# 2024 Senate and House of Representatives Candidates' Wikipedia Hyperlink Graphs Analysis

Mingming Gu and Leslie Stovall
MSDS 452: Web and Network Data Science
Northwestern University
June 9, 2024

## Summary

This study investigates the network characteristics and community structures of the 2024 U.S. Senate and House candidates based on their Wikipedia pages, utilizing graph theory and network analysis techniques. By constructing and analyzing directed hyperlink graphs, we examined the connectivity and assortativity among candidates, focusing on attributes such as incumbency, party affiliation, state, and candidacy status. Our findings reveal distinct patterns of connectivity and reciprocity within the Senate and House candidate networks. In particular, we identify the presence of tightly-knit communities and significant variations in candidate connectivity across different states and political affiliations. Through visualizations including Sankey diagrams and adjacency matrix heatmaps, we provide a comprehensive overview of the underlying structures and attribute distributions within these political candidate networks. This analysis contributes to a deeper understanding of the digital presence and interconnectivity of political figures, offering insights into the dynamics of online political representation.

## 1. Data Collection

Candidates for the U.S. Senate and U.S. House of Representatives 2024 elections were scraped from their respective Ballotpedia pages. Ballotpedia (https://ballotpedia.org/Main_Page) is a nonprofit and nonpartisan online political encyclopedia that covers elections and public policy in the United States. The desired candidates lists were located within tables organized by state and contained information such as candidate name, party affiliation, office and candidacy status. Python’s “requests" and “BeautifulSoup" libraries were utilized to scrape the Ballotpedia webpages and extract the tables from the raw HTML content.

After identifying the required tables, additional preprocessing steps were necessary to clean the tables columns and append individual state’s tables into two Python dataframes: one for Senate candidates (dfs) and one for the House candidates (dfh). This process included extracting the “Incumbent” tag from within the candidate’s name column and introducing a new “incumbency” column. This involved identifying instances where candidates were tagged as "Incumbent" in their names, removing these tags, and creating a separate column to denote incumbency status.

A key aspect of this research involved collecting the Wikipedia page of each candidate. To achieve this, using the wikipediaapi Python module (https://github.com/martin-majlis/Wikipedia-API), a function was created to check if a Wikipedia page for a given name existed. However, finding a page did not imply that it correctly corresponded to the candidate, necessitating additional validation and processing steps. This initial automated approach helped identify potential Wikipedia pages associated with each candidate’s name.

To ensure the Wikipedia pages identified were correct, we performed the following additional processing: manual verification and cross-referencing with other sources to confirm the accuracy. Wikipedia itself had a page for both the 2024 Senate (https://en.wikipedia.org/wiki/2024_United_States_Senate_elections) and House of Representative (https://en.wikipedia.org/wiki/2024_United_States_House_of_Representatives_elections) elections, which provided links to a candidate’s personal wikipedia page if it existed. The tables in these Wikipedia pages were not as thorough or updated as the Ballotpedia tables, but served as an initial automated method to cross-reference results found from searching Wikipedia for the candidates’ names.

For candidates who did not have Wikipedia pages identified through automated means, further efforts were made to manually search and verify their pages. This involved using variations of their names and checking additional sources. This thorough process ensured that the dataset included the most accurate and comprehensive information possible.

Through this systematic approach, we ensured a comprehensive collection of candidate information, facilitating the construction of a robust network analysis based on the available Wikipedia pages for 2024 U.S. Senate and House of Representatives candidates. Next, we will discuss the creation of Senate and House hyperlink graphs using the validated Wikipedia pages for the collected data.

# 2. Creation of Hyperlink Graphs

The creation of hyperlink graphs is a crucial step in visualizing the relationships and connections among the candidates for the 2024 U.S. Senate and House of Representatives elections. By mapping out the hyperlinks between the Wikipedia pages of the candidates, we can analyze the interconnectedness and network structure of the political landscape.

## 2.1. Obtaining Edge Values

To begin, the validated Wikipedia pages for each candidate were used as the basis for constructing each hyperlink graph. Each Wikipedia page in both dataframes was inspected to extract hyperlinks pointing to other Wikipedia pages. These hyperlinks represent connections between different candidates. To obtain these hyperlinks, a for-loop utilizing the “wikipediaapi.Wikipedia” Python library was used to systematically traverse each candidate’s Wikipedia page and compile a list of hyperlinks. Within the loop, we retrieved, sorted, and filtered out self-referencing links shown on each candidate's page. We stored the edge pairs in the hyperlink list when we found intersecting links with the validated Wikipedia pages.This approach allowed us to identify and capture all outgoing hyperlinks between candidates’ Wikipedia pages to be used as the edges in our network graph.

## 2.2. Building the Graphs

The two hyperlink graphs were constructed using the NetworkX library in Python (https://networkx.org/), which is designed for the creation, manipulation, and study of complex networks. Both the Senate candidate's graph (Gs) and the House candidate's graph (Gh) were initiated as a NetworkX DiGraph (directed graph). Each candidate was represented by his/her Wikipedia page as a node in their respective graph, and the hyperlinks between their Wikipedia pages (nodes) were represented as edges connecting these nodes.

- ***Nodes***: Each candidate with a validated Wikipedia page was added as a node in the graph. Additional attributes such as party affiliation, office, incumbency status, and state were assigned to each node to provide context and facilitate further analysis.
- ***Edges***: Hyperlinks extracted from the Wikipedia pages were used to create directed edges between nodes. These edges indicate a hyperlink from one candidate's Wikipedia page to another, capturing the nature of their interconnectedness.

## 2.3. Visualizations

The constructed graphs were visualized using Python's "Holoviews" library (https://www.holoviews.org/). Figures 1 and 2 display the hyperlink graphs of the Senate and House candidates' Wikipedia pages, respectively. Different visual attributes were used to enhance the clarity and interpretability of the graphs. Nodes were sized by in-degree attribute and colored by party affiliation.

**Fig 1: Senate Candidates Hyperlink Graph of Wikipedia Pages**

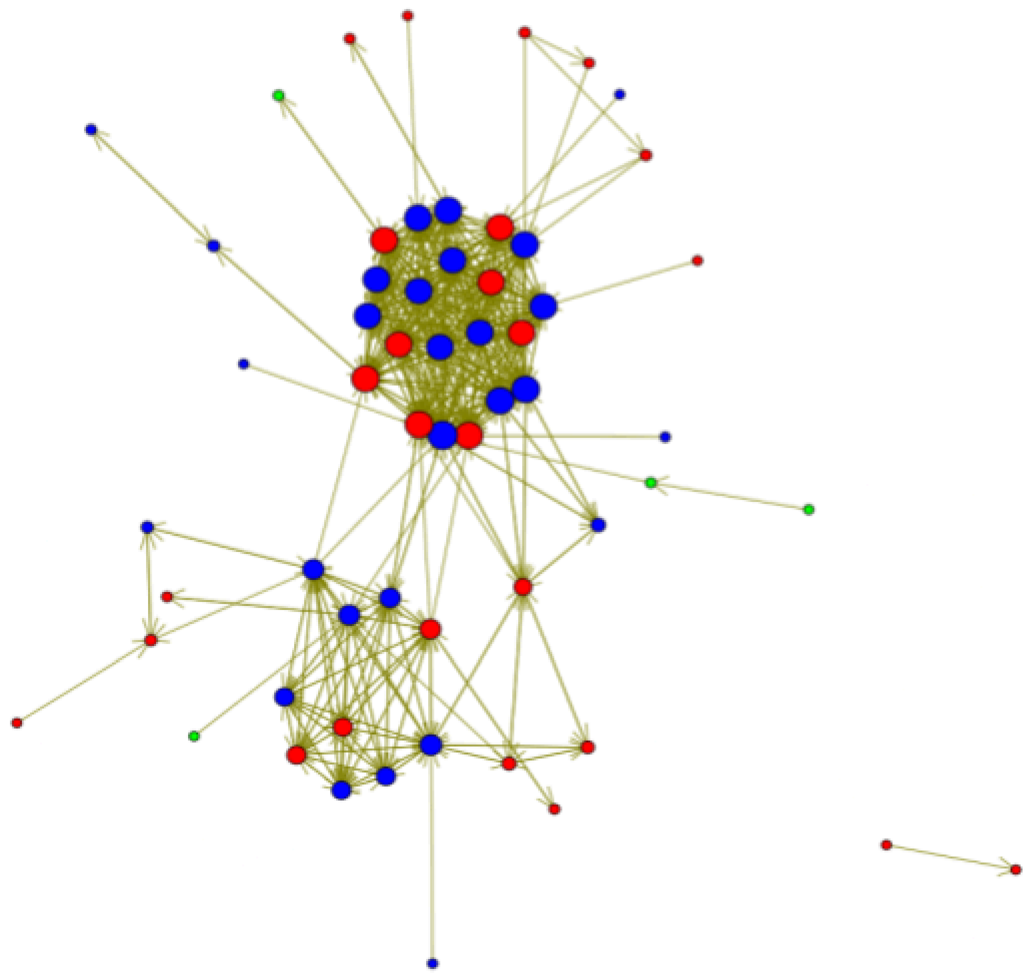
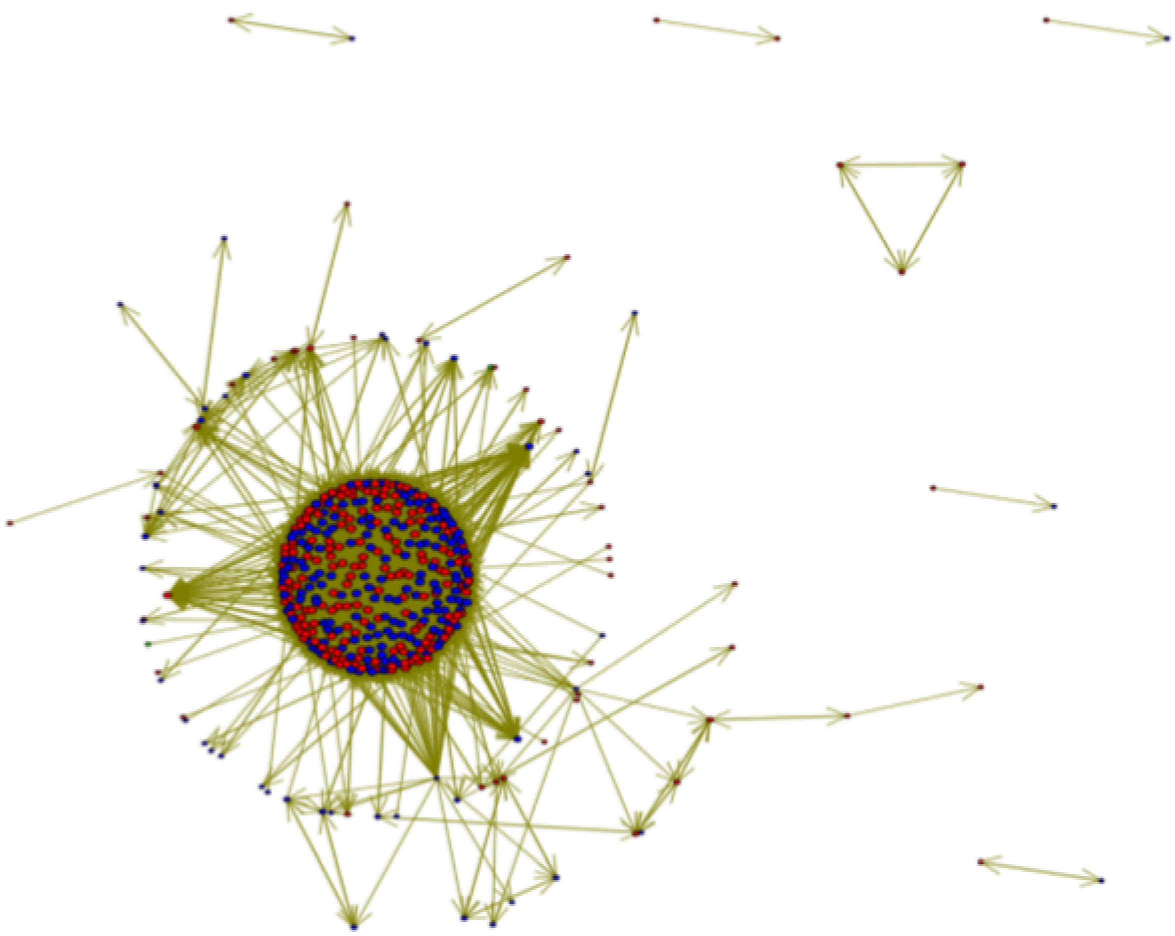


Fig 2: House Candidates Hyperlink Graph of Wikipedia Pages



# 3. Connectivity of Hyperlink Graphs

In graph theory, connectivity is a fundamental concept that describes how nodes are connected to one another within a graph (https://en.wikipedia.org/wiki/Connectivity_(graph_theory)). There are different types of connectivity depending on whether the graph is directed or undirected, each providing insights into the graph's properties and behavior. Before describing the connectedness of the Senate and House hyperlink graphs, we define these concepts.

