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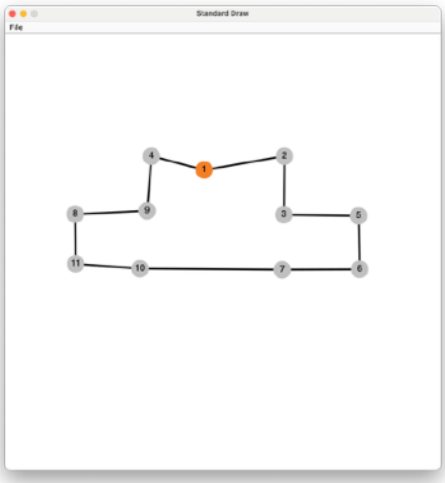
Google Drive Link for full size images: https://drive.google.com/drive/folders/1KngMjSXvRJ3N8MD6lZcMXSPRTzVl2ygQ?usp=share_link

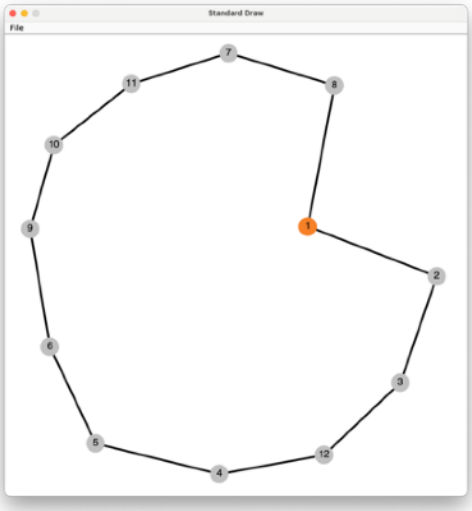
Outputs Using the Brute Force Method

input01.txt



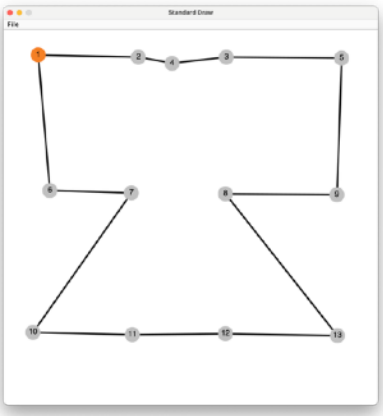

```
/Users/boramacbook/Library/Java/JavaVirtualMachines/openjdk-21.0.2/Contents/Home/bin/java -javaagent:/Applications/IntelliJ IDEA CE.app/Contents/lib/idea_rt.ja
Method: Brute-Force Method
Shortest distance: 1.7952913856772432
[1, 4, 9, 8, 11, 10, 7, 6, 5, 3, 2, 1]
Time it takes to find the shortest path: 0.084 seconds.
```

input02.txt



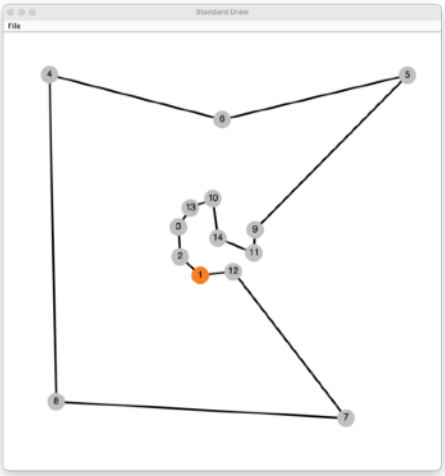

```
/Users/boramacbook/Library/Java/JavaVirtualMachines/openjdk-21.0.2/Contents/Home/bin/java -javaagent:/Applications/IntelliJ IDEA CE.app/Contents/lib/idea_rt.ja
Method: Brute-Force Method
Shortest distance: 2.935877143237598
[1, 8, 7, 11, 10, 9, 6, 5, 4, 12, 3, 2, 1]
Time it takes to find the shortest path: 0.72 seconds.

Process finished with exit code 130 (interrupted by signal 2:SIGINT)
```

