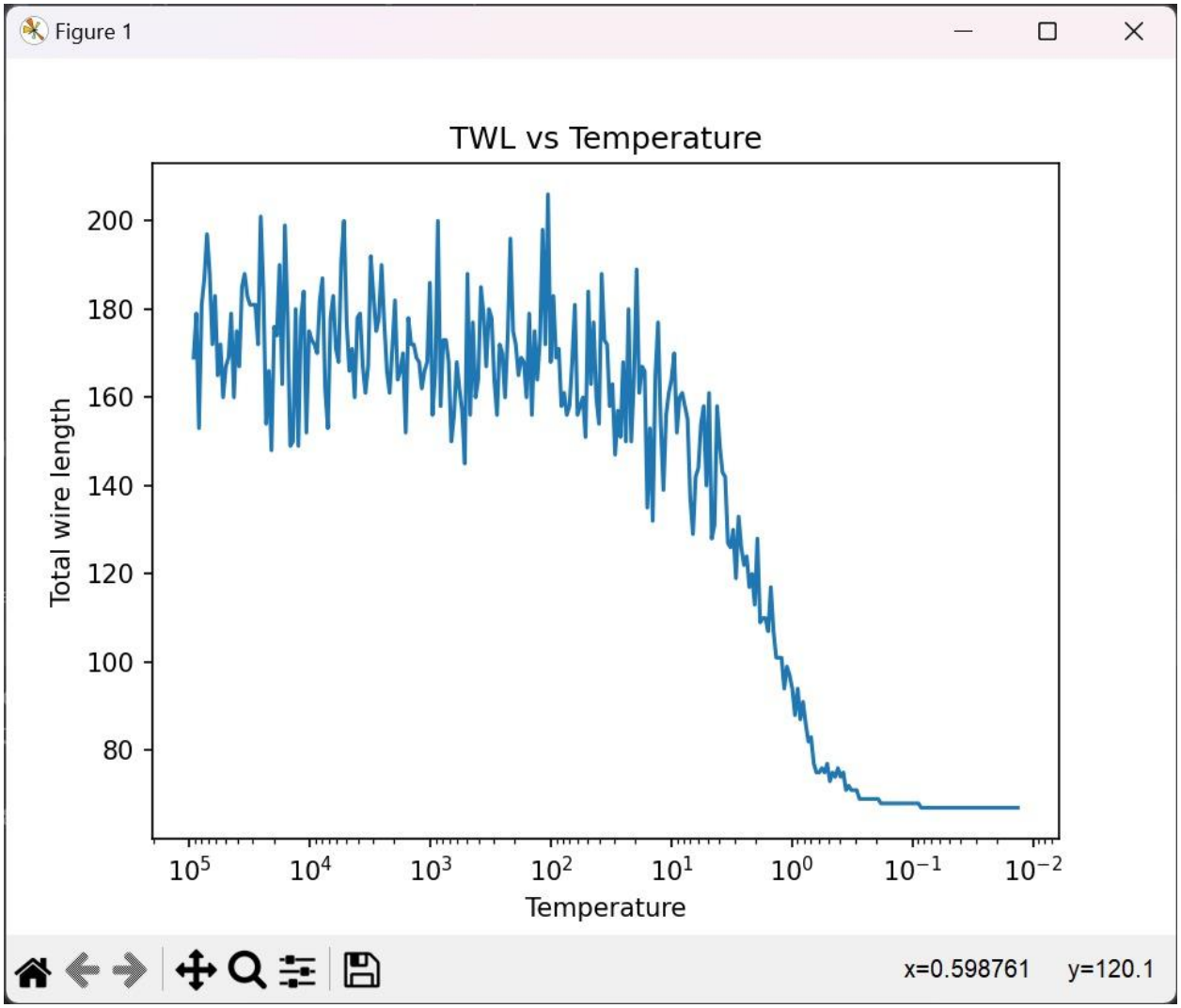


Figure 1
TWL vs Temperature
Total wire length
200
180
160
140
120
100
80
10^5
10^4
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
Temperature
x=0.598761
y=120.1

D2:

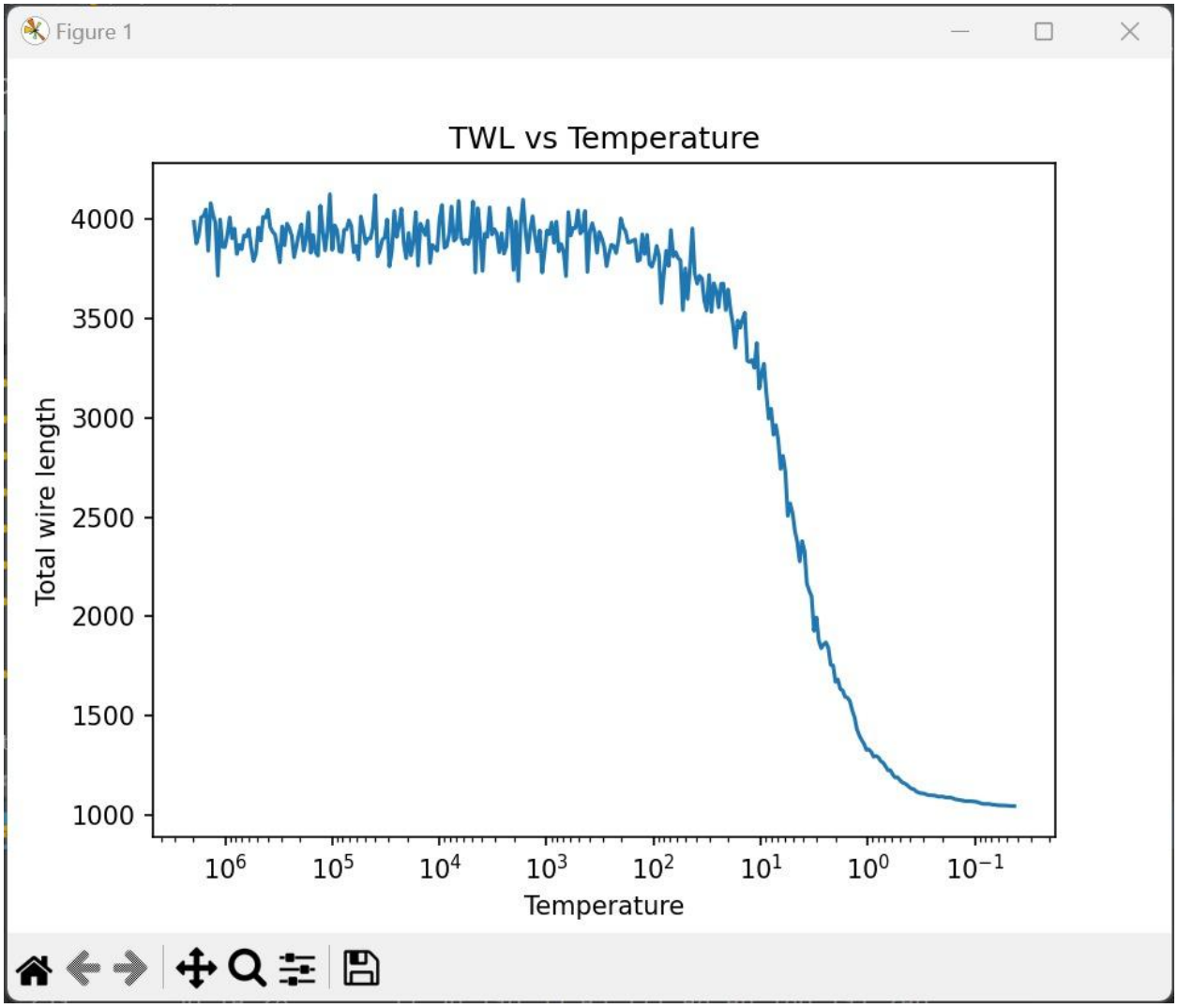


Figure 1
TWL vs Temperature
Total wire length
4000
3500
3000
2500
2000
1500
1000
10^6
10^5
10^4
10^3
10^2
10^1
10^0
10^{-1}
Temperature

D3:

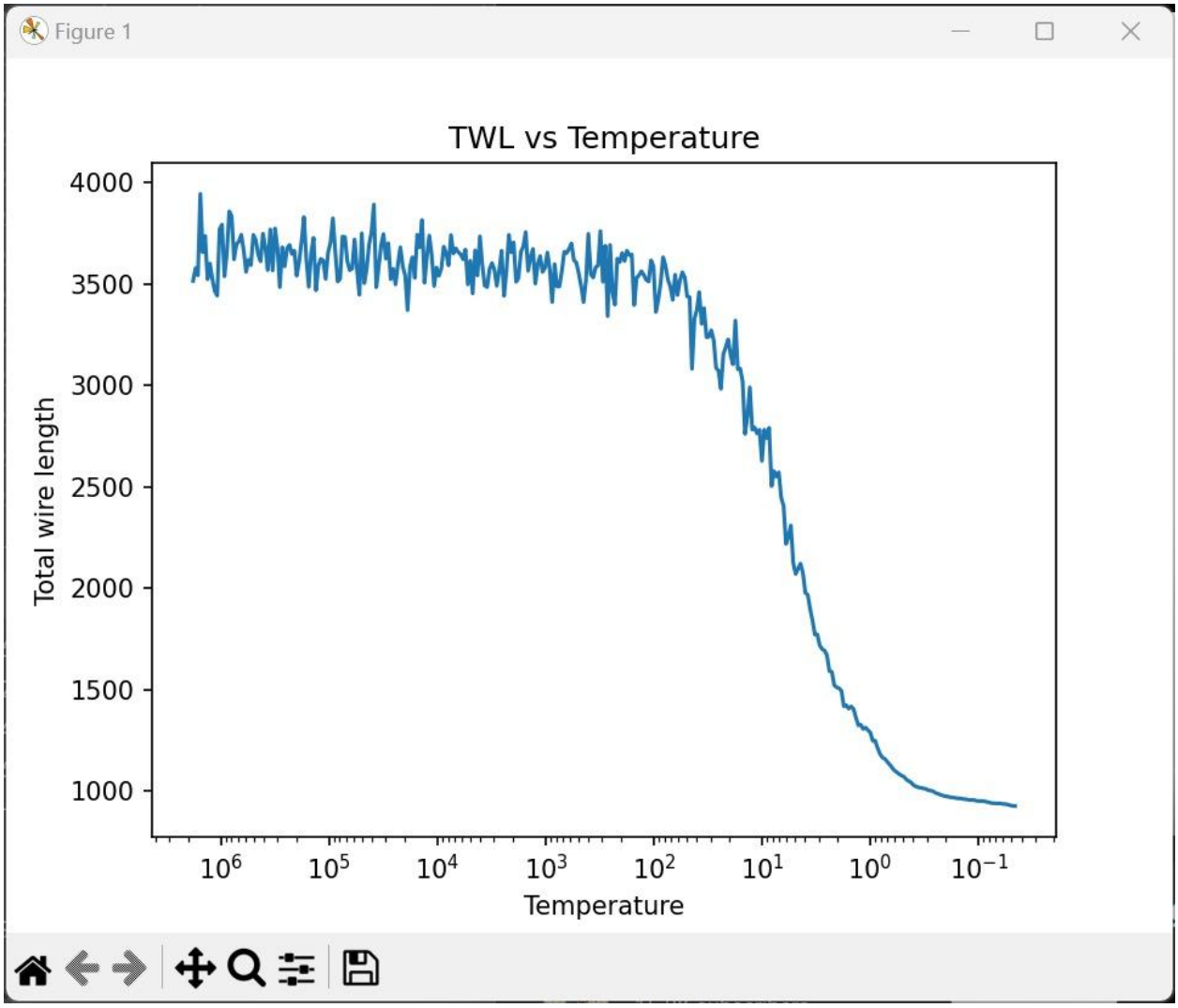


Figure 1
TWL vs Temperature
Total wire length
4000
3500
3000
2500
2000
1500
1000
10^6
10^5
10^4
10^3
10^2
10^1
10^0
10^{-1}
Temperature

T1:

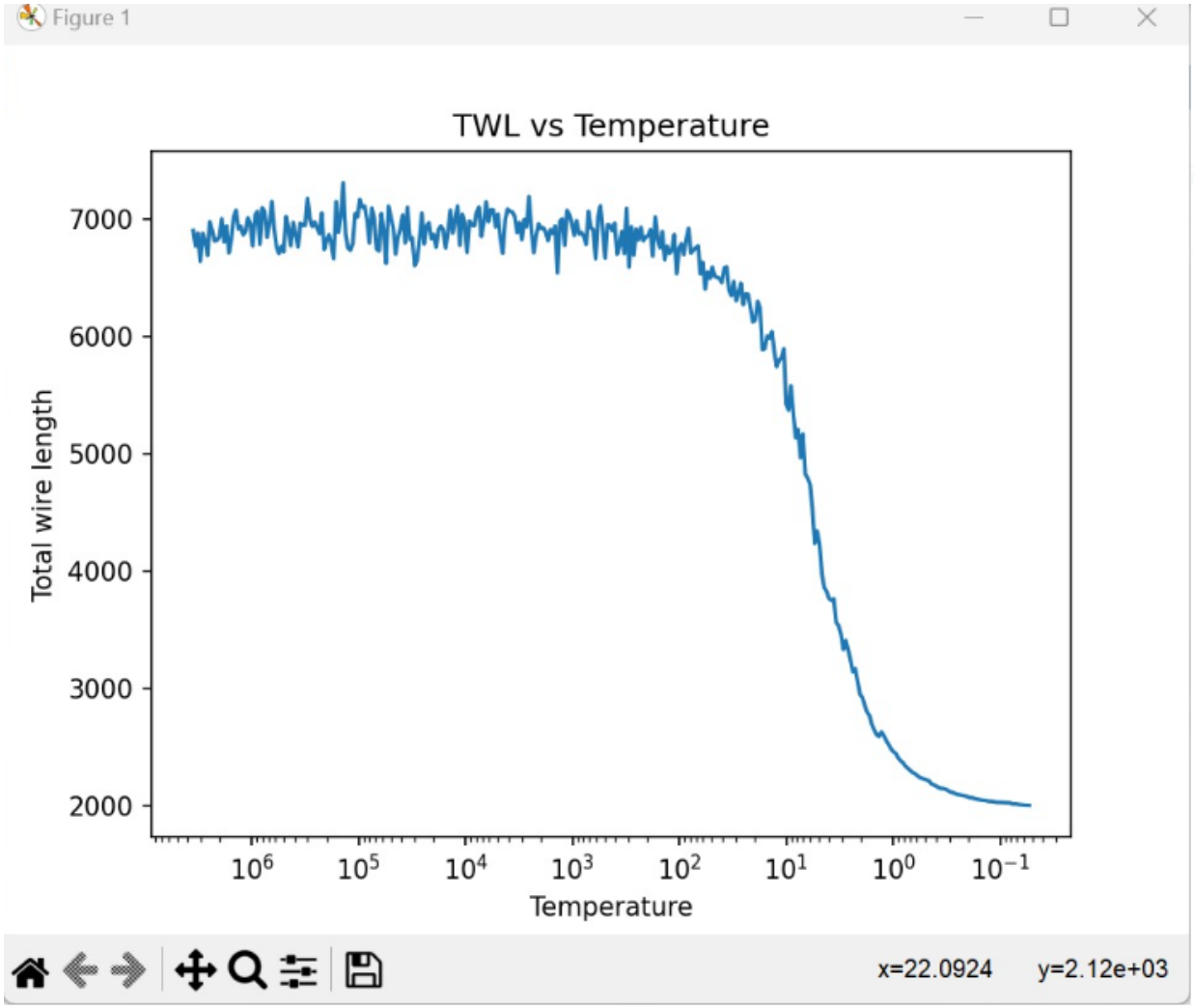
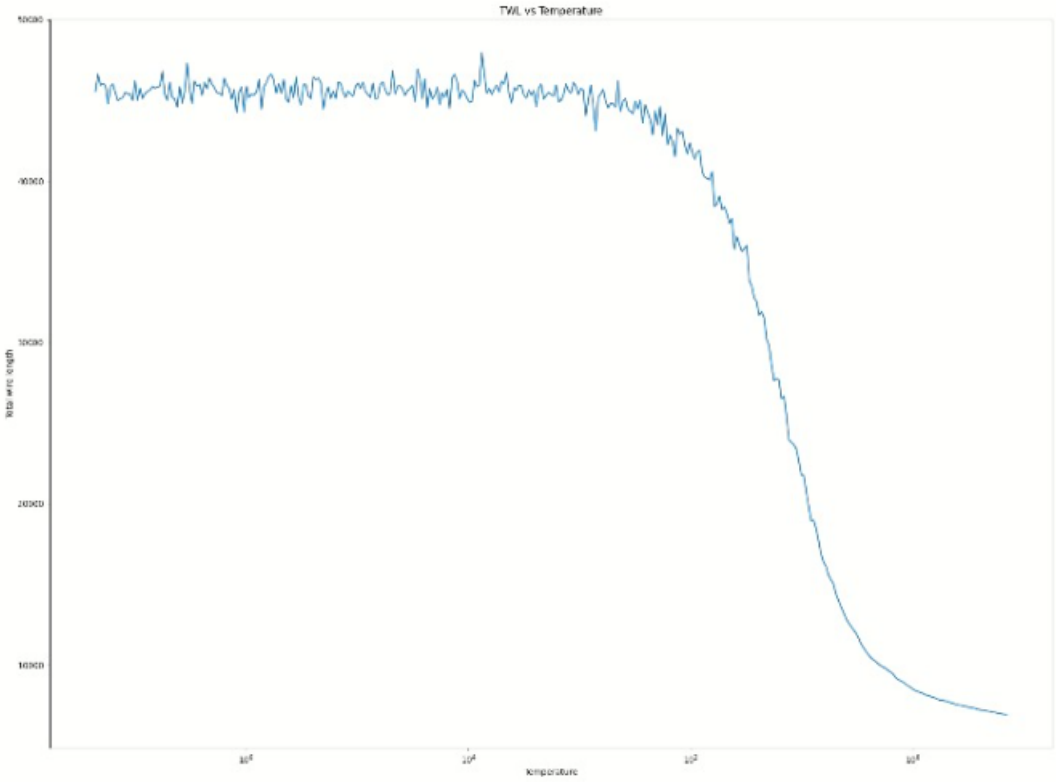
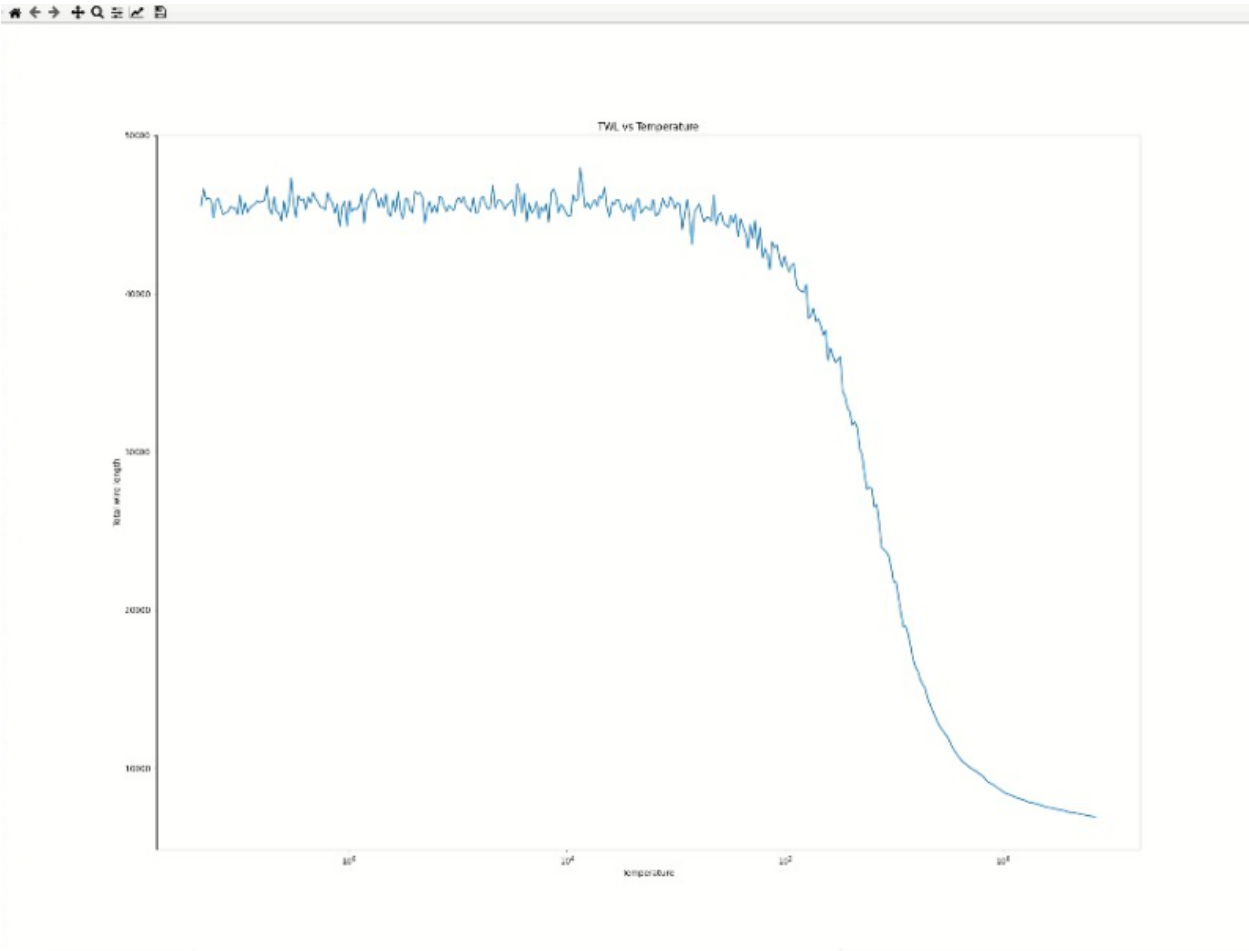