## 3.1. Connectivity in Undirected Graphs

In an undirected graph, edges have no direction, meaning the connection between any two nodes is bidirectional.

- ***Connected Component*:** A connected component in an undirected graph is a subgraph in which any two nodes are connected to each other by paths, and which is connected to no additional nodes in the supergraph.
- ***Giant Connected Component:*** The giant connected component is the largest connected subgraph that typically contains a substantial proportion of the entire undirected graph's vertices and edges.

## 3.2. Connectivity in Directed Graphs

In directed graphs, edges have directions, indicating the relationship flows from one node to another. This gives rise to more nuanced concepts of connectivity: weak connectivity and strong connectivity.

- ***Weakly Connected Component:*** A weakly connected component is a subgraph where if the direction of edges is ignored, the subgraph is connected. This means that replacing all directed edges with undirected edges results in a connected component.
- ***Giant Weakly Connected Component:*** This is the largest weakly connected subgraph in the directed graph.
- ***Strongly Connected Component:*** A strongly connected component is a subgraph where for every pair of nodes (u, v) in the graph, there is a directed path from u to v and also another directed path from v to u.
- ***Giant Strongly Connected Component:*** This is the largest strongly connected subgraph in the directed graph.

## 3.3. Connectivity of Candidate Hyperlink Graphs

In the tables below, the enumeration column corresponds to the decreasing order of sizes of the corresponding connected components. We observe that the weakly connected component subgraphs contain more candidates compared to the strongly connected component subgraphs in both the Senate and the House, which is consistent with their definitions.

**Table 1: Table of Weakly Connected Component Subgraphs for Senate Candidates**

| Enumeration | No. of candidates | No. vertices in subgraph | No. edges in subgraph |
|---:|---:|---:|---:|
| 0 | 56 | 56 | 580 |
| 1 | 2 | 2 | 1 |

**Table 2: Table of Strongly Connected Component Subgraphs for Senate Candidates**

| Enumeration | No. of candidates | No. vertices in subgraph | No. edges in subgraph |
|---:|---:|---:|---:|
| 0 | 43 | 43 | 564 |

Table 3: Table of Weakly Connected Component Subgraphs for House Candidates

| Enumeration | No. of candidates | No. nodes in subgraph | No. edges in subgraph |
|---|---|---|---|
| 0 | 429 | 429 | 116708 |
| 1 | 3 | 3 | 6 |
| 2 | 2 | 2 | 1 |
| 3 | 2 | 2 | 1 |
| 4 | 2 | 2 | 1 |
| 5 | 2 | 2 | 2 |
| 6 | 2 | 2 | 2 |

Table 4: Table of Strongly Connected Component Subgraphs for House Candidates

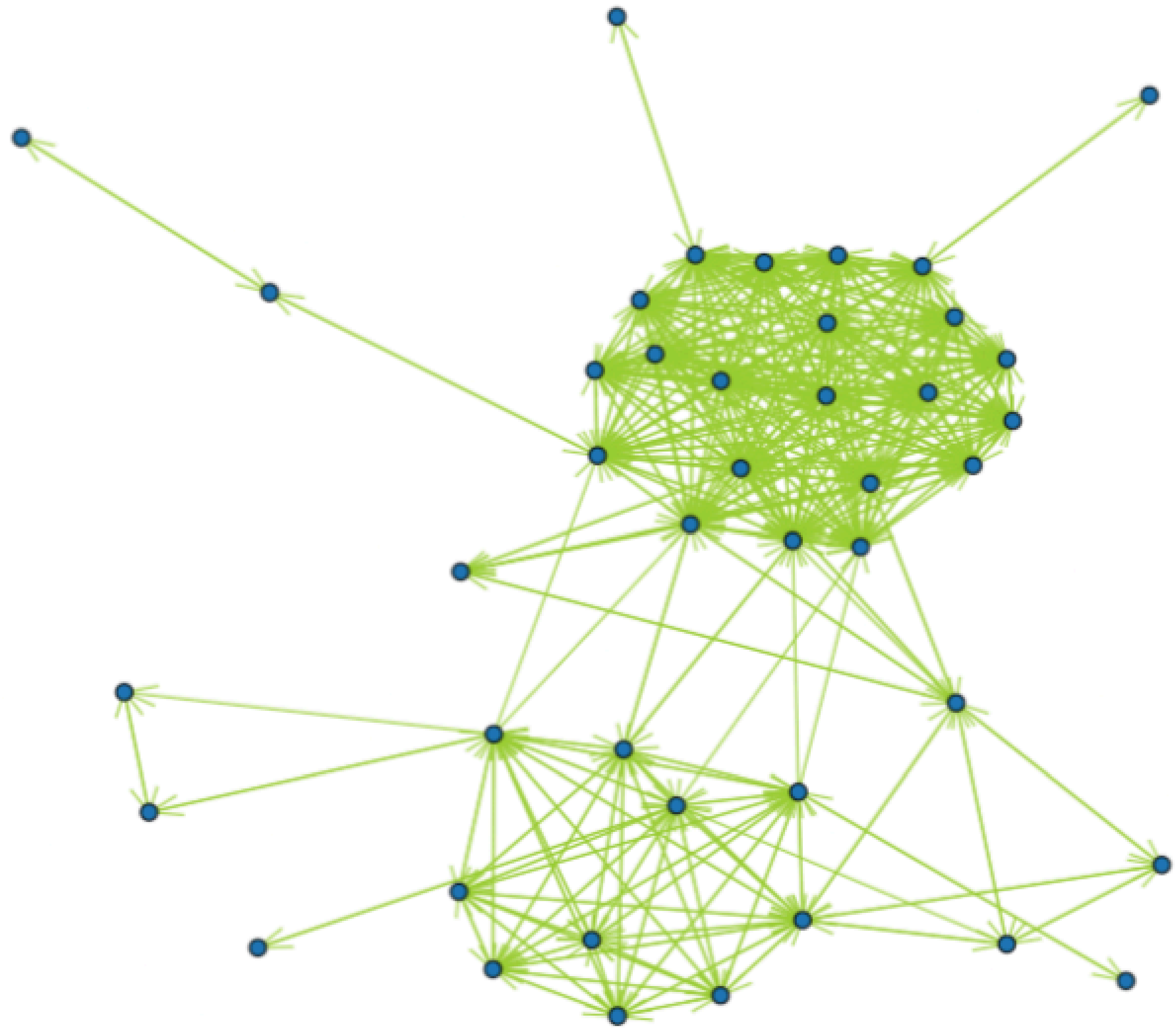
| Enumeration | No. of candidates | No. nodes in subgraph | No. edges in subgraph |
|---|---|---|---|
| 0 | 386 | 386 | 116263 |
| 1 | 4 | 4 | 8 |
| 2 | 3 | 3 | 6 |
| 3 | 3 | 3 | 6 |
| 4 | 2 | 2 | 2 |
| 5 | 2 | 2 | 2 |
| 6 | 2 | 2 | 2 |
| 7 | 2 | 2 | 2 |

## 3.4. Plots of Candidate Hyperlink Graphs

**Fig 3: Giant Weakly Connected Component of the Senate Candidates**

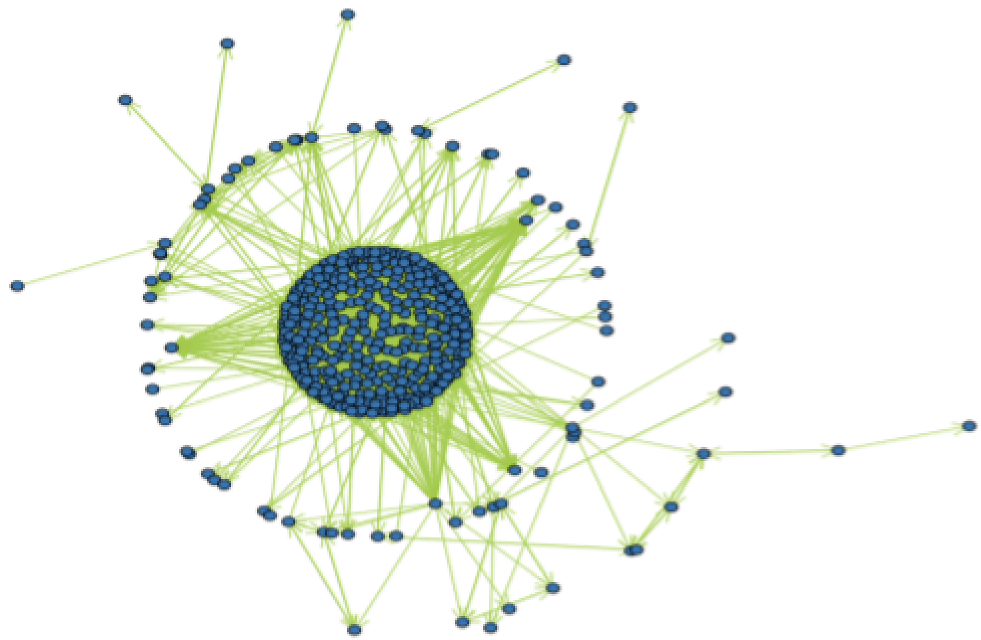
Giant weakly connected component of Senate Candidates graph has 56 nodes and 580 edges.

## Fig 4: Giant Strongly Connected Component of Senate Candidates



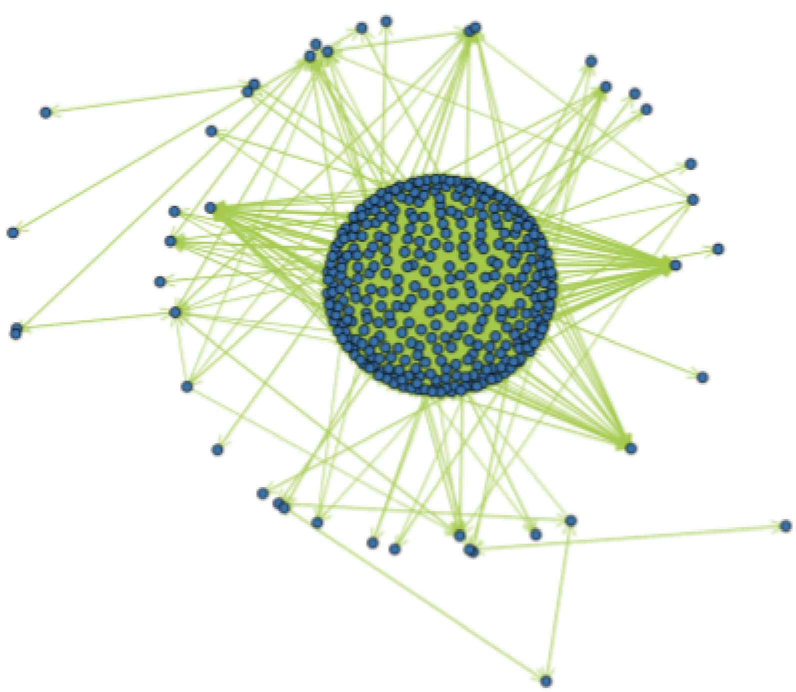
Giant strongly connected component of Senate Candidates graph has 43 nodes and 564 edges.

**Fig 5: Giant Weakly Connected Component of the House Candidates**



Giant weakly-connected component of the House candidates graph contains 429 nodes and 116,708 edges.

**Fig 6: Giant Strongly Connected Component of the House Candidates**



Giant strongly-connected component of the House candidates graph contains 386 nodes and 116,263 edges.

