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DS210 - Final Project Report

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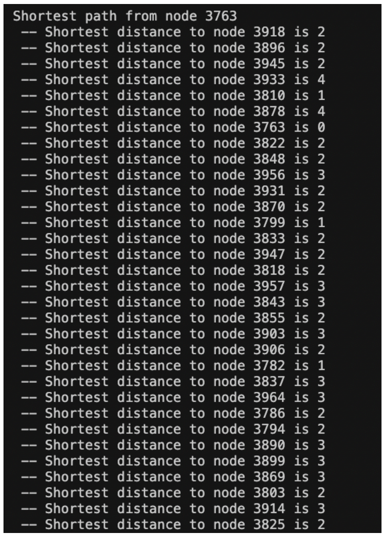
In the era of social media, relationships in social networks can represent important data analysis and trends. My project aims to address this question: "Are the friends of my friends also my friends?" By analyzing a dataset obtained from Facebook, I explore the interconnectedness of individuals within social networks. I do this by understanding how similar the sets of neighboring vertices for 2 nodes that are connected are.

Dataset Description:
The dataset comprises anonymized 'circles' or 'friends lists' from Facebook, collected via a survey app. Each node represents a user profile, and edges denote friendships between individuals.

Code Output:

**** How to get output:** You can comment out certain lines in my main module to only see specific outputs. The overall output is my shortest paths, followed by similarity scores for each node pair, followed by the statistical analysis of mean, max, and percentages with a given BFS distance. You can change the BFS distance in the main function to be 1,2,3 etc and see how it affects the statistical analysis. I have long outputs for the shortest path and jaccard similarity, so I will only be including part of what is printed for each in this report.

Shortest path output: Prints for all the nodes the node at the top is connected to and how far the distance is. The shortest paths from each node to all other nodes in the network, and it indicates how many steps it takes to reach each node from a given starting node. It provides insights into the connectivity and structure of the social network.