input03.txt



```
/Users/boramacbook/Library/Java/JavaVirtualMachines/openjdk-21.0.2/Contents/Home/bin/java -javaagent:/Applications/IntelliJ IDEA CE.app/Contents/lib/idea_rt.ja
Method: Brute-Force Method
Shortest distance: 3.802919361826042
[1, 2, 4, 3, 5, 9, 8, 13, 12, 11, 10, 7, 6, 1]
Time it takes to find the shortest path: 9.296 seconds.
```

input04.txt

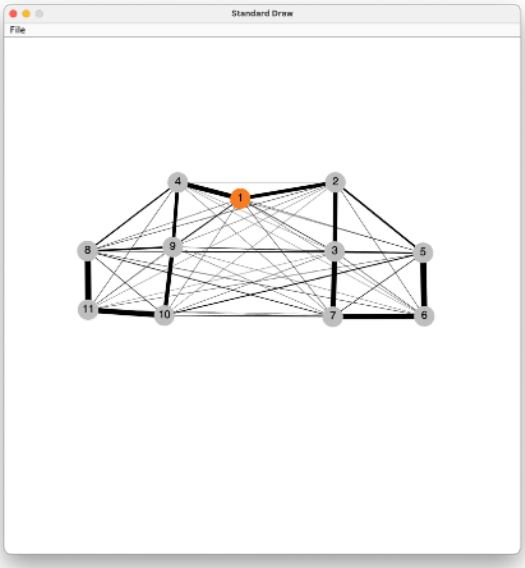


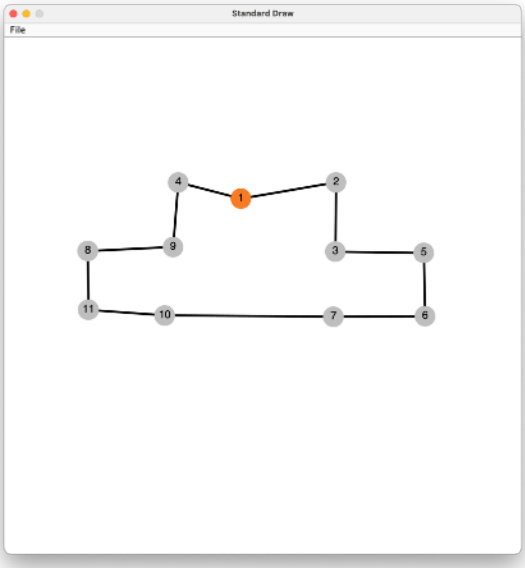
```
/Users/boramacbook/Library/Java/JavaVirtualMachines/openjdk-21.0.2/Contents/Home/bin/java -javaagent:/Applications/IntelliJ IDEA CE.app/Contents/lib/idea_rt.ja
Method: Brute-Force Method
Shortest distance: 3.710988906673479
[1, 2, 3, 13, 10, 14, 11, 9, 5, 6, 4, 8, 7, 12, 1]
Time it takes to find the shortest path: 122.907 seconds.
```

(input05.txt is not demonstrated because of extreme time durations)