# 4. Reciprocated Subgraphs of Candidate Hyperlink Graphs

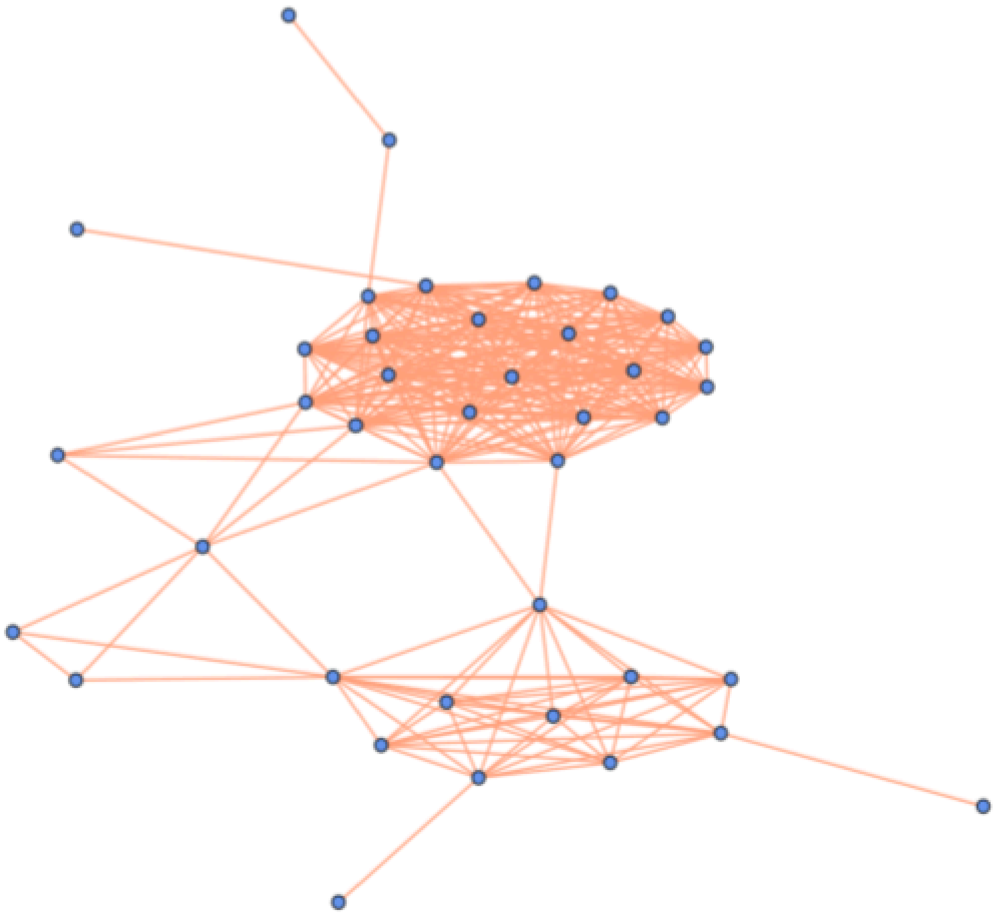
Evaluating reciprocity in directed graphs provides insight into the mutual connections between nodes. Concerning the case of candidate hyperlink graphs, to begin with, we created the reciprocated hyperlink subgraphs for both Senate (Gs) and House (Gh) candidates. Reciprocity in this context refers to pairs of candidates whose Wikipedia pages contain hyperlinks to each other. The reciprocated hyperlink subgraphs capture these mutual connections.

In a directed graph, a reciprocated edge is defined as one where, if there is a directed edge from node A to node B, there is also a directed edge from node B to node A (https://www.smrfoundation.org/networks/overall-metrics-defined/). A reciprocated graph is a subgraph consisting solely of reciprocated edges (conventionally identified as an undirected type of graph). To identify reciprocated edges for both the Gs and Gh, we iterated through all the edges in each graph and checked for a corresponding edge in the opposite direction. Using the NetworkX library, we created the reciprocated graphs, denoted as recGs and recGh, by selecting the subgraph produced from the identified reciprocated edges. To quantify reciprocity, we calculated the reciprocity coefficient, which is defined as the ratio of the number of reciprocated edges to the total number of edges in the graph (https://en.wikipedia.org/wiki/Reciprocity_(network_science)). This metric provides insight into the level of mutual pairwise connectivity within the network.

## 4.1. Reciprocity of Senate Candidates (recGs)

The reciprocity coefficient of Gs is 0.953, which represents a substantially high level of mutual pairwise connectivity among the Senate candidates' Wikipedia pages. The reciprocated graph of the US Senate candidates is composed of 43 nodes and 278 edges.

**Fig 7: Reciprocated Hyperlink Graph for Senate Candidates**

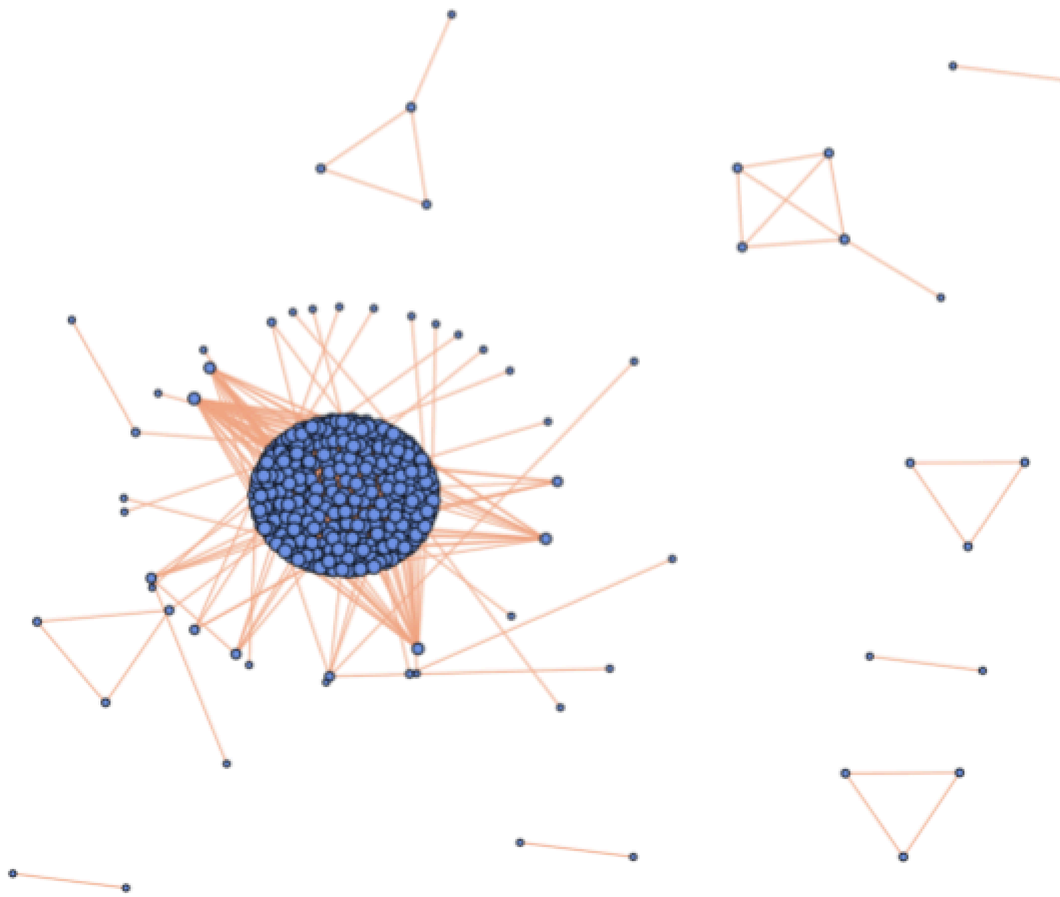


As shown in Figure 7, there is only 1 connected component in the Senate candidates reciprocated hyperlink graph.

## 4.2. Reciprocity of House Candidates (recGh)

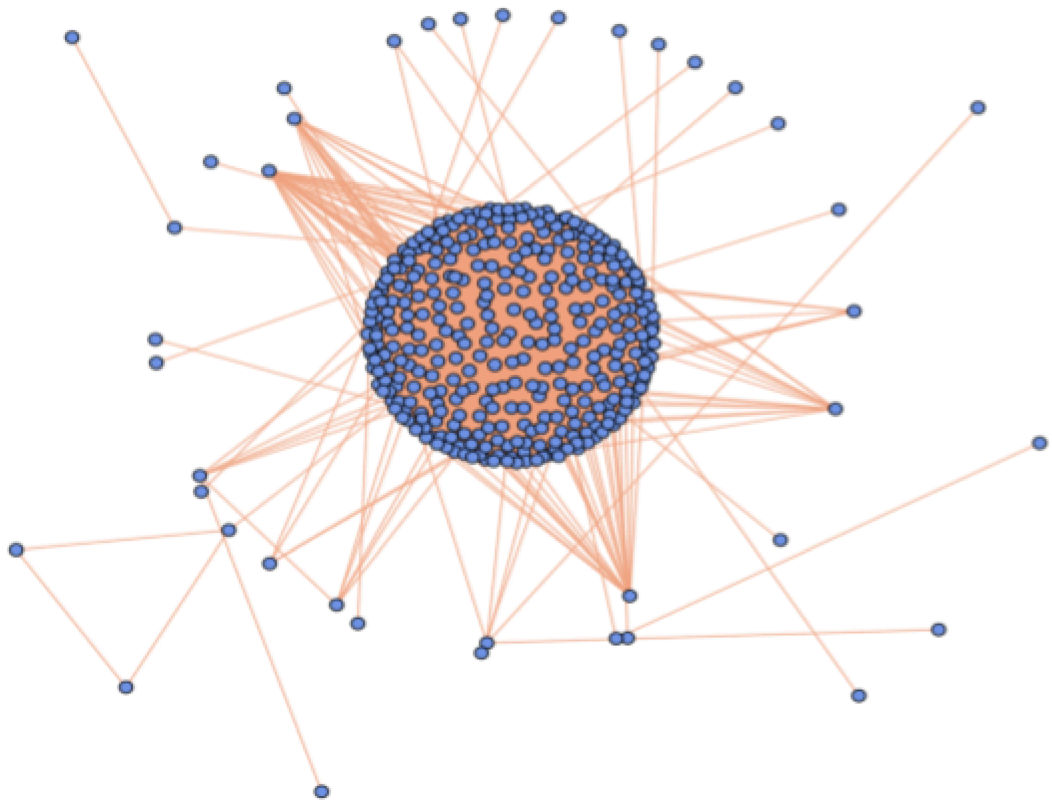
The reciprocity coefficient of Gh is 0.9903, indicating a significantly high level of mutual pairwise connectivity among the House candidates' Wikipedia pages. The reciprocated graph of the US House candidates contains 403 nodes and 57795 edges.

**Fig 8: Reciprocated Hyperlink Graph for House Candidates**



As seen in Figure 8, there are nine connected components in the House candidates reciprocated hyperlink graph. Figure 9 displays the giant connected component containing 380 nodes and 57,774 edges.

**Fig 9: Giant Connected Component of Reciprocated House Candidates Hyperlink Graph**



# 5. Attributes

In this section, we describe the process of assigning four key attributes to all candidates for both the Senate and House. These attributes are:

- Incumbency: This indicates whether the candidate currently holds the position or is a challenger.
- Party affiliation: This represents the candidate's political party, such as Democratic, Republican, Independent.
- State: This refers to the state from which the candidate is running for office.

- Candidacy status: This refers to the current status of the candidate's campaign, such as Candidacy Declared Primary, Candidacy Declared General, On the Ballot Primary, On the Ballot General, and On the Ballot Convention.

It is worth noting that we are not currently filtering out candidates who have withdrawn, been disqualified, or lost their status. Future work on this should include this preprocessing step.

From the Senate data frame (dfs) and the House data frame (dfh), we created four dictionaries that map each candidate to their respective attributes (incumbency, party, state, and status) and inherited these dictionaries to the nodes of the graphs Gs and Gh, respectively. By analyzing the subgraphs of Gs and Gh based on each attribute, we identified the number of nodes and edges of the largest weakly connected component for each unique attribute value. For example, we figured that there are 37 candidates having incumbency as "Challenger" and 21 candidates as "Incumbent" with 121 and 420 hyperlinks respectively. Among them, in the largest weakly connected components, there are 21 candidates as "Challenger" with 115 hyperlinks and 21 candidates as "Incumbent" with 420 hyperlinks.

Next, we assigned the attribute values to the nodes of the reciprocated graphs, recGs and recGh. By analyzing the subgraphs of recGs and recGh based on each attribute, we also derived the number of nodes and edges of the connected component for each unique attribute value. For instance, in the reciprocated graph, there are 19 "Challenger" candidates and 21 "Incumbent" candidates with 55 and 210 edges respectively. In the largest connected components, 16 "Challenger" candidates have 54 edges, and 21 "Incumbent" candidates have 210 edges. These attributes are used throughout the remainder of this paper to evaluate characteristics of the Senate and House graphs.

# 6. General Statistics

In this section, we provide an overview of general statistics of the Senate and House candidates graphs with stacked bar charts. The three graphs show the counts of candidates by different values in four attribute groups for overall candidates listed on Ballotpedia pages, candidates having Wikipedia pages, and candidates who are in our network graphs. The fourth graph displays the attribute value counts for the reciprocated candidates' graphs.