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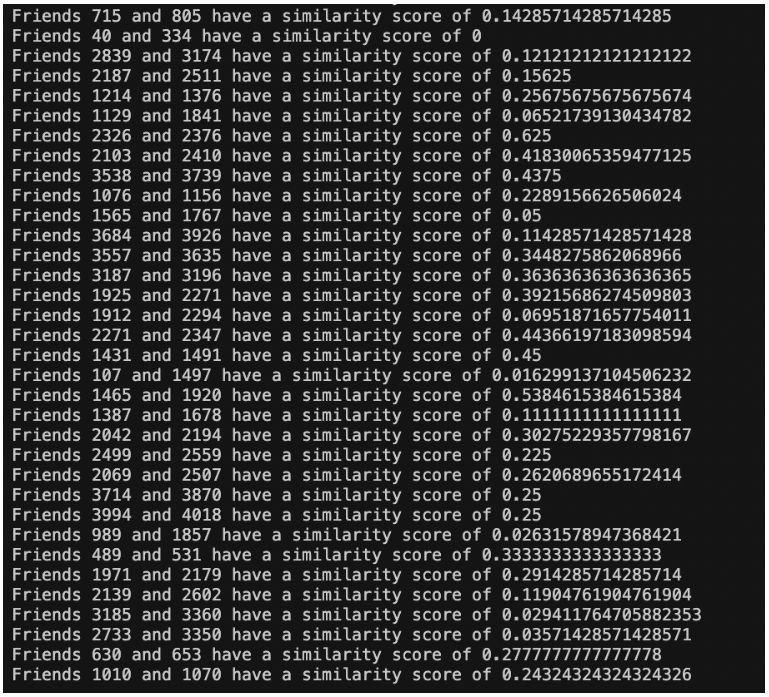
Shortest path from node 3763
 -- Shortest distance to node 3918 is 2
 -- Shortest distance to node 3896 is 2
 -- Shortest distance to node 3945 is 2
 -- Shortest distance to node 3933 is 4
 -- Shortest distance to node 3810 is 1
 -- Shortest distance to node 3878 is 4
 -- Shortest distance to node 3763 is 0
 -- Shortest distance to node 3822 is 2
 -- Shortest distance to node 3848 is 2
 -- Shortest distance to node 3956 is 3
 -- Shortest distance to node 3931 is 2
 -- Shortest distance to node 3870 is 2
 -- Shortest distance to node 3799 is 1
 -- Shortest distance to node 3833 is 2
 -- Shortest distance to node 3947 is 2
 -- Shortest distance to node 3818 is 2
 -- Shortest distance to node 3957 is 3
 -- Shortest distance to node 3843 is 3
 -- Shortest distance to node 3855 is 2
 -- Shortest distance to node 3903 is 3
 -- Shortest distance to node 3906 is 2
 -- Shortest distance to node 3782 is 1
 -- Shortest distance to node 3837 is 3
 -- Shortest distance to node 3964 is 3
 -- Shortest distance to node 3786 is 2
 -- Shortest distance to node 3794 is 2
 -- Shortest distance to node 3890 is 3
 -- Shortest distance to node 3899 is 3
 -- Shortest distance to node 3869 is 3
 -- Shortest distance to node 3803 is 2
 -- Shortest distance to node 3914 is 3
 -- Shortest distance to node 3825 is 2
```

Jaccard similarity score output (For a BFS distance of 1):



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Friends 715 and 805 have a similarity score of 0.14285714285714285
Friends 40 and 334 have a similarity score of 0
Friends 2839 and 3174 have a similarity score of 0.12121212121212122
Friends 2187 and 2511 have a similarity score of 0.15625
Friends 1214 and 1376 have a similarity score of 0.25675675675675674
Friends 1129 and 1841 have a similarity score of 0.06521739130434782
Friends 2326 and 2376 have a similarity score of 0.625
Friends 2103 and 2410 have a similarity score of 0.41830065359477125
Friends 3538 and 3739 have a similarity score of 0.4375
Friends 1076 and 1156 have a similarity score of 0.2289156626506024
Friends 1565 and 1767 have a similarity score of 0.05
Friends 3684 and 3926 have a similarity score of 0.11428571428571428
Friends 3557 and 3635 have a similarity score of 0.3448275862068966
Friends 3187 and 3196 have a similarity score of 0.36363636363636365
Friends 1925 and 2271 have a similarity score of 0.39215686274509803
Friends 1912 and 2294 have a similarity score of 0.06951871657754011
Friends 2271 and 2347 have a similarity score of 0.44366197183098594
Friends 1431 and 1491 have a similarity score of 0.45
Friends 107 and 1497 have a similarity score of 0.016299137104506232
Friends 1465 and 1920 have a similarity score of 0.5384615384615384
Friends 1387 and 1678 have a similarity score of 0.1111111111111111
Friends 2042 and 2194 have a similarity score of 0.30275229357798167
Friends 2499 and 2559 have a similarity score of 0.225
Friends 2069 and 2507 have a similarity score of 0.2620689655172414
Friends 3714 and 3870 have a similarity score of 0.25
Friends 3994 and 4018 have a similarity score of 0.25
Friends 989 and 1857 have a similarity score of 0.02631578947368421
Friends 489 and 531 have a similarity score of 0.3333333333333333
Friends 1971 and 2179 have a similarity score of 0.2914285714285714
Friends 2139 and 2602 have a similarity score of 0.11904761904761904
Friends 3185 and 3360 have a similarity score of 0.029411764705882353
Friends 2733 and 3350 have a similarity score of 0.03571428571428571
Friends 630 and 653 have a similarity score of 0.2777777777777778
Friends 1010 and 1070 have a similarity score of 0.24324324324324326
```

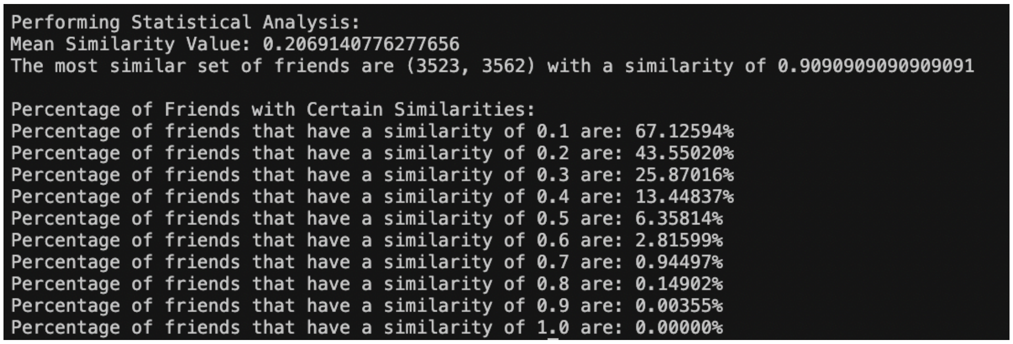
So what is a jaccard similarity and what does it measure?

