

DS210 Final Project Report

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Analysis of S&P 500 stock data from 2013 to 2018 (for 5 years)

1. Introduction

Since I was young, I was deeply interested in financial markets and wanted to find out what factors caused the substantial changes into the market. According to the historical patterns captured from the stock market, there always have been stocks that led the entire market's movement during a specific period of time. Thus, in this project, I will delve into the world of financial markets to uncover underlying patterns and relationships between stocks using network analysis. By applying centrality measures on a graph constructed from stock data, the goal is to identify key stocks that significantly influence market dynamics.

2. Components of Project

main.rs - serves as the entry point of the application, coordinating the flow of data through various modules

graph_construction.rs - handles the construction of the graph from the dataset, defining nodes as stocks and edges as correlations between their returns

centrality.rs - contains algorithms to compute betweenness centrality using Breadth-First Search (BFS) for understanding the relationship between stocks

3. Details of the Modules

graph_construction.rs

- Structures and data parsing: I defined a *StockRecord* struct for parsing csv data while focusing on *close* prices and stock *name*.
- fn build_graph: this function dynamically constructs a directed graph where nodes represent stocks and edges represent the strength of correlation between their closing prices

centrality.rs

- fn calculate_betweenness_centrality: this function calculates and analyzes the centrality of nodes within the graph, identifying key stocks that act as bridges in the financial network.

4. Insights from Analysis

The betweenness centrality analysis of stocks within the S&P index provides profound insight into which stock plays the pivotal role in the market network. This analysis describes who key influencers are and their potential impact on the market's dynamics.

Key Market Influencers

- First Energy Corp (FE) with a centrality score of 2369.8785, stands out as the most influential stock in the network. This indicates that this stock acts as a major hub through which a significant volume of market activity is channeled, thereby playing a major role in market connectivity.
- American Airlines (AAL) and Illumina (ILMN) followed with scores of 1325.1954 and 1161.4172, respectively. Their positions underscore the strategic importance of these companies within the market, possibly due to their sectoral impacts or trading behaviors that link diverse market segments.
- Other notable stocks like AT&T (T), WestRock (WRK), and PPG industries (PPG) also exhibit high centrality scores, further highlighting their roles as central nodes within the market. These companies help bridge different parts of the financial ecosystem, facilitating the flow of capital and information

Insights on Market Structure

- The distribution of centrality scores shows a wide variance, indicating a heterogeneous connectivity landscape within the S&P 500. Stocks with very high centrality scores, such as FE and AAL, might be seen as critical nodes whose performance or trading patterns could have disproportionate effects on the broader market.
- The presence of diverse sectors among the top-ranked stocks by centrality—ranging from utilities and airlines to biotechnology and telecommunications—suggests that influential roles are not confined to traditional financial heavyweights like banks or tech giants. This diversity underscores the complex, interconnected nature of modern financial markets.
- The analysis also highlights that not all high-capitalization stocks are necessarily central in terms of network flow, and vice versa. This dissociation between market cap and network centrality points to potential undervalued strategic

positions or overvalued stocks with less influence on market structure than presumed.

Strategic Implications

These insights are invaluable for investors, market analysts, and portfolio managers. Understanding which stocks are central to the market network can help in devising strategies that are resilient to shocks or capable of capitalizing on the pivotal roles of these stocks. Additionally, regulatory bodies might interest themselves in these insights to better monitor systemic risks and ensure market stability.

Breadth-First Search (BFS) for the Dataset

I chose to use the Betweenness Centrality measure algorithm based on Breadth-First Search (BFS) for this project for several compelling reasons:

- **Unweighted Graph:** The dataset, consisting of stock interactions based on uniform correlations (binary conditions or simple interactions), makes it ideal for using BFS. This algorithm is perfectly suited for graphs where all edges have equivalent weight, as it explores nodes layer by layer according to their distance from the source node, ensuring that the shortest paths in terms of the number of edges are considered first.
- **Importance of Connections:** Betweenness Centrality measured through BFS helps highlight nodes that act as critical connectors within the network. Stocks with high betweenness centrality scores play a crucial role in facilitating and influencing the flow of transactions and information across the market. Such nodes are strategic bridging points that can significantly impact the network's efficiency and resilience.
- **Efficient Path Discovery:** BFS efficiently explores all shortest paths (by edge count) between nodes in an unweighted setting. This capability is critical in networks where path costs are uniform or undefined, allowing the algorithm to swiftly map out the connectivity landscape of the entire network, which is especially useful in expansive datasets like those of the S&P 500 stocks.
- **Computational Simplicity:** While BFS is straightforward, its ability to handle large datasets—such as the extensive connections among S&P 500 stocks simplifies implementation and reduces computational overhead. The algorithm operates with a complexity of $O(V+E)$ where V is the number of vertices and E is the number of edges.
- **Non-Directional Analysis:** Unlike scenarios that require recognizing directional data (as in the flow from one specific stock to another), BFS treats the graph as undirected at the level of path discovery, focusing purely on connectivity. This

approach is suitable when the direction of influence is uniform or bidirectional, typical in correlation networks where mutual influences are the norm.