## 6.1. Senate Statistics

Figure 10 shows "Challenger" candidates (426) are significantly dominating the candidates who are running in the campaign. The number of candidates who do have a Wikipedia page is only 72 compared to 378. Table 5 displays the values represented in the graph.

**Fig 10: Values of Attributes of All Senate Candidates**

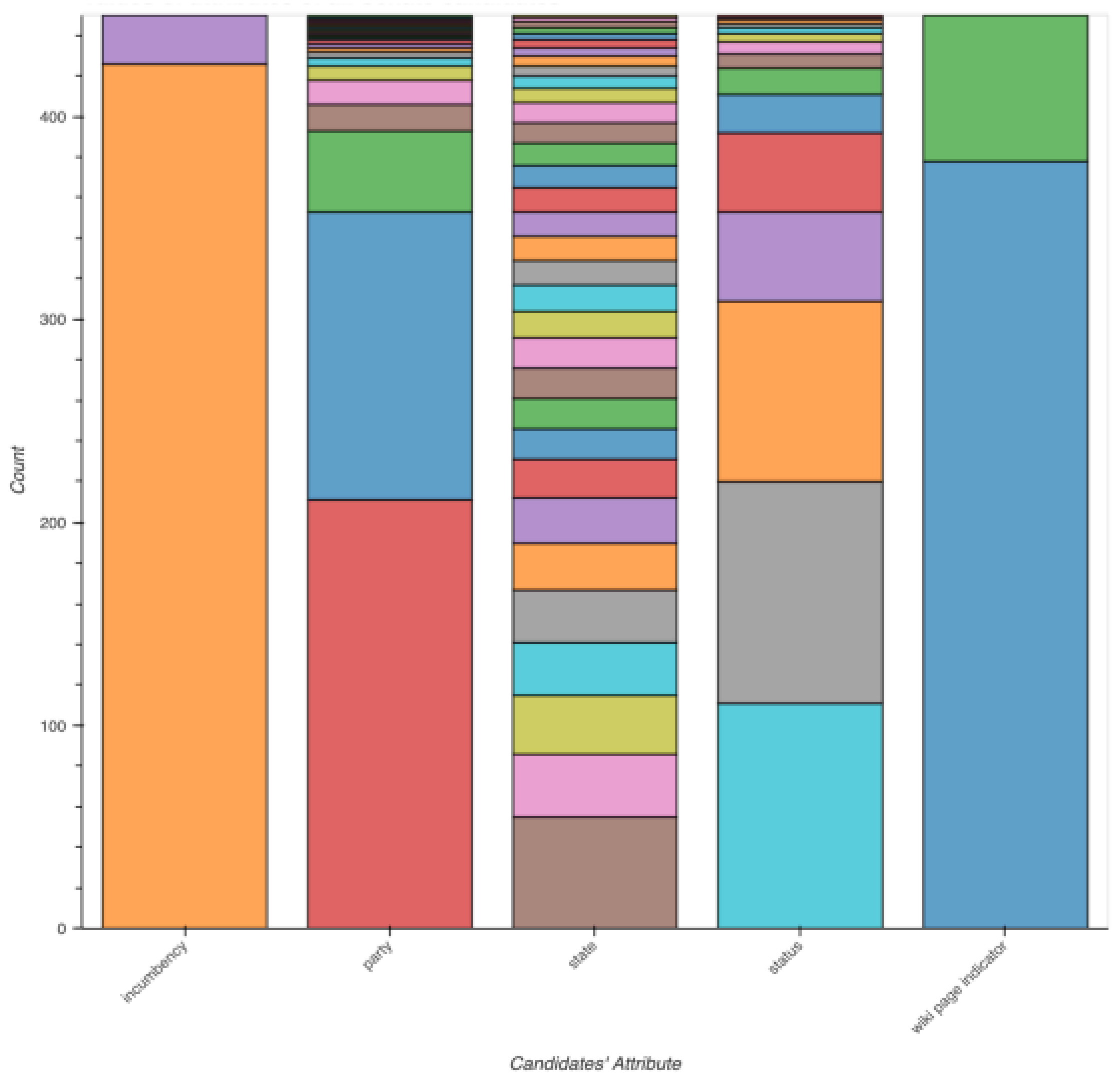



**Table 5: Attribute Counts of All Senate Candidates**

| variable | value | count |
|---|---|---|
| incumbency | Challenger | 426 |
| incumbency | Incumbent | 24 |
| party | Republican | 211 |
| party | Democratic | 142 |
| party | Independent | 40 |
| party | Libertarian | 13 |
| party | Green | 12 |

| | | |
|---|---|---|
| party | No party preference | 7 |
| party | No Political Party | 4 |
| party | No Party Affiliation | 3 |
| party | American Independent Party | 2 |
| party | Independent American Party of Utah | 2 |
| party | Legal Marijuana Now Party | 2 |
| party | American Independent Party of California | 1 |
| party | Constitution Party | 1 |
| party | Independence-Alliance Party of Minnesota | 1 |
| party | Independent American Party | 1 |
| party | Nonpartisan | 1 |
| party | One Earth Party | 1 |
| party | Progressive Party | 1 |
| party | Socialist Equality Party | 1 |
| party | Unenrolled | 1 |
| party | Vienmerisce Veittemeignzce USA | 1 |
| party | Wisdom People Party | 1 |
| party | Workers Party | 1 |
| state | CA | 55 |
| state | FL | 31 |
| state | MD | 29 |
| state | NV | 26 |
| state | TX | 26 |
| state | MI | 23 |
| state | NJ | 22 |
| state | UT | 19 |
| state | AZ | 15 |

| | | |
|---|---|---|
| state | IN | 15 |
| state | NY | 15 |
| state | VA | 15 |
| state | TN | 13 |
| state | WV | 13 |
| state | MA | 12 |
| state | MO | 12 |
| state | MT | 12 |
| state | WI | 12 |
| state | PA | 11 |
| state | WA | 11 |
| state | MN | 10 |
| state | NM | 10 |
| state | NE | 7 |
| state | OH | 6 |
| state | DE | 5 |
| state | RI | 5 |
| state | CT | 4 |
| state | MS | 4 |
| state | HI | 3 |
| state | ME | 3 |
| state | ND | 3 |
| state | WY | 2 |
| state | VT | 1 |
| status | Candidacy Declared Primary | 111 |
| status | Withdrew Primary | 109 |
| status | On the Ballot Primary | 89 |
| status | Candidacy Declared General | 44 |
| status | Lost Primary | 39 |

| | | |
|---|---|---|
| status | On the Ballot General | 19 |
| status | Withdrew General | 13 |
| status | On the Ballot Convention | 7 |
| status | Disqualified Primary | 6 |
| status | Lost (Write-in) Primary | 4 |
| status | Candidacy Declared (Write-in) General | 3 |
| status | On the Ballot Round 1 | 2 |
| status | Withdrew (Write-in) Primary | 2 |
| status | Disqualified General | 1 |
| status | Withdrew Round 1 | 1 |
| wiki page indicator | 0 | 378 |
| wiki page indicator | 1 | 72 |

In Figure 11, out of the 72 candidates who have Wikipedia pages, 21 are Incumbent, and 51 are "Challenger". Republican and Democratic candidates are nearly evenly split with a few independent candidates. Michigan and Nevada are the top two ranked states with more candidates. For status, "On the Ballot Primary" takes up the most group with 31 candidates, and "Candidacy Declared Primary" is the second group with 27 candidates. Table 6 displays the values represented in the graph.

Fig 11: Values of Attributes of All Senate Candidates having Wiki Pages

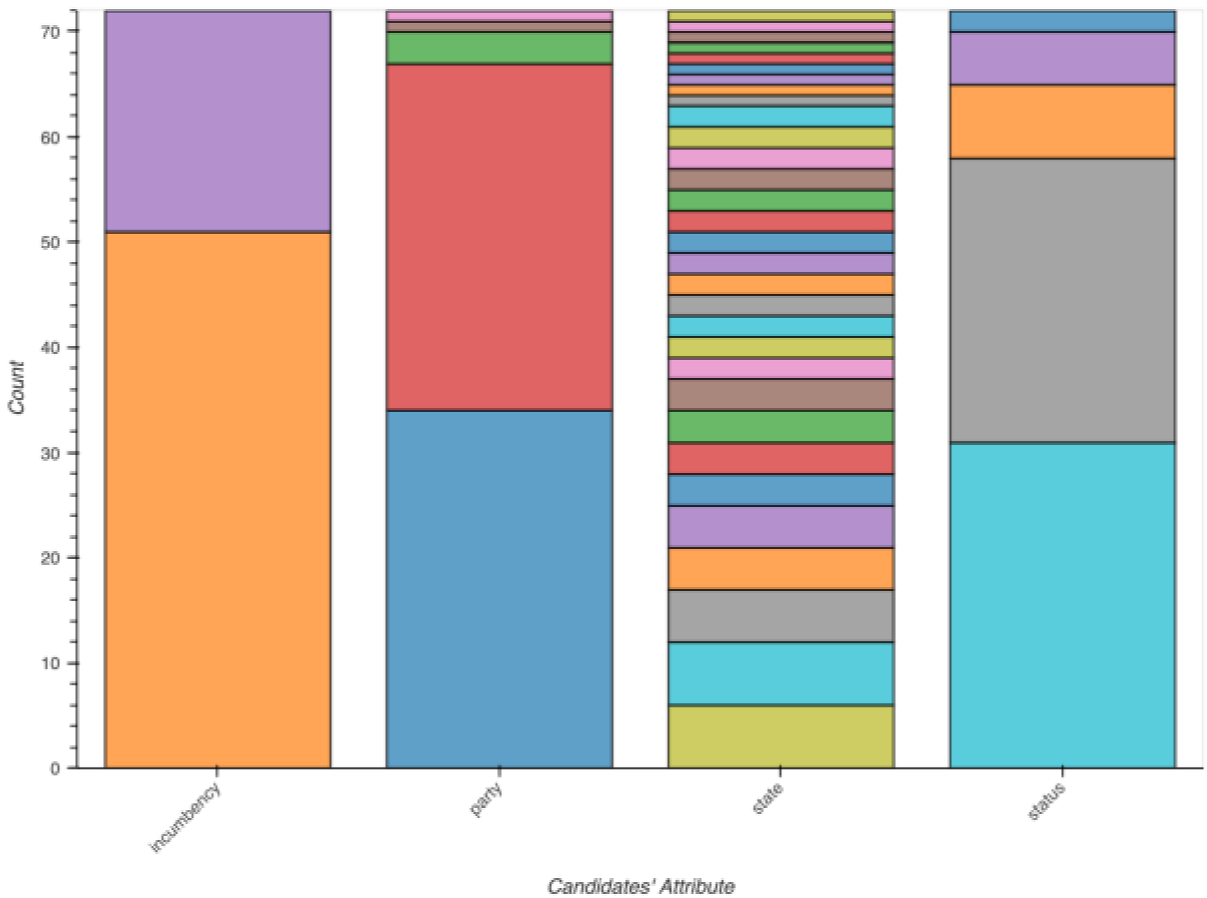



**Table 6: Attribute Counts of All Senate Candidates having Wiki Pages**

| variable | value | count |
|---|---|---|
| incumbency | Challenger | 51 |
| incumbency | Incumbent | 21 |
| party | Democratic | 34 |
| party | Republican | 33 |
| party | Independent | 3 |
| party | Green | 1 |
| party | Nonpartisan | 1 |
| state | MI | 6 |
| state | NV | 6 |
| state | FL | 5 |

| | | |
|---|---|---|
| state | MD | 4 |
| state | UT | 4 |
| state | AZ | 3 |
| state | MO | 3 |
| state | TN | 3 |
| state | WV | 3 |
| state | CA | 2 |
| state | DE | 2 |
| state | IN | 2 |
| state | MA | 2 |
| state | MN | 2 |
| state | MT | 2 |
| state | NE | 2 |
| state | NY | 2 |
| state | OH | 2 |
| state | PA | 2 |
| state | RI | 2 |
| state | TX | 2 |
| state | WI | 2 |
| state | CT | 1 |
| state | HI | 1 |
| state | MS | 1 |
| state | ND | 1 |
| state | NJ | 1 |
| state | NM | 1 |
| state | VA | 1 |
| state | WA | 1 |
| state | WY | 1 |
| status | On the Ballot Primary | 31 |

| | | |
|---|---|---|
| status | Candidacy Declared Primary | 27 |
| status | On the Ballot General | 7 |
| status | Candidacy Declared General | 5 |
| status | On the Ballot Convention | 2 |

As we looked at the number of candidates in the Figure 12, we found that the counts slightly changed in these attribute groups from the “having Wikipedia pages” graph, such as “Challenger” in incumbency, parties, and “On the Ballot Primary” status. Table 7 displays the values represented in the graph.