Outputs Utilizing Ant Colony Optimization Methods

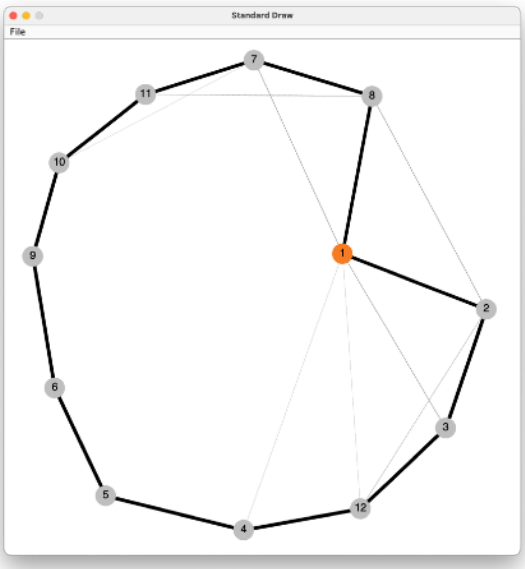
input01.txt

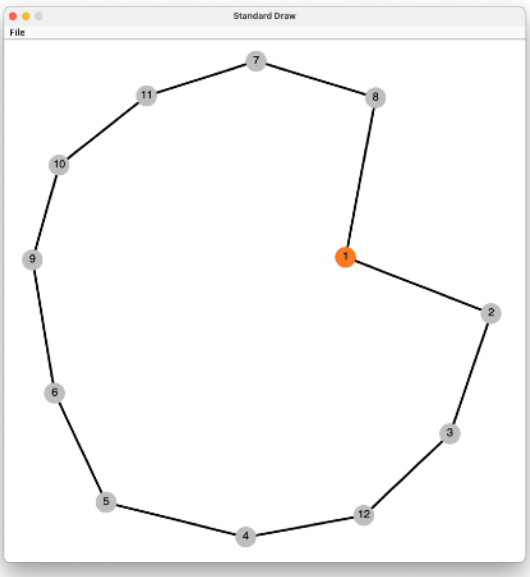





```
/Users/boramacbook/Library/Java/JavaVirtualMachines/openjdk-21.0.2/Contents/Home/bin/java -javaagent:/Applications/IntelliJ IDEA CE.app/Contents/lib/idea_rt.jar=5
Method: Ant Colony Optimization Method
Shortest Distance: 1.795291385677243
Path: [1, 2, 3, 5, 6, 7, 10, 11, 8, 9, 4, 1]
Time it takes to find the shortest path: 0.183 seconds.
```

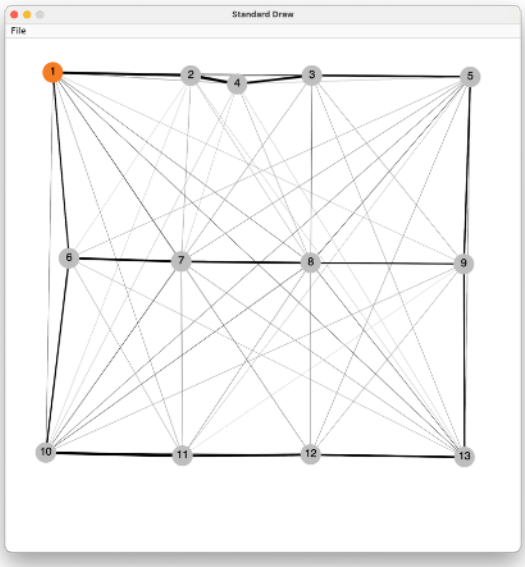
İnput02.txt

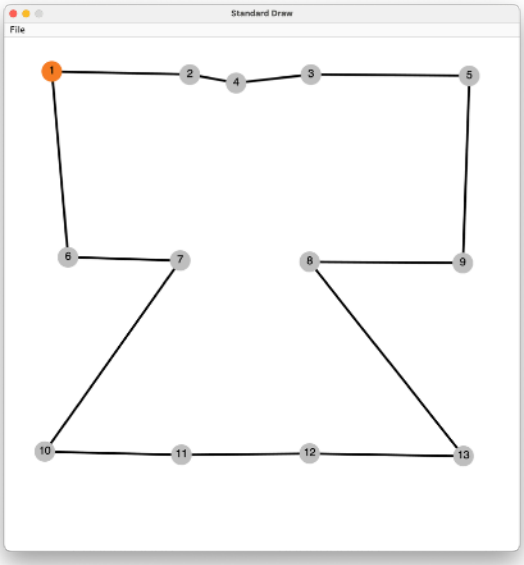





```
/Users/boramacbook/Library/Java/JavaVirtualMachines/openjdk-21.0.2/Contents/Home/bin/java -javaagent:/Applications/IntelliJ IDEA CE.app/Contents/lib/idea_rt.jar=5
Method: Ant Colony Optimization Method
Shortest Distance: 2.9358771432375974
Path: [1, 2, 3, 12, 4, 5, 6, 9, 10, 11, 7, 8, 1]
Time it takes to find the shortest path: 0.135 seconds.
```