Jaccard similarity is a measure of similarity between two sets. It is defined as the size of the intersection of the sets divided by the size of the union of the sets. In the context of social networks, Jaccard similarity can be used to quantify the similarity between the neighborhoods (sets of connections) of two individuals. In my project, I used it to find the similarity of neighboring vertices for 2 connected nodes. Jaccard similarity scores for pairs of nodes, showing the degree of overlap in their mutual connections. Higher scores imply greater similarity between the neighborhoods.

Formula for Jaccard's:

$\boldsymbol{J(A,B)= (\ |A \cap B| }$ **divided by** $\boldsymbol{|A \cup B| \ )}$ where A and B is the size of the intersection of sets A and B (number of common elements), and A or B is the size of the union of sets A and B (total number of distinct elements).

Statistical analysis output (for a BFS distance of 1):



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Performing Statistical Analysis:
Mean Similarity Value: 0.2069140776277656
The most similar set of friends are (3523, 3562) with a similarity of 0.9090909090909091

Percentage of Friends with Certain Similarities:
Percentage of friends that have a similarity of 0.1 are: 67.12594%
Percentage of friends that have a similarity of 0.2 are: 43.55020%
Percentage of friends that have a similarity of 0.3 are: 25.87016%
Percentage of friends that have a similarity of 0.4 are: 13.44837%
Percentage of friends that have a similarity of 0.5 are: 6.35814%
Percentage of friends that have a similarity of 0.6 are: 2.81599%
Percentage of friends that have a similarity of 0.7 are: 0.94497%
Percentage of friends that have a similarity of 0.8 are: 0.14902%
Percentage of friends that have a similarity of 0.9 are: 0.00355%
Percentage of friends that have a similarity of 1.0 are: 0.00000%
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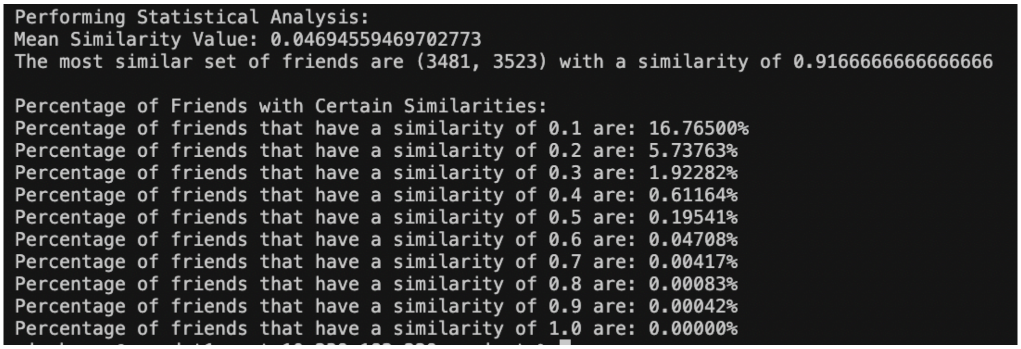
Statistical analysis output (for a BFS distance of 2):



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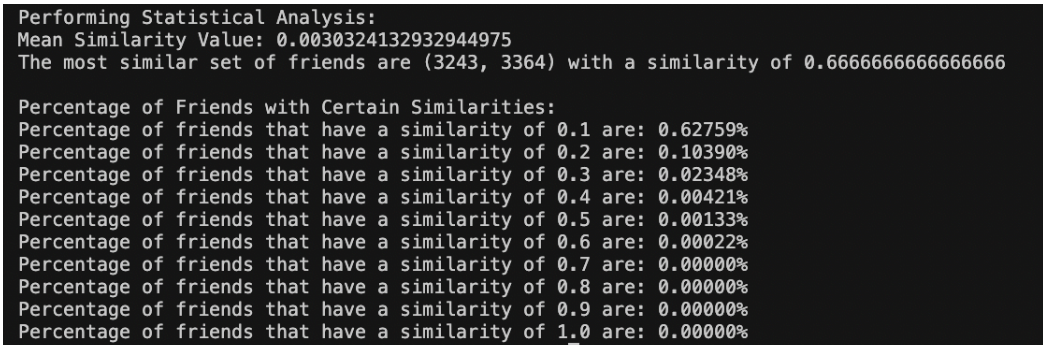
Performing Statistical Analysis:
Mean Similarity Value: 0.04694559469702773
The most similar set of friends are (3481, 3523) with a similarity of 0.9166666666666666