**Fig 12: Values of Attributes of All Senate Candidates in the Senate Graph**

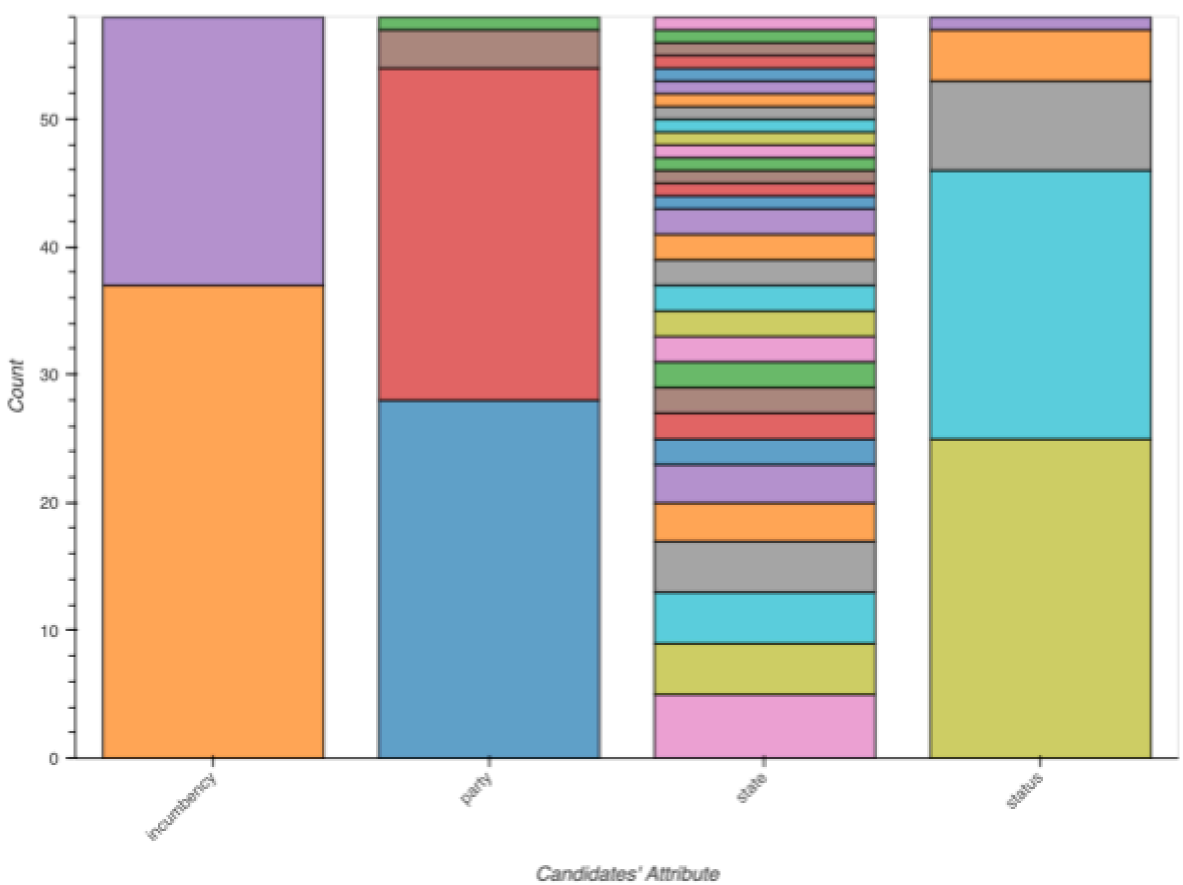


**Table 7: Attribute Counts of All Senate Candidates in the Senate Graph**

| variable | value | count |
|---|---|---|
| incumbency | Challenger | 37 |
| incumbency | Incumbent | 21 |
| party | Democratic | 28 |
| party | Republican | 26 |
| party | Independent | 3 |
| party | Green | 1 |
| state | MI | 5 |
| state | FL | 4 |
| state | MD | 4 |
| state | NV | 4 |
| state | TN | 3 |
| state | WV | 3 |
| state | AZ | 2 |
| state | CA | 2 |
| state | MA | 2 |
| state | MO | 2 |
| state | NE | 2 |
| state | OH | 2 |
| state | PA | 2 |
| state | TX | 2 |
| state | UT | 2 |
| state | WI | 2 |
| state | CT | 1 |
| state | DE | 1 |
| state | HI | 1 |
| state | IN | 1 |
| state | MN | 1 |

| | | |
|---|---|---|
| state | MS | 1 |
| state | MT | 1 |
| state | ND | 1 |
| state | NJ | 1 |
| state | NM | 1 |
| state | NY | 1 |
| state | RI | 1 |
| state | VA | 1 |
| state | WA | 1 |
| state | WY | 1 |
| status | On the Ballot Primary | 25 |
| status | Candidacy Declared Primary | 21 |
| status | On the Ballot General | 7 |
| status | Candidacy Declared General | 4 |
| status | On the Ballot Convention | 1 |

**Table 8: Top Candidates in Senate Graph by out-degree**

| candidate | incumbency | party | status | state | out_degree |
|---|---|---|---|---|---|
| Elizabeth Warren | Incumbent | Democratic | Candidacy Declared Primary | MA | 23 |
| Amy Klobuchar | Incumbent | Democratic | Candidacy Declared Primary | MN | 22 |
| Kirsten Gillibrand | Incumbent | Democratic | Candidacy Declared Primary | NY | 22 |
| Ted Cruz | Incumbent | Republican | On the Ballot General | TX | 21 |
| Sherrod Brown | Incumbent | Democratic | On the Ballot General | OH | 21 |
| Rick Scott | Incumbent | Republican | Candidacy Declared Primary | FL | 21 |
| Deb Fischer | Incumbent | Republican | On the Ballot Primary | NE | 21 |
| Josh Hawley | Incumbent | Republican | Candidacy Declared Primary | MO | 21 |
| Bob Casey Jr. | Incumbent | Democratic | On the Ballot Primary | PA | 20 |
| Kevin Cramer | Incumbent | Republican | On the Ballot Primary | ND | 20 |

**Table 9: Top Candidates in Senate Graph by in-degree**

| candidate | incumbency | party | status | state | in_degree |
|---|---|---|---|---|---|
| Elizabeth Warren | Incumbent | Democratic | Candidacy Declared Primary | MA | 26 |
| Jacky Rosen | Incumbent | Democratic | On the Ballot Primary | NV | 23 |
| Ted Cruz | Incumbent | Republican | On the Ballot General | TX | 23 |
| Rick Scott | Incumbent | Republican | Candidacy Declared Primary | FL | 22 |
| Amy Klobuchar | Incumbent | Democratic | Candidacy Declared Primary | MN | 22 |
| Josh Hawley | Incumbent | Republican | Candidacy Declared Primary | MO | 22 |
| Marsha Blackburn | Incumbent | Republican | On the Ballot Primary | TN | 22 |
| Kirsten Gillibrand | Incumbent | Democratic | Candidacy Declared Primary | NY | 22 |
| Bob Casey Jr. | Incumbent | Democratic | On the Ballot Primary | PA | 21 |
| Deb Fischer | Incumbent | Republican | On the Ballot Primary | NE | 21 |

The reciprocated Senate graph, Figure 13, is a smaller subset of the Senate graph, containing only bidirectional edges. For incumbency, the number of “Challenger” candidates decreased from 37 to 21. Similarly, the sizes of subgroup values for each other attribute reduce as the number of hyperlinks in the reciprocated graph diminishes. Table 10 displays the values represented in the graph.

**Fig 13: Values of Attributes of All Senate Candidates in the Reciprocated Senate Graph**

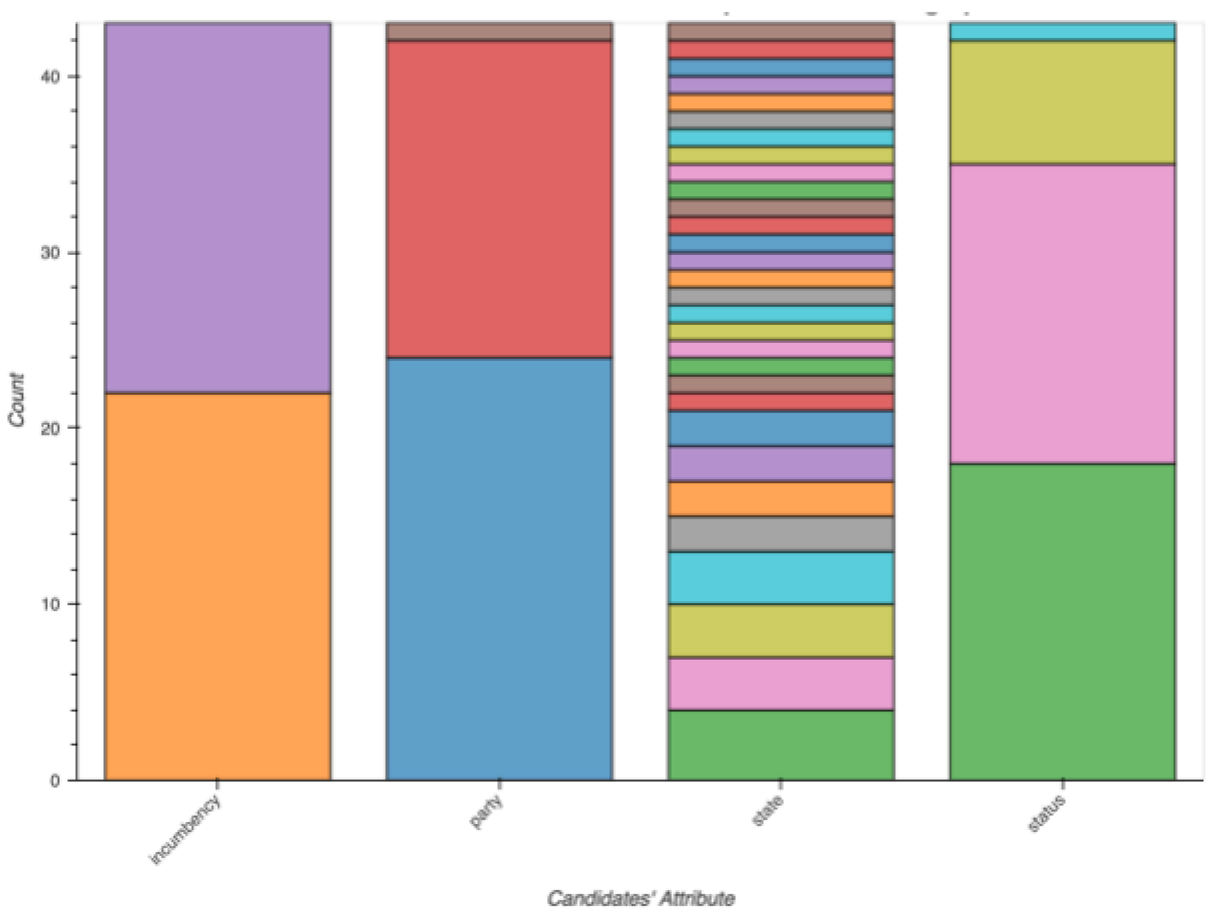



**Table 10: Attribute Counts of All Senate Candidates in the Reciprocated Senate Graph**

| variable | value | count |
|---|---|---|
| incumbency | Challenger | 22 |
| incumbency | Incumbent | 21 |
| party | Democratic | 24 |
| party | Republican | 18 |

| | | |
|---|---|---|
| party | Independent | 1 |
| state | MI | 4 |
| state | FL | 3 |
| state | MD | 3 |
| state | WV | 3 |
| state | CA | 2 |
| state | NE | 2 |
| state | OH | 2 |
| state | TX | 2 |
| state | AZ | 1 |
| state | DE | 1 |
| state | HI | 1 |
| state | IN | 1 |
| state | MA | 1 |
| state | MN | 1 |
| state | MO | 1 |
| state | MS | 1 |
| state | MT | 1 |
| state | ND | 1 |
| state | NJ | 1 |
| state | NM | 1 |
| state | NV | 1 |
| state | NY | 1 |
| state | PA | 1 |
| state | RI | 1 |
| state | TN | 1 |
| state | UT | 1 |
| state | VA | 1 |
| state | WA | 1 |

| | | |
|---|---|---|
| state | WI | 1 |
| state | WY | 1 |
| status | Candidacy Declared Primary | 18 |
| status | On the Ballot Primary | 17 |
| status | On the Ballot General | 7 |
| status | Candidacy Declared General | 1 |

**Table 11: Top Candidate in Reciprocated Senate Graph by degree**

| candidate | incumbency | party | status | state | degree |
|---|---|---|---|---|---|
| Elizabeth Warren | Incumbent | Democratic | Candidacy Declared Primary | MA | 23 |
| Amy Klobuchar | Incumbent | Democratic | Candidacy Declared Primary | MN | 22 |
| Kirsten Gillibrand | Incumbent | Democratic | Candidacy Declared Primary | NY | 22 |
| Ted Cruz | Incumbent | Republican | On the Ballot General | TX | 21 |
| Sherrod Brown | Incumbent | Democratic | On the Ballot General | OH | 21 |
| Deb Fischer | Incumbent | Republican | On the Ballot Primary | NE | 21 |
| Rick Scott | Incumbent | Republican | Candidacy Declared Primary | FL | 21 |

## 6.2. House Statistics

Figure 14 displays the counts of the attributes for all the House candidates. The incumbency column shows that the majority of candidates (2,176) are of type “Challenger,” and 421 are of type “Incumbent.” The party attribute displays that Republican and Democratic are pretty evenly split and dominate the party attribute. Additionally, we see that a small proportion of the candidate’s have a Wikipedia page (504). Table 12 displays the values represented in the graph.