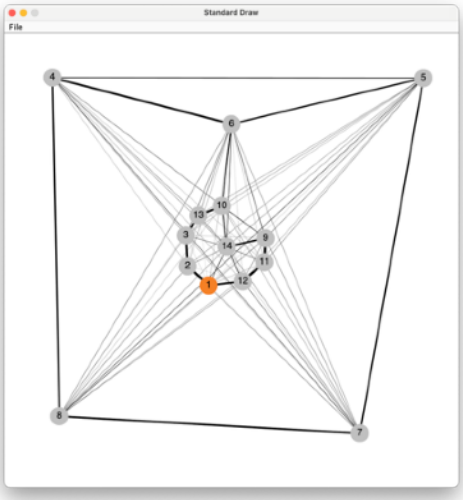
input03.txt

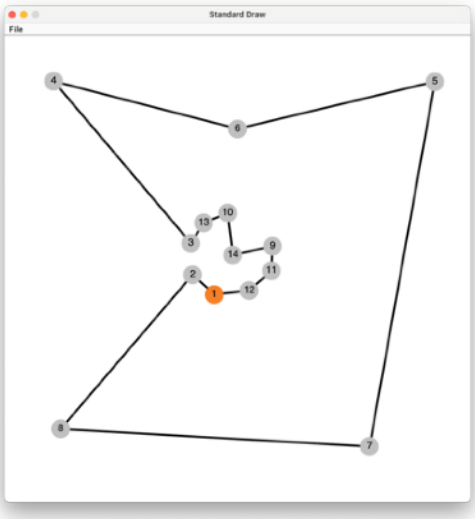





```
/Users/boramacbook/Library/Java/JavaVirtualMachines/openjdk-21.0.2/Contents/Home/bin/java -javaagent:/Applications/IntelliJ IDEA CE.app/Contents/lib/idea_rt.jar=5(
Method: Ant Colony Optimization Method
Shortest Distance: 3.802919361826042
Path: [1, 6, 7, 10, 11, 12, 13, 8, 9, 5, 3, 4, 2, 1]
Time it takes to find the shortest path: 0.139 seconds.
```