Percentage of Friends with Certain Similarities:
Percentage of friends that have a similarity of 0.1 are: 16.76500%
Percentage of friends that have a similarity of 0.2 are: 5.73763%
Percentage of friends that have a similarity of 0.3 are: 1.92282%
Percentage of friends that have a similarity of 0.4 are: 0.61164%
Percentage of friends that have a similarity of 0.5 are: 0.19541%
Percentage of friends that have a similarity of 0.6 are: 0.04708%
Percentage of friends that have a similarity of 0.7 are: 0.00417%
Percentage of friends that have a similarity of 0.8 are: 0.00083%
Percentage of friends that have a similarity of 0.9 are: 0.00042%
Percentage of friends that have a similarity of 1.0 are: 0.00000%
```

Statistical analysis output (for a BFS distance of 3):



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Performing Statistical Analysis:
Mean Similarity Value: 0.0030324132932944975
The most similar set of friends are (3243, 3364) with a similarity of 0.6666666666666666

Percentage of Friends with Certain Similarities:
Percentage of friends that have a similarity of 0.1 are: 0.62759%
Percentage of friends that have a similarity of 0.2 are: 0.10390%
Percentage of friends that have a similarity of 0.3 are: 0.02348%
Percentage of friends that have a similarity of 0.4 are: 0.00421%
Percentage of friends that have a similarity of 0.5 are: 0.00133%
Percentage of friends that have a similarity of 0.6 are: 0.00022%
Percentage of friends that have a similarity of 0.7 are: 0.00000%
Percentage of friends that have a similarity of 0.8 are: 0.00000%
Percentage of friends that have a similarity of 0.9 are: 0.00000%
Percentage of friends that have a similarity of 1.0 are: 0.00000%
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The values of mean and max similarity are really important as the BFS distance changes, and it shows how similarities can change when there are more ‘steps’ between two nodes whose neighboring vertices are analyzed. The percentage of nodes with similarity scores above various thresholds is used to understand the strength and distribution of connections within the network. For each BFS we can see the percentage of friends in the whole dataset who are at least that threshold similar from 0.1-1.0. The similarity value 1.0 is identical. An interesting finding is that even with a BFS distance of 1 (the closest connections between nodes), the percent of friends with a similarity of 1.0 is 0%. This means that in my Facebook dataset, no two people have the exact same friends. When we look at a similarity of 0.6 for the same distance (which is more than 50% similar), 2.81% of people are that similar, and while this number is still low, it proves that it is true that for some people, their friends can also be their friends friends to a pretty similar degree.

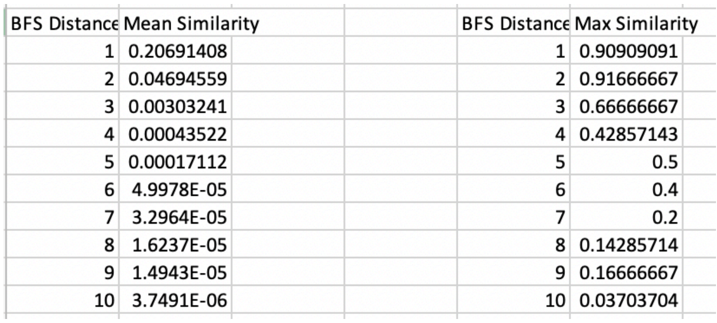
Further analysis on my program:

Code Explanations:
Graph Representation: I have used a graph data structure to model the social network, with nodes representing user profiles and edges indicating friendships. The Graph module facilitates the creation of the graph from a file and computation of shortest paths between nodes.
Shortest Path Calculation: Using the Breadth-First Search (BFS) algorithm, the Shortest Path module calculates the shortest paths from all nodes in the graph. This information is useful for understanding the closeness of nodes, and more broadly, the connections between individuals in the social network. BFS systematically visits all the neighboring nodes of the current node before moving on to the next level of neighbors. It operates by maintaining a queue data structure to keep track of nodes to be visited, making sure that nodes are visited in the order of their distance from the source node.