**Fig 14: Values of Attributes of All House Candidates**

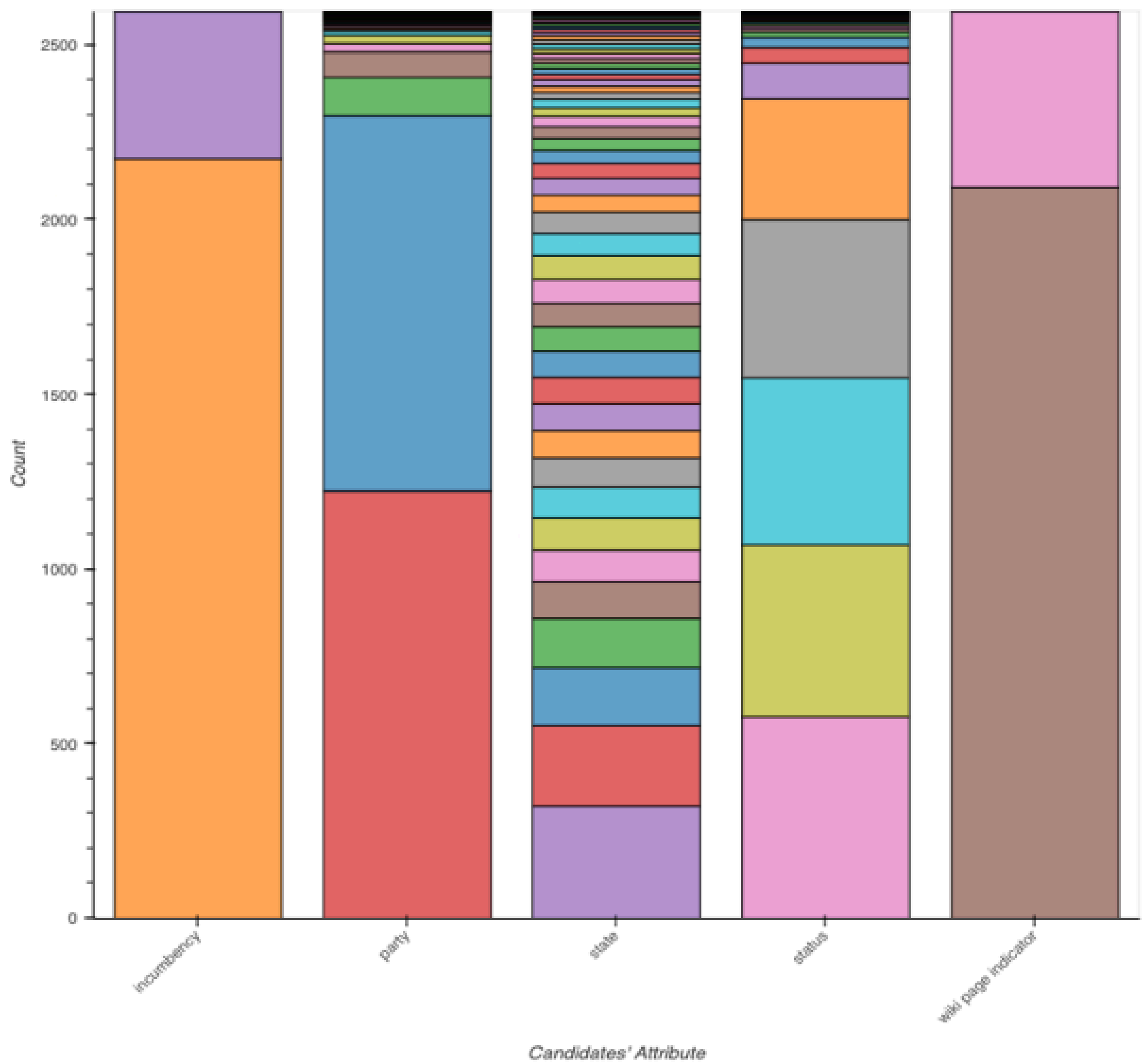



**Table 12: Attribute Counts of All House Candidates**

| variable | value | count |
|---|---|---|
| incumbency | Challenger | 2176 |
| incumbency | Incumbent | 421 |
| party | Republican | 1224 |
| party | Democratic | 1075 |
| party | Independent | 110 |
| party | Libertarian | 73 |

| | | |
|---|---|---|
| party | No Party Affiliation | 23 |
| party | No party preference | 23 |
| party | Green | 13 |
| party | Constitution Party | 6 |
| party | Conservative Party | 5 |
| party | No Political Party | 5 |
| party | Independent American Party | 4 |
| party | Peace and Freedom Party | 3 |
| party | Unaffiliated | 3 |
| party | Working Families Party | 3 |
| party | Alliance Party | 2 |
| party | Unity Party | 2 |
| party | American Constitution Party | 1 |
| party | American Independent Party | 1 |
| party | American People's Freedom Party | 1 |
| party | Bipartisan Party | 1 |
| party | Calm Rational GOP Party | 1 |
| party | Colorado Forward Party | 1 |
| party | Congress Sucks Party | 1 |
| party | Connecticut Conservative Party | 1 |
| party | Constitutional Party | 1 |
| party | George Wallace Party | 1 |
| party | Independence Party | 1 |
| party | MAGA Democratic Party | 1 |
| party | MAGA Republican Party | 1 |
| party | People's Party | 1 |
| party | Progressive Party | 1 |
| party | Trump Republican Party | 1 |
| party | Unenrolled | 1 |

| | | |
|---|---|---|
| party | Union Party | 1 |
| party | United Citizens Party | 1 |
| party | United Utah Party | 1 |
| party | Unity Party of Colorado | 1 |
| party | Veteran's Party | 1 |
| party | Wisdom People Party | 1 |
| state | CA | 323 |
| state | TX | 230 |
| state | FL | 165 |
| state | NY | 142 |
| state | MD | 104 |
| state | CO | 92 |
| state | IN | 92 |
| state | NC | 86 |
| state | OH | 85 |
| state | GA | 78 |
| state | AZ | 77 |
| state | VA | 76 |
| state | WA | 75 |
| state | IL | 70 |
| state | MI | 68 |
| state | NJ | 67 |
| state | PA | 67 |
| state | TN | 64 |
| state | MO | 62 |
| state | AL | 49 |
| state | SC | 48 |
| state | OR | 42 |
| state | NV | 37 |

| | | |
|---|---|---|
| state | WI | 35 |
| state | MN | 34 |
| state | UT | 29 |
| state | KY | 25 |
| state | OK | 24 |
| state | MT | 20 |
| state | MA | 18 |
| state | NH | 18 |
| state | CT | 16 |
| state | KS | 16 |
| state | LA | 15 |
| state | IA | 14 |
| state | MS | 14 |
| state | AR | 13 |
| state | WV | 13 |
| state | ID | 12 |
| state | NE | 12 |
| state | ME | 10 |
| state | ND | 10 |
| state | DE | 7 |
| state | NM | 7 |
| state | DC | 6 |
| state | GU | 6 |
| state | SD | 6 |
| state | MP | 4 |
| state | AK | 3 |
| state | RI | 3 |
| state | AS | 2 |
| state | HI | 2 |

| | | |
|---|---|---|
| state | VT | 2 |
| state | VI | 1 |
| state | WY | 1 |
| status | On the Ballot Primary | 577 |
| status | Withdrew Primary | 493 |
| status | On the Ballot General | 478 |
| status | Lost Primary | 453 |
| status | Candidacy Declared Primary | 346 |
| status | Candidacy Declared General | 102 |
| status | Disqualified Primary | 45 |
| status | Withdrew General | 28 |
| status | On the Ballot Primary Runoff | 16 |
| status | Candidacy Declared (Write-in) General | 8 |
| status | On the Ballot (Write-in) General | 8 |
| status | Lost (Write-in) Primary | 6 |
| status | On the Ballot Round 1 | 6 |
| status | Disqualified General | 4 |
| status | Lost (unofficially withdrew) Primary | 3 |
| status | Lost Primary Runoff | 3 |
| status | On the Ballot (Write-in) Primary | 3 |
| status | Advanced Round 1 | 2 |
| status | Candidacy Declared Round 1 | 2 |
| status | Lost Convention | 2 |
| status | On the Ballot (unofficially withdrew) Primary | 2 |
| status | Withdrew (Write-in) General | 2 |
| status | Withdrew (unofficially withdrew) Primary | 2 |
| status | Candidacy Declared (Write-in) Primary | 1 |

| | | |
|---|---|---|
| status | Lost (unofficially withdrew) Primary Runoff | 1 |
| status | On the Ballot (Write-in) Round 1 | 1 |
| status | On the Ballot Convention | 1 |
| status | Withdrew Round 1 | 1 |
| status | Won General | 1 |
| wiki page indicator | 0 | 2093 |
| wiki page indicator | 1 | 504 |

In Figure 15, we look at the subset of candidates that have Wikipedia pages. The predominant value for the incumbency is ‘Incumbent’ with 352, compared to 152 of type Challenger. Republican and Democratic continue to remain almost evenly split for the party attribute. California has the largest number of candidates, followed by Texas and Florida. There are 10 values for status, however, “on the ballot general”, “on the ballot primary” and “candidacy declared primary” make up the majority. Table 13 displays the values represented in the graph.