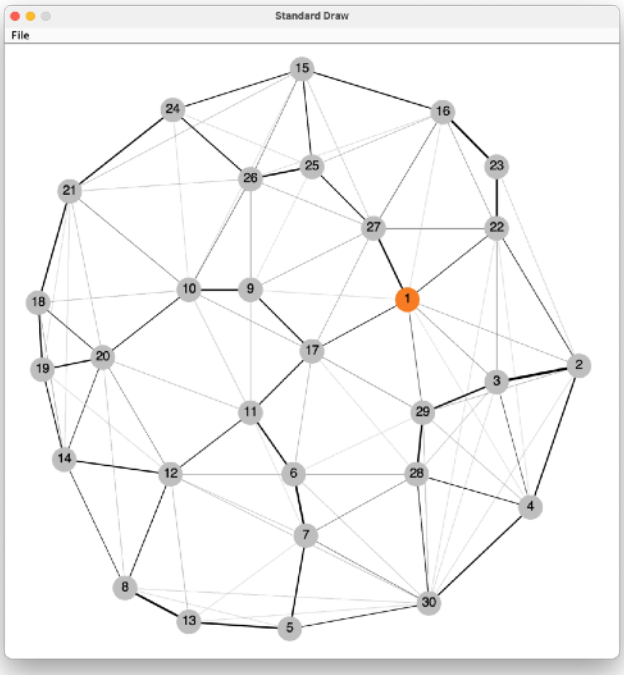
input04.txt

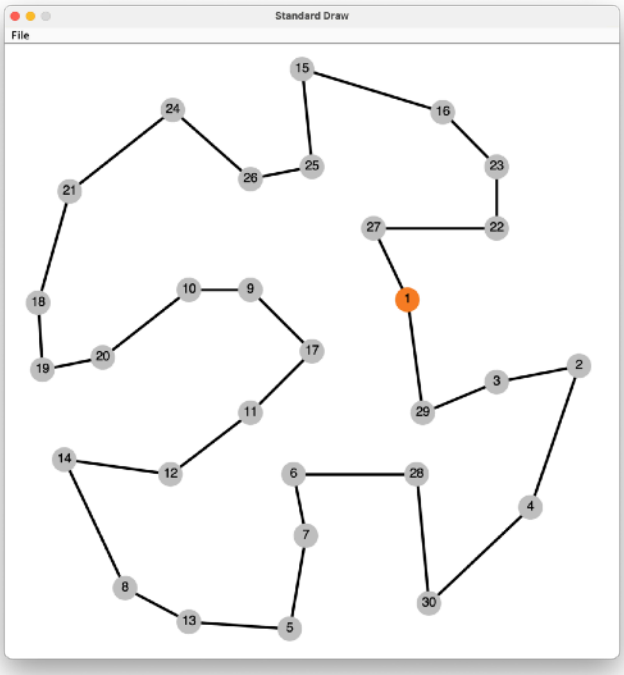


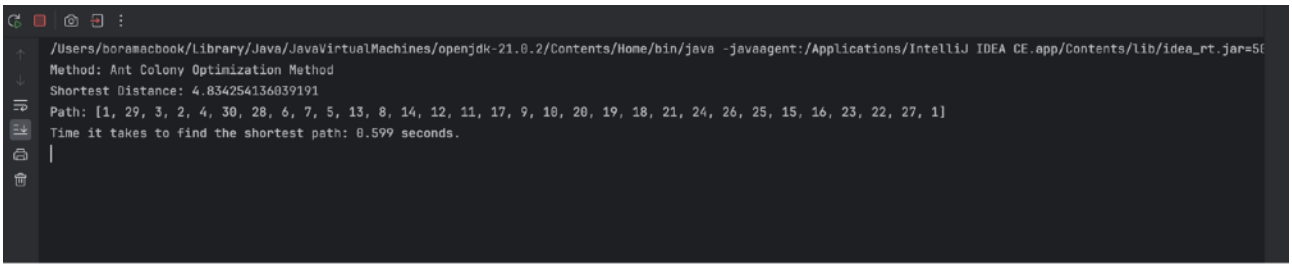



```
/Users/boramacbook/Library/Java/JavaVirtualMachines/openjdk-21.0.2/Contents/Home/bin/java -javaagent:/Applications/IntelliJ IDEA CE.app/Contents/lib/idea_rt.jar=56
Method: Ant Colony Optimization Method
Shortest Distance: 3.726292241180679
Path: [1, 2, 8, 7, 5, 6, 4, 3, 13, 10, 14, 9, 11, 12, 1]
Time it takes to find the shortest path: 0.168 seconds.
```

input05.txt







Based on trial and error, the most ideal values for the hyper parameters I've found are:

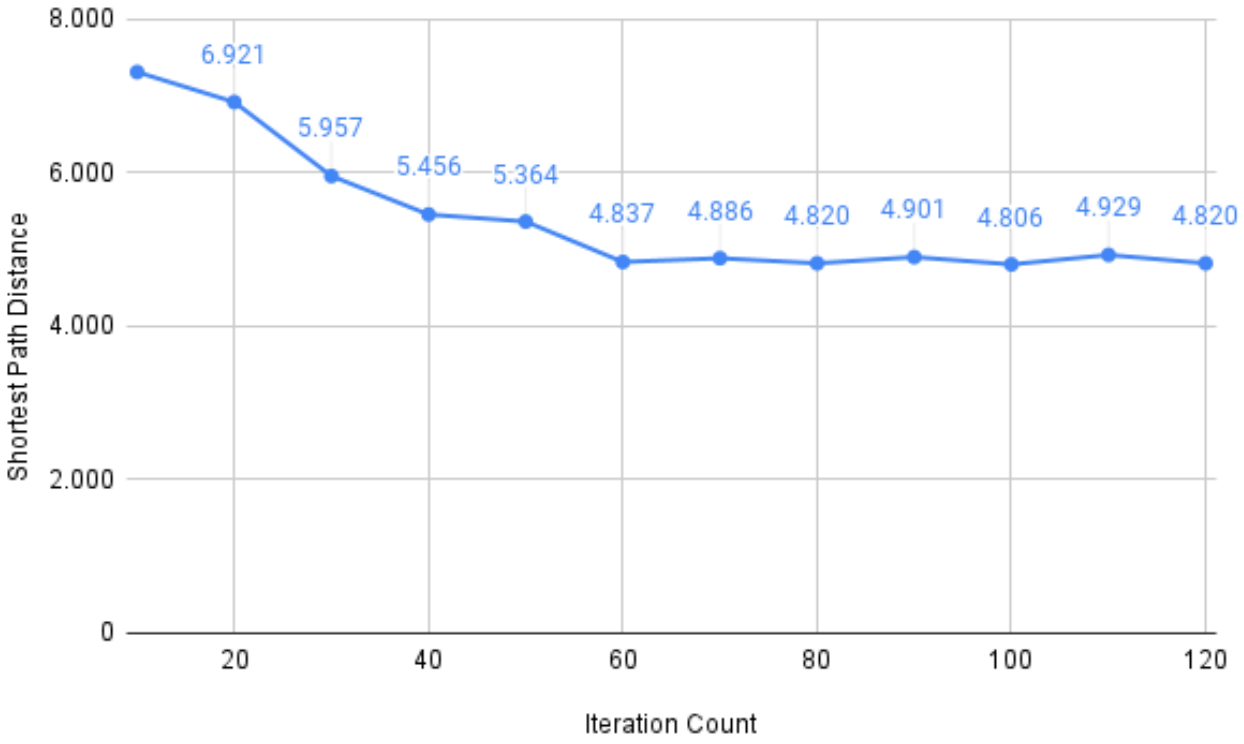
Number of ants - 150
Number of iterations - 80
Alpha - 1
Beta - 1.6
Evaporation Rate - 0.9
Q - 0.0001
Pheromone Intensity - 0.01

A Comparison of Both Methods

Input File	Number of Houses + Micros	Brute Force Time (seconds)	Ant Colony Time (seconds)	Speed Up Factor
Input1	11	0,084 (Distance: 1,79529)	0,103 (Distance: 1,79529)	0,81 times as fast
Input2	12	0,72 (Distance: 2,93587)	0,135 (Distance: 2,93587)	5 times faster

Input File	Number of Houses + Micros	Brute Force Time (seconds)	Ant Colony Time (seconds)	Speed Up Factor
Input3	13	9,296 (Distance: 3,80291)	0,139 (Distance: 3,80291)	66 times faster
Input4	14	122,907 (Distance: 3,71090)	0,168 (Distance: 3,72629)	731 times faster
Input5	30	(too long to compute)	0,599 (Distance: 4,83425)	(able to reach a result in a realistic time interval)

The Effect of Iteration Count over the Shortest Path Distance



Some External Resources I Have Utilized

https://youtu.be/EJKdmEbGre8?si=wGtDB93-t_px3Eua
https://youtu.be/oXb2nC-e_EA?si=LqGTgVSxhpde5i07

Advantages of the Ant Colony Method (Compared to Brute Force)
- Much faster, and less demanding on hardware to perform
- Easily scaleable (to larger amounts of data
- Reaches a sufficient amount of accuracy for most cases

Disadvantages of the Ant Colony Method (Compared to Brute Force)
- It is uncertain whether the end result is the actual shortest route
- Slower than brute force for small amounts of data (10 nodes or less)
- Harder to implement