Similarity Score Computation: The Similarity Scores module computes the Jaccard similarity between the neighborhoods of pairs of nodes in the graph. This metric measures the similarity of mutual connections and is the main way to understand if friends of friends are friends themselves too or not, scored from a range of 0.0 to 1.0. Higher similarity scores suggest a greater overlap in mutual connections, indicating that friends of friends are likely to be friends themselves.
Statistical Analysis: My Statistical Analysis module conducts statistical analyses on the computed similarity scores. These include determining the mean similarity between pairs of nodes, identifying the maximum similarity, and analyzing the percentage of nodes with similarity scores above specified thresholds, like the percent of friends that are over 0.5% similar (meaning their connections are 50% similar too).
Testing: I used a test.txt with just 4 nodes to test all my functions (at the bottom of the main module). I did a cargo test, and all 4 tests passed.

Analysis of project output:

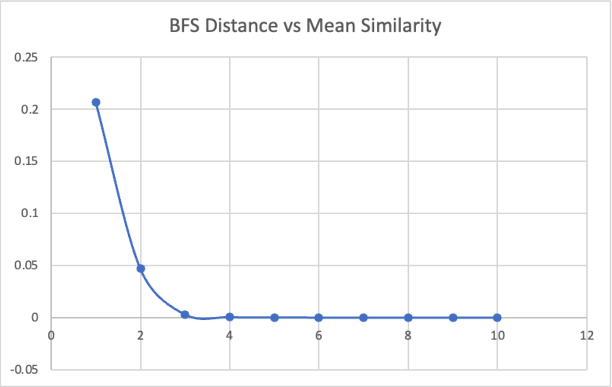
While analyzing the change in mean and max similarity values for different BFS neighbors (i.e. 1, 2, 3), if we make a table and graph the similarity outputs for each BFS distance, this is the result:

Table:

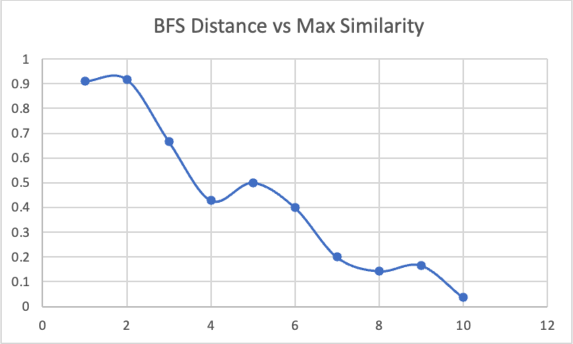


BFS Distance	Mean Similarity			BFS Distance	Max Similarity
1	0.20691408			1	0.90909091
2	0.04694559			2	0.91666667
3	0.00303241			3	0.66666667
4	0.00043522			4	0.42857143
5	0.00017112			5	0.5
6	4.9978E-05			6	0.4
7	3.2964E-05			7	0.2
8	1.6237E-05			8	0.14285714
9	1.4943E-05			9	0.16666667
10	3.7491E-06			10	0.03703704

Plot for Mean Similarity:



Plot for Max Similarity:



These plots show that as the Jaccard similarity is computed on more distances of BFS (like 2 nodes between a connection, 3, 4 or more), the similarity tends to decrease. This, for my project, allows me to infer that individuals who are less close to other individuals tend to have less similarities and different friends too. Therefore, the closer you are to someone, (3 or less degrees away), the more likely you are to have similar friend groups as them and as a result it is more likely that the friends of your friend are also your friends.

The maximum similarly found in my dataset for a BFS distance of 1 was around 0.909, which means the "individuals" 577 and 578 are almost identical when it comes to their connections. These neighboring vertices were 0.909 the same, making the nodes they were connected to (577 and 578) very similar as well. This shows that when friends are connected by a short degree (i.e. 1), they have a lot of mutual friends (almost 91%). However, when you go further away, like with a BFS distance of 3 separating the friends, the maximum is just 0.66, which shows that they do not have that many mutual connections anymore. This data can be utilized for real work applications in terms of Facebook, like perhaps if someone is interested in an advertisement/something displayed on Facebook Marketplace, it would be useful for the algorithm to also present the advertisement to their close connections and vertices (mutuals) of the close connections (BFS distance of 3 or less) to gain as much revenue as possible.

Overall, this project demonstrates the utility of graph algorithms and similarity scores in analyzing social network connectivity. By computing similarity scores and conducting statistical analysis, I'm providing insights into the structure and dynamics of social networks, confirming the hypothesis that friends of friends tend to share mutual connections, but only if they are pretty well connected themselves.