**Fig 15: Values of Attributes of All House Candidates Having Wiki Pages**

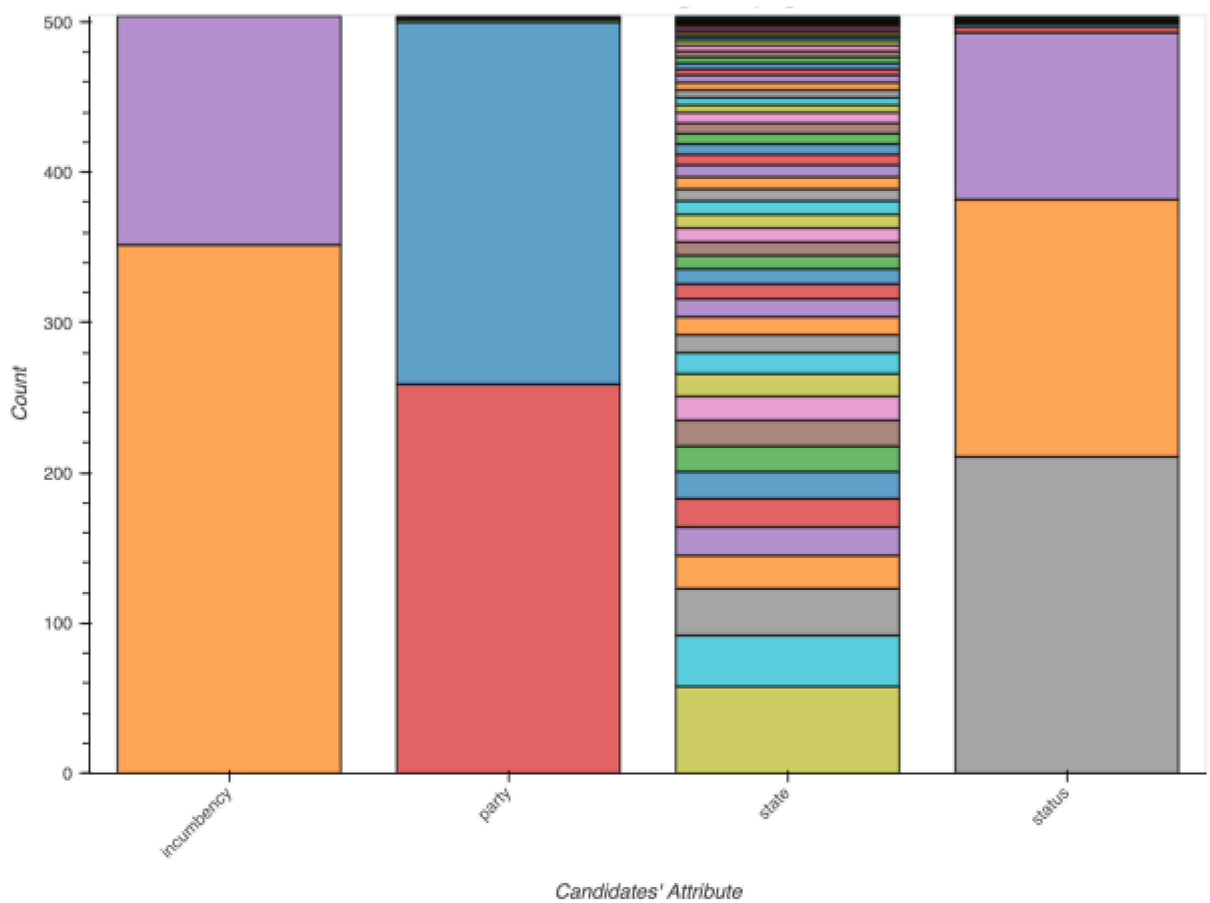



**Table 13: Attribute Counts of All House Candidates having Wiki Pages**

| variable | value | count |
|---|---|---|
| incumbency | Incumbent | 352 |
| incumbency | Challenger | 152 |
| party | Republican | 259 |
| party | Democratic | 241 |
| party | Independent | 2 |
| party | Alliance Party | 1 |
| party | Constitution Party | 1 |
| state | CA | 58 |
| state | TX | 34 |
| state | FL | 31 |

| | | |
|---|---|---|
| state | NY | 22 |
| state | AZ | 19 |
| state | PA | 19 |
| state | MI | 18 |
| state | GA | 17 |
| state | IL | 17 |
| state | OH | 16 |
| state | CO | 15 |
| state | WA | 14 |
| state | MN | 12 |
| state | MO | 12 |
| state | VA | 12 |
| state | OR | 10 |
| state | SC | 10 |
| state | IN | 9 |
| state | MA | 9 |
| state | MT | 9 |
| state | NC | 9 |
| state | TN | 9 |
| state | MD | 8 |
| state | NJ | 8 |
| state | WI | 8 |
| state | AL | 7 |
| state | CT | 7 |
| state | KY | 7 |
| state | LA | 7 |
| state | NV | 7 |
| state | IA | 5 |
| state | ND | 5 |

| | | |
|---|---|---|
| state | NE | 5 |
| state | OK | 5 |
| state | UT | 5 |
| state | AR | 4 |
| state | KS | 4 |
| state | ME | 4 |
| state | MS | 4 |
| state | NH | 4 |
| state | ID | 3 |
| state | AK | 2 |
| state | GU | 2 |
| state | HI | 2 |
| state | NM | 2 |
| state | WV | 2 |
| state | DC | 1 |
| state | DE | 1 |
| state | RI | 1 |
| state | SD | 1 |
| state | VT | 1 |
| state | WY | 1 |
| status | On the Ballot General | 211 |
| status | On the Ballot Primary | 171 |
| status | Candidacy Declared Primary | 111 |
| status | On the Ballot Round 1 | 4 |
| status | On the Ballot Primary Runoff | 2 |
| status | Candidacy Declared (Write-in) General | 1 |
| status | Candidacy Declared General | 1 |
| status | Lost Primary | 1 |

| | | |
|---|---|---|
| status | Withdrew Primary | 1 |
| status | Won General | 1 |

Figure 16, displays the subset of attributes that appears in the House candidates' graph (Gh). The distribution of values for each attribute is similar to what we saw in Figure 15. One noticeable difference is the reduced number of "Challengers" in the incumbency attribute: 99 compared to 152. The number of "Incumbents" only reduced by 9. Table 14 displays the values represented in the graph.

Fig 16: Values of Attributes of All House Candidates in the House Graph

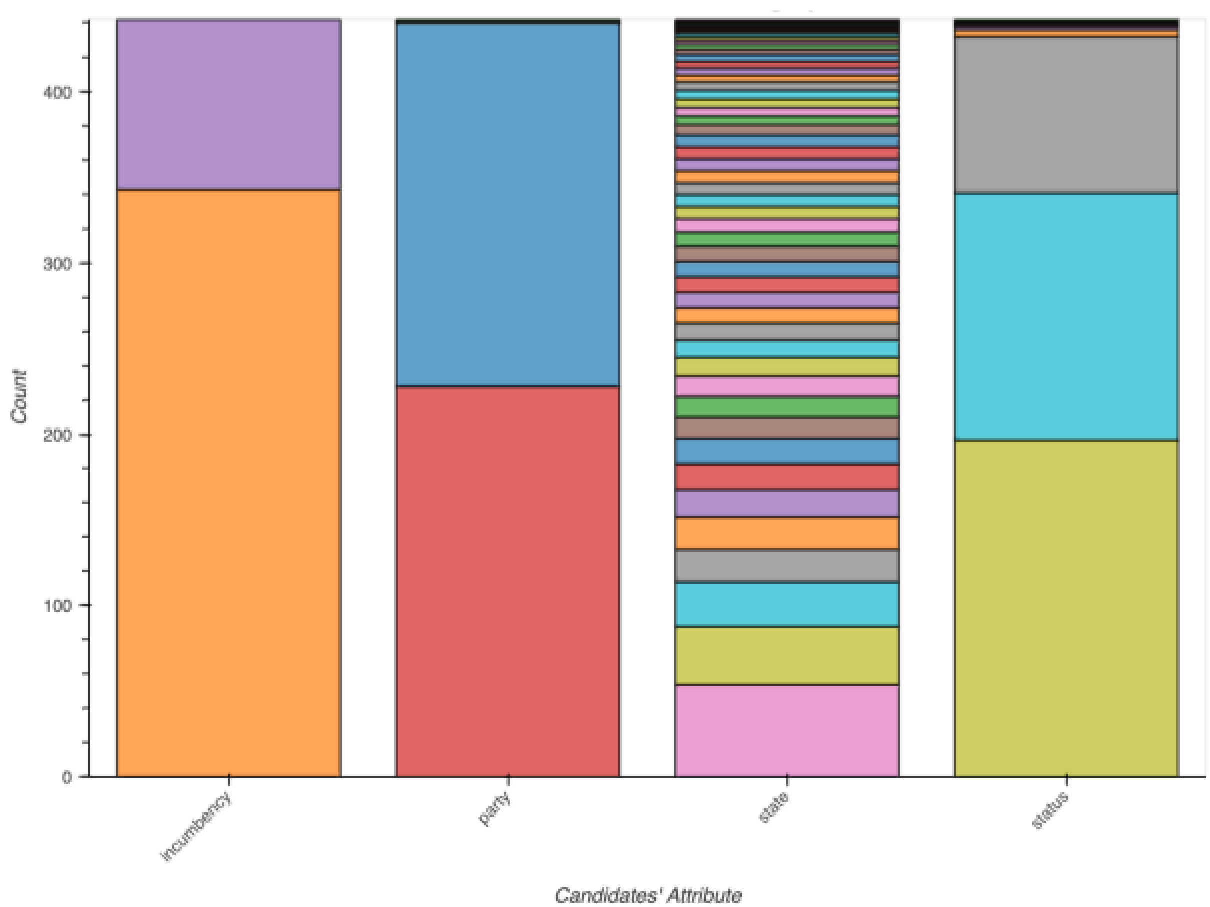


**Table 14: Attribute Counts of All House Candidates in the House Graph**

| variable | value | count |
|---|---|---|
| incumbency | Incumbent | 343 |
| incumbency | Challenger | 99 |
| party | Republican | 228 |
| party | Democratic | 212 |
| party | Constitution Party | 1 |
| party | Independent | 1 |
| state | CA | 54 |
| state | TX | 34 |
| state | FL | 26 |
| state | NY | 19 |
| state | PA | 19 |
| state | IL | 16 |
| state | GA | 15 |
| state | OH | 15 |
| state | AZ | 12 |
| state | CO | 12 |
| state | MI | 12 |
| state | VA | 11 |
| state | OR | 10 |
| state | WA | 10 |
| state | MA | 9 |
| state | MN | 9 |
| state | MO | 9 |
| state | MT | 9 |
| state | TN | 9 |
| state | IN | 8 |
| state | SC | 8 |

| | | |
|---|---|---|
| state | CT | 7 |
| state | KY | 7 |
| state | LA | 7 |
| state | MD | 7 |
| state | NC | 7 |
| state | NJ | 7 |
| state | WI | 7 |
| state | AL | 6 |
| state | IA | 5 |
| state | NE | 5 |
| state | NV | 5 |
| state | OK | 5 |
| state | UT | 5 |
| state | AR | 4 |
| state | KS | 4 |
| state | ME | 4 |
| state | MS | 4 |
| state | ID | 3 |
| state | ND | 3 |
| state | AK | 2 |
| state | HI | 2 |
| state | NM | 2 |
| state | DC | 1 |
| state | GU | 1 |
| state | NH | 1 |
| state | RI | 1 |
| state | SD | 1 |
| state | VT | 1 |
| state | WV | 1 |

| | | |
|---|---|---|
| state | WY | 1 |
| status | On the Ballot General | 197 |
| status | On the Ballot Primary | 144 |
| status | Candidacy Declared Primary | 91 |
| status | On the Ballot Round 1 | 4 |
| status | On the Ballot Primary Runoff | 2 |
| status | Candidacy Declared (Write-in) General | 1 |
| status | Lost Primary | 1 |
| status | Withdrew Primary | 1 |
| status | Won General | 1 |

In Tables 15 and 16 we display the top number of candidates in the House candidates graph (Gh) based on out-degree and in-degree, respectively. None of the candidates in the top out-degree are listed in the top in-degree list, and vice-versa.

**Table 15: Top Candidates in House Graph by out-degree**

| candidate | incumbency | party | status | state | out_degree |
|---|---|---|---|---|---|
| Young Kim | Incumbent | Republican | On the Ballot General | CA | 345 |
| Erin Houchin | Incumbent | Republican | On the Ballot General | IN | 342 |
| Victoria Spartz | Incumbent | Republican | On the Ballot General | IN | 342 |
| Jim Baird | Incumbent | Republican | On the Ballot General | IN | 342 |
| Judy Chu | Incumbent | Democratic | On the Ballot General | CA | 342 |
| Rudy Yakym | Incumbent | Republican | On the Ballot General | IN | 342 |
| Mary Peltola | Incumbent | Democratic | Candidacy Declared Primary | AK | 342 |
| Frank Mrvan | Incumbent | Democratic | On the Ballot General | IN | 342 |
| William Timmons | Incumbent | Republican | On the Ballot Primary | SC | 342 |
| Lori Chavez-DeRemer | Incumbent | Republican | On the Ballot Primary | OR | 342 |
| Paul Tonko | Incumbent | Democratic | Candidacy Declared Primary | NY | 342 |
| Steve Scalise | Incumbent | Republican | Candidacy Declared Primary | LA | 342 |

**Table 16: Top Candidates in House Graph by in-degree**

| candidate | incumbency | party | status | state | in_degree |
|---|---|---|---|---|---|
| Nancy Pelosi | Incumbent | Democratic | On the Ballot General | CA | 349 |
| Ryan K. Zinke | Incumbent | Republican | On the Ballot Primary | MT | 346 |
| Mike Johnson | Incumbent | Republican | Candidacy Declared Primary | LA | 345 |
| Derrick Van Orden | Incumbent | Republican | Candidacy Declared Primary | WI | 344 |
| Matt Gaetz | Incumbent | Republican | On the Ballot Primary | FL | 344 |
| Paul Gosar | Incumbent | Republican | On the Ballot Primary | AZ | 344 |
| Pat Ryan | Incumbent | Democratic | Candidacy Declared Primary | NY | 344 |
| Hakeem Jeffries | Incumbent | Democratic | Candidacy Declared Primary | NY | 344 |
| Bob Good | Incumbent | Republican | On the Ballot Primary | VA | 344 |

Figure 17 displays the values of attributes from the reciprocated House graph. In the incumbency attribute, we see a fewer number of “Challengers” than we did in the full graph: 61 compared to 99. The number of “Incumbents” is only one fewer: 342 compared to 343. “Republicans” and “Democratics” still make up the majority of the party attribute, with a single candidate having value “Constitution Party.” The top 3 state attribute values remain California, Texas and Florida. The values of the status attribute remain similar to the full graph as well. Table 17 displays the values represented in the graph.