Figure 1
TWL vs Temperature
Total wire length
7000
6000
5000
4000
3000
2000
10^6
10^5
10^4
10^3
10^2
10^1
10^0
10^{-1}
Temperature
x=22.0924
y=2.12e+03

T2:



T3:



TWL and cooling rate:

D1:

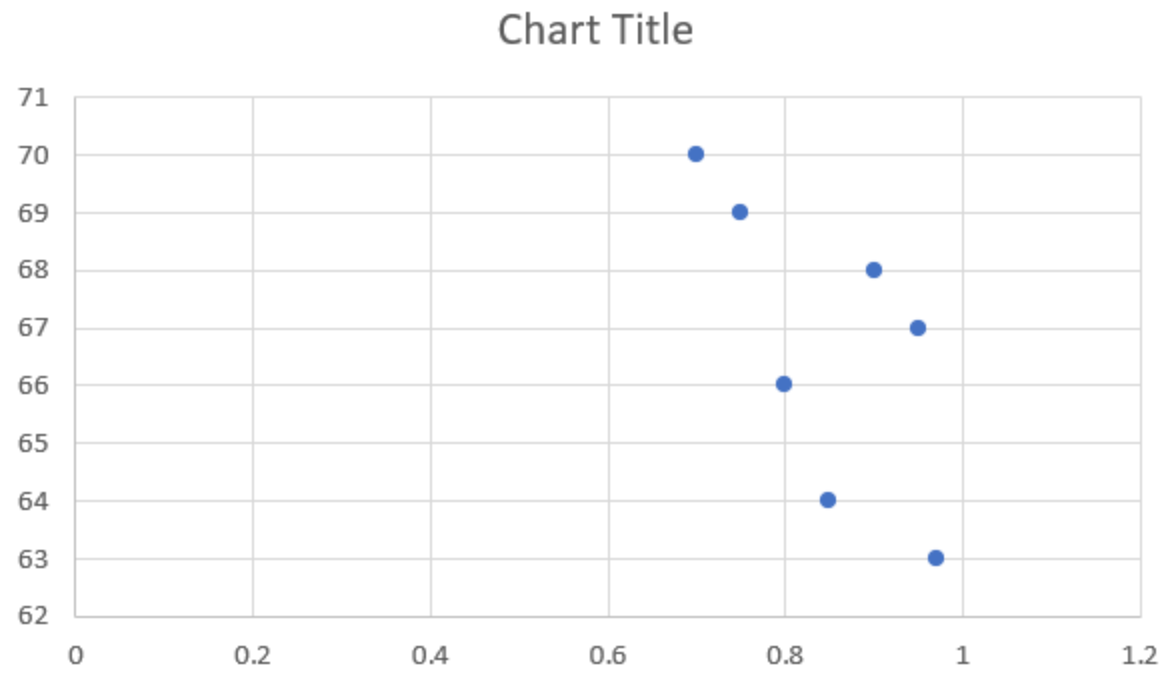


Chart Title
71
70
69
68
67
66
65
64
63
62
0
0.2
0.4
0.6
0.8
1
1.2

D2:

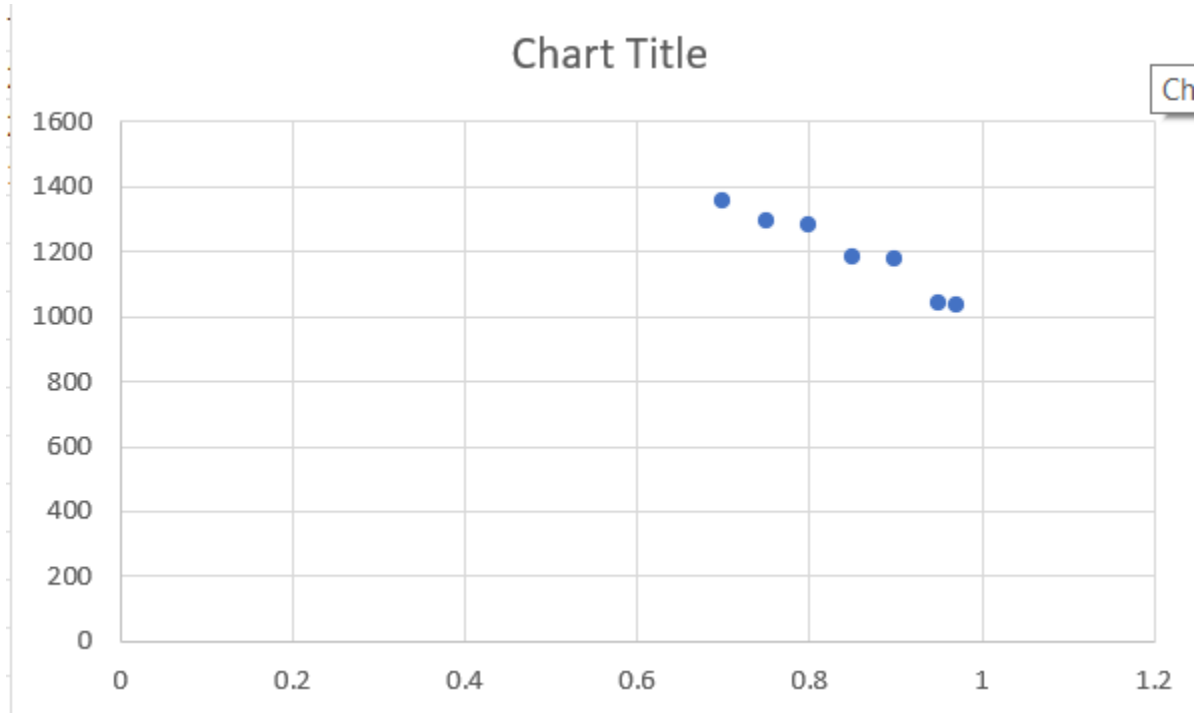


Chart Title
1600
1400
1200
1000
800
600
400
200
0
0
0.2
0.4
0.6
0.8
1
1.2

D3:

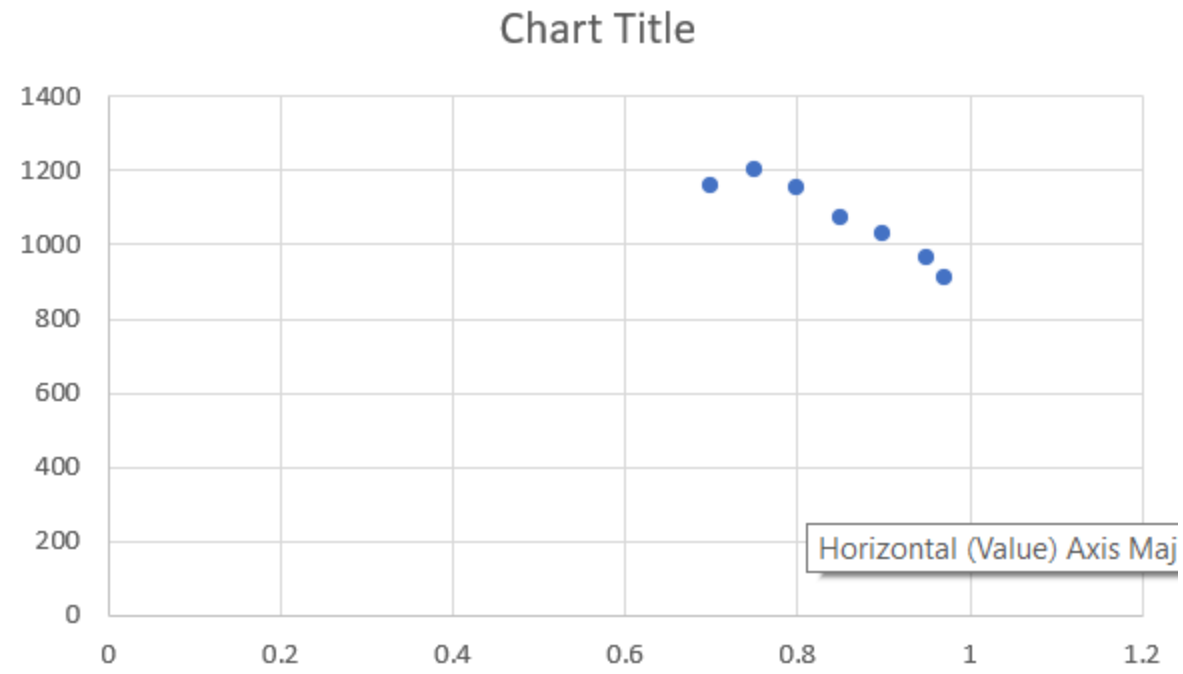


Chart Title
1400
1200
1000
800
600
400
200
0
0
0.2
0.4
0.6
0.8
1
1.2
Horizontal (Value) Axis Maj

T1:

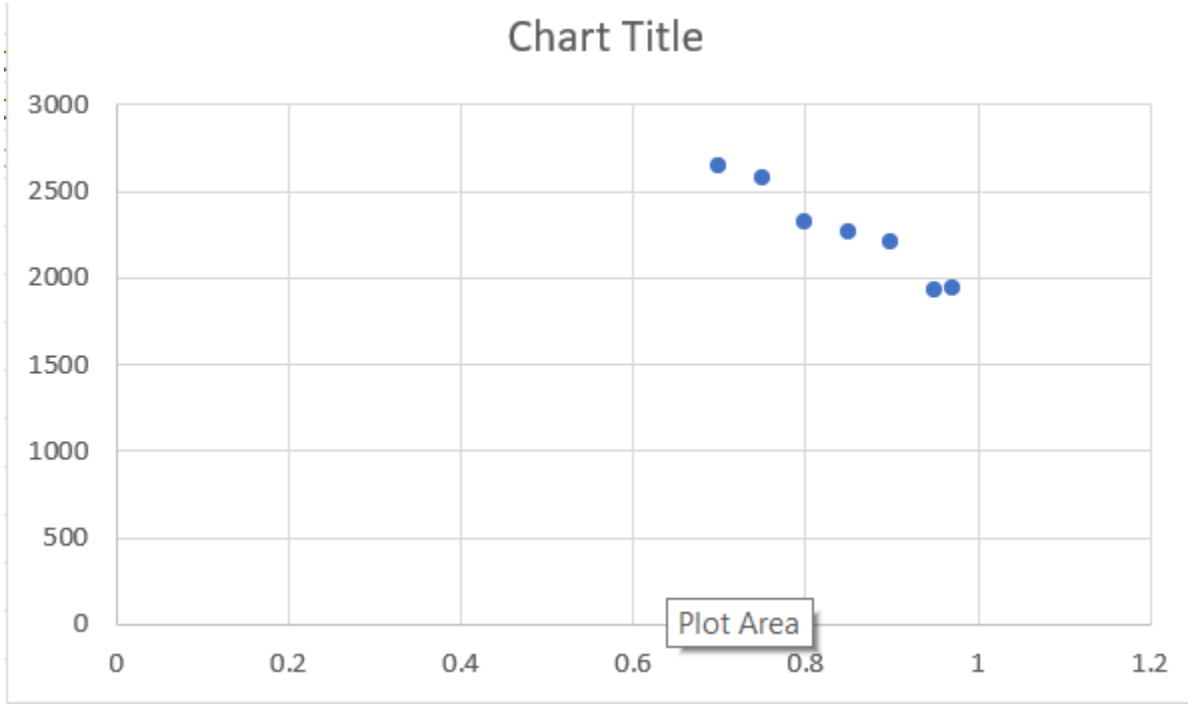


Chart Title
3000
2500
2000
1500
1000
500
0
0
0.2
0.4
0.6
0.8
1
1.2
Plot Area

T2:

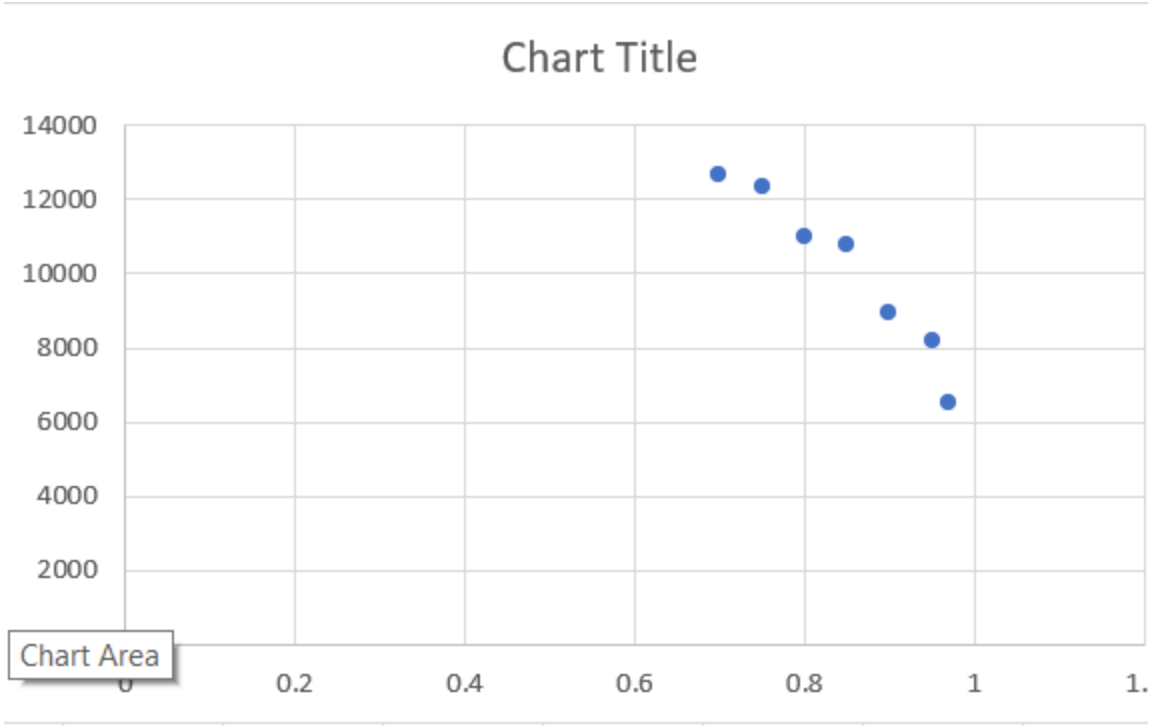


Chart Title
14000
12000
10000
8000
6000
4000
2000
Chart Area
0.2
0.4
0.6
0.8
1

T3:

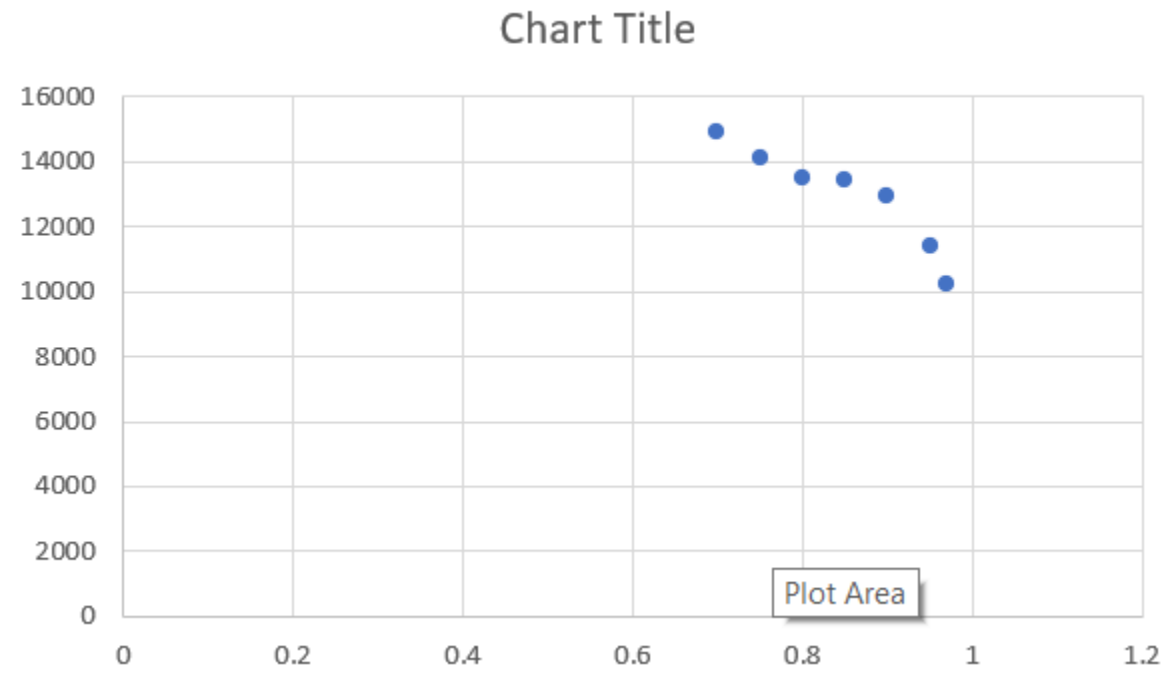


Chart Title
16000
14000
12000
10000
8000
6000
4000
2000
0
Plot Area
0
0.2
0.4
0.6
0.8
1
1.2

Bonus

Bonus 1: We made the final placement grid displays graphically.
Bonus 2: We created a GIF for the random placement of the grid at each swap. It saves the images of the grid at each swap then creates the gif.