5. Output

```
[  Finished dev [unoptimized + debuginfo] target(s) in 0.17s
  Running `~/Users/seunghwan/Desktop/DS210/final_project/stock_analysis/target/debug/stock_analysis`  
Stock: FE, Centrality: 2369.8785  
Stock: AAL, Centrality: 1325.1954  
Stock: ILMN, Centrality: 1161.4172  
Stock: T, Centrality: 1044.0239  
Stock: WRK, Centrality: 1010.4212  
Stock: PPG, Centrality: 960.2549  
Stock: EQR, Centrality: 789.7252  
Stock: SEE, Centrality: 751.2416  
Stock: UNP, Centrality: 748.6045  
Stock: UHS, Centrality: 714.6370  
Stock: WBA, Centrality: 690.1234  
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Stock: ESRX, Centrality: 84.8221
Stock: EL, Centrality: 82.6881
Stock: XL, Centrality: 80.9536
Stock: CFG, Centrality: 80.0976
Stock: DVA, Centrality: 79.8902
Stock: LEN, Centrality: 79.0217
Stock: GM, Centrality: 77.7283
Stock: VNO, Centrality: 77.2614
Stock: MPC, Centrality: 76.4856
Stock: CHRW, Centrality: 75.4375
Stock: PPL, Centrality: 74.4558
Stock: PBCT, Centrality: 74.2255
Stock: DHI, Centrality: 71.2218
Stock: VLO, Centrality: 70.2771
Stock: AKAM, Centrality: 67.7339
Stock: PDCO, Centrality: 66.3774
Stock: WLTW, Centrality: 65.8052
Stock: KSS, Centrality: 60.5345
Stock: HPE, Centrality: 58.0464
Stock: WMT, Centrality: 58.0098
Stock: JNPR, Centrality: 56.8144
Stock: FOXA, Centrality: 55.5728
Stock: CBS, Centrality: 54.0323
Stock: GE, Centrality: 49.1419
Stock: EXC, Centrality: 48.4585
Stock: KO, Centrality: 47.7696
Stock: NI, Centrality: 41.3352
Stock: KHC, Centrality: 38.5511
Stock: FOX, Centrality: 37.2887
Stock: GWW, Centrality: 36.6272
Stock: CA, Centrality: 35.1849
Stock: LKQ, Centrality: 30.5050
Stock: NFX, Centrality: 27.0581
Stock: FAST, Centrality: 23.3266
Stock: TGT, Centrality: 20.8777
Stock: HRB, Centrality: 13.2891
Stock: EVHC, Centrality: 8.7234
Stock: BHF, Centrality: 4.0000
Stock: DWDP, Centrality: 4.0000
Stock: CSRA, Centrality: 2.1428
Stock: HLT, Centrality: 1.4144
Stock: VTR, Centrality: 0.8085
Stock: YUM, Centrality: 0.5501
Stock: BHGE, Centrality: 0.0000
Stock: VZ, Centrality: 0.0000
Stock: APTV, Centrality: 0.0000

6. Conclusion

Utilizing betweenness centrality calculated through Breaths-First Search (BFS) has unveiled critical nodes within the stock market network, providing a nuanced understanding of market dynamics. This analysis not only identifies which stocks are pivotal in influencing market flows but also enhances our understanding of how interconnectedness in financial networks can be leveraged to optimize trading strategies. The insights gained underscore the importance of network theory in financial analysis and highlight the potential for these methods to inform more sophisticated investment approaches.

7. Test

```
((base) seunghwan@crc-dot1x-nat-10-239-233-201 src % cargo test
Compiling stock_analysis v0.1.0 (/Users/seunghwan/Desktop/DS210/final_project/stock_analysis)
Finished test [unoptimized + debuginfo] target(s) in 0.50s
Running unitests src/main.rs (/Users/seunghwan/Desktop/DS210/final_project/stock_analysis/target/debug/deps/stock_analysis-f1692ce68cff5dfa)

running 1 test
test tests::test_simple_graph_construction ... ok

test result: ok. 1 passed; 0 failed; 0 ignored; 0 measured; 0 filtered out; finished in 0.00s
```

8. Resources

- Rust Documentation - <https://doc.rust-lang.org/>
- Std::io <https://doc.rust-lang.org/std/io/index.html>
- DS210 lectures (28, 30)
- Petgraph Library Documentation
<https://docs.rs/petgraph/latest/petgraph/graph/struct.Graph.html>
- Breadth-First Search (BFS) - https://en.wikipedia.org/wiki/Breadth-first_search
- Dataset - <https://www.kaggle.com/datasets/camnugent/sandp500>

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