**Fig 17: Values of Attributes of All House Candidates in the Reciprocated House Graph**

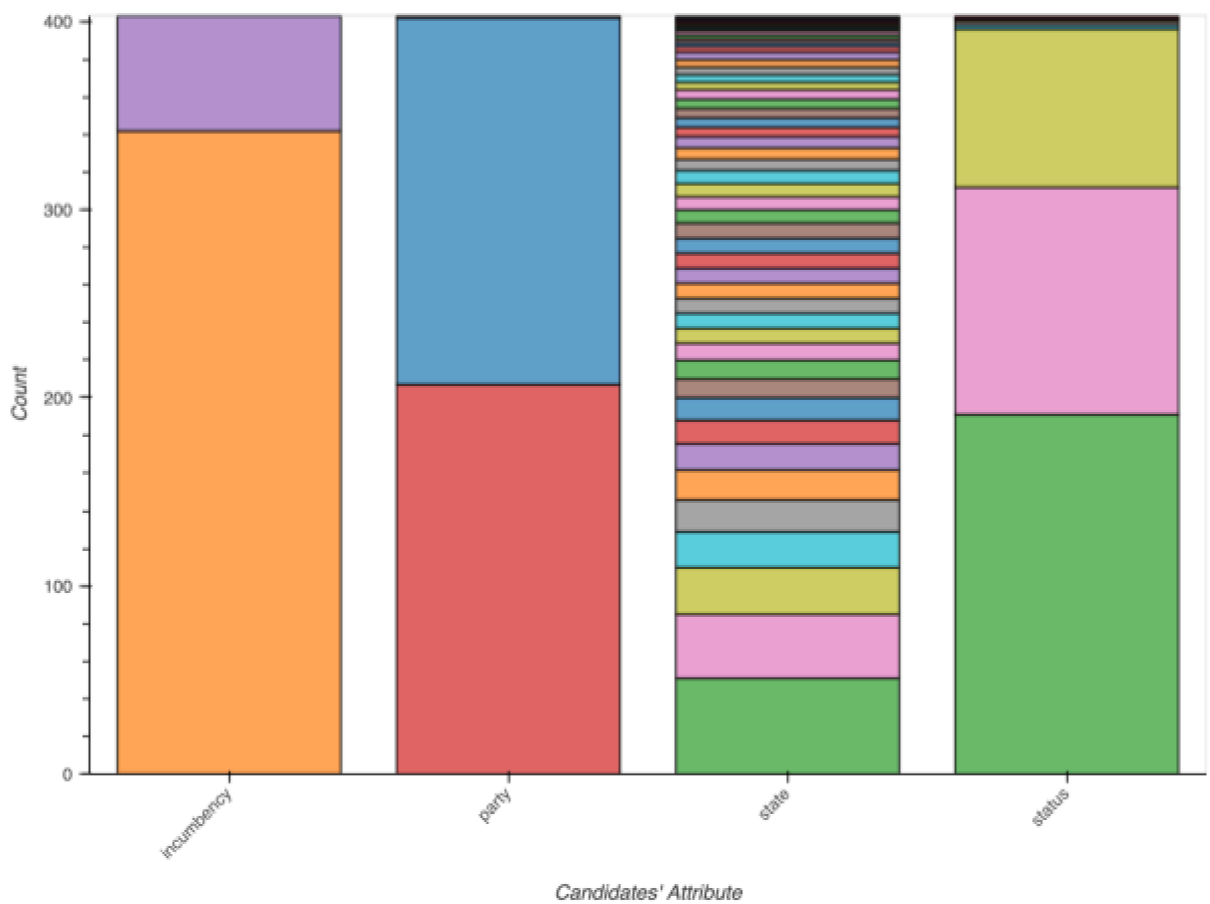


**Table 17: Attribute Counts of All House Candidates in the Reciprocated House Graph**

| variable | value | count |
|---|---|---|
| incumbency | Incumbent | 342 |
| incumbency | Challenger | 61 |
| party | Republican | 207 |
| party | Democratic | 195 |
| party | Constitution Party | 1 |
| state | CA | 51 |
| state | TX | 34 |
| state | FL | 25 |
| state | PA | 19 |
| state | NY | 17 |
| state | IL | 16 |
| state | OH | 14 |
| state | GA | 12 |
| state | MI | 12 |
| state | CO | 10 |
| state | OR | 10 |
| state | MA | 9 |
| state | AZ | 8 |
| state | IN | 8 |
| state | MN | 8 |
| state | MO | 8 |
| state | SC | 8 |
| state | TN | 8 |
| state | VA | 8 |
| state | WA | 8 |

| | | |
|---|---|---|
| state | KY | 7 |
| state | LA | 7 |
| state | NC | 7 |
| state | NJ | 7 |
| state | AL | 6 |
| state | CT | 6 |
| state | MT | 6 |
| state | IA | 5 |
| state | MD | 5 |
| state | NE | 5 |
| state | OK | 5 |
| state | WI | 5 |
| state | AR | 4 |
| state | KS | 4 |
| state | MS | 4 |
| state | NV | 4 |
| state | UT | 4 |
| state | ID | 3 |
| state | AK | 2 |
| state | HI | 2 |
| state | ME | 2 |
| state | NM | 2 |
| state | DC | 1 |
| state | GU | 1 |
| state | NH | 1 |
| state | RI | 1 |
| state | SD | 1 |
| state | VT | 1 |
| state | WV | 1 |

| | | |
|---|---|---|
| state | WY | 1 |
| status | On the Ballot General | 191 |
| status | On the Ballot Primary | 121 |
| status | Candidacy Declared Primary | 84 |
| status | On the Ballot Primary Runoff | 2 |
| status | On the Ballot Round 1 | 2 |
| status | Lost Primary | 1 |
| status | Withdrew Primary | 1 |
| status | Won General | 1 |

**Table 18: Top Candidate in Reciprocated House Graph by degree**

| candidate | incumbency | party | status | state | degree |
|---|---|---|---|---|---|
| Jim Baird | Incumbent | Republican | On the Ballot General | IN | 341 |
| Paul Tonko | Incumbent | Democratic | Candidacy Declared Primary | NY | 341 |
| Victoria Spartz | Incumbent | Republican | On the Ballot General | IN | 341 |
| William Timmons | Incumbent | Republican | On the Ballot Primary | SC | 341 |
| Claudia Tenney | Incumbent | Republican | Candidacy Declared Primary | NY | 341 |
| Erin Houchin | Incumbent | Republican | On the Ballot General | IN | 341 |
| Nancy Pelosi | Incumbent | Democratic | On the Ballot General | CA | 341 |
| Judy Chu | Incumbent | Democratic | On the Ballot General | CA | 341 |
| Rudy Yakym | Incumbent | Republican | On the Ballot General | IN | 341 |
| Frank Mrvan | Incumbent | Democratic | On the Ballot General | IN | 341 |
| Lori Chavez-DeRemer | Incumbent | Republican | On the Ballot Primary | OR | 341 |

# 7. Visualizations of Moderate Size Attributed Graphs

## 7.1. Senate Candidate Graphs

The four attributes were embedded in the graph as described in Section 5, therefore it is straightforward to create corresponding graphs based on any of these attributes. The Senate graph contains a total of 58 nodes, so we decided to include all of them in our graphs. Figure 18 displays the same as the reciprocated hyperlink graph we derived earlier, and without distinguishing by attributes.

**Fig 18: Senate Graph without Attributes**

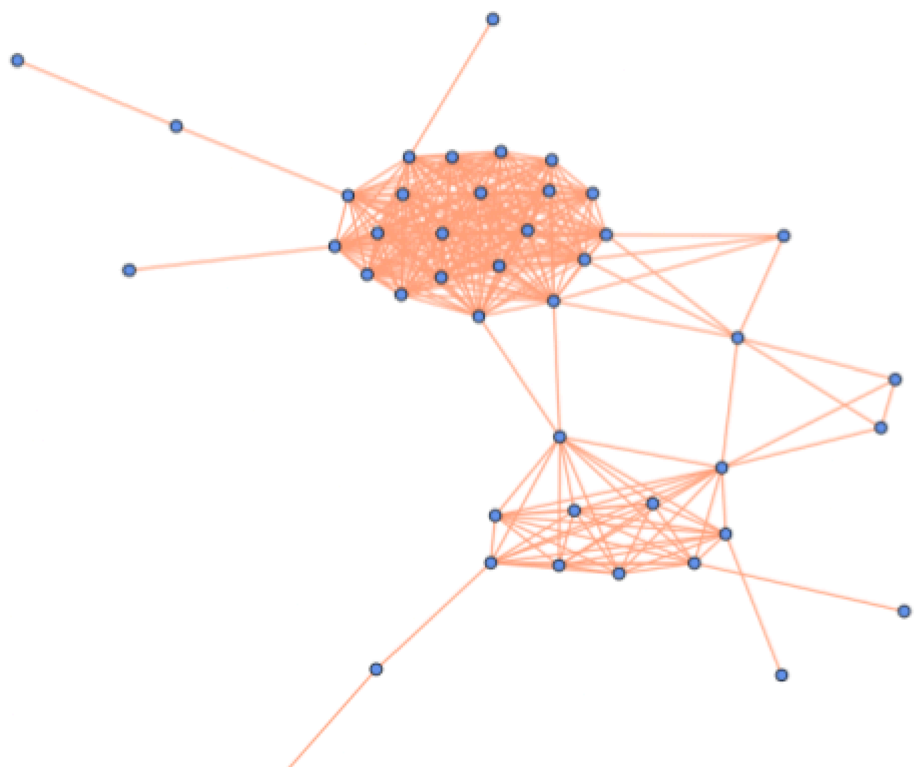
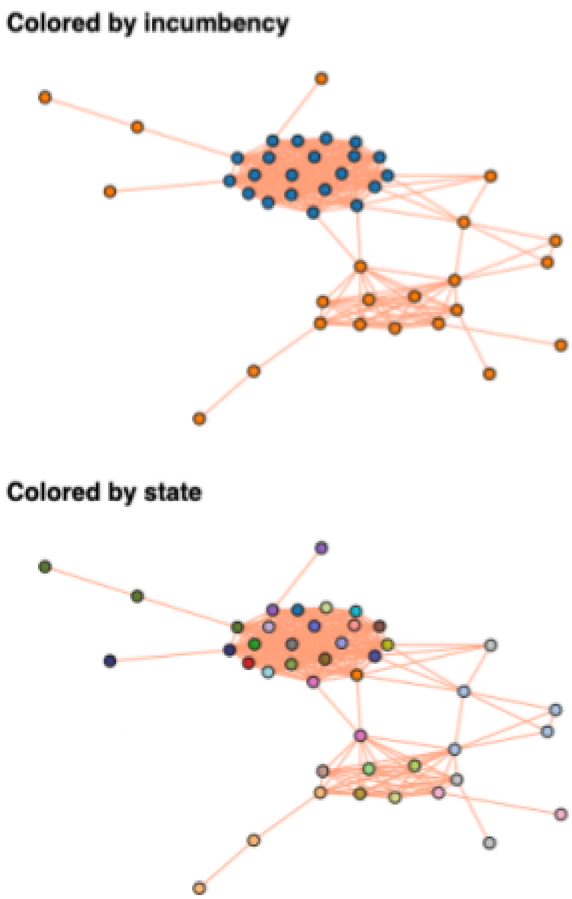


Figure 19 displays the reciprocated Senate graph with candidate nodes colored according to their respective attribute values. Each of the four graphs emphasizes a different attribute out of incumbency, party, state, and status. In the incumbency graph, 21 blue nodes represent “Incumbent” candidates and 19 orange nodes represent “Challengers”. The party affiliation graph illustrates the distribution of political parties among the candidates: 24 nodes colored blue represent “Democratic” candidates, and 15 nodes colored red represent “Republican” candidates. Additionally, only 1 node is colored yellow, meaning “Independent” affiliation. The state graph includes 30 distinct states, with Michigan having the highest number of candidates, totaling 4. The last graph, the status-attributed graph has 4 groups, where 18 blue-colored nodes are “Candidacy Declared Primary”, 15 red-colored nodes are “On the Ballot Primary”, 6 orange-colored nodes are “On the Ballot General”, and only 1 green-colored nodes are “Candidacy Declared General”.

**Fig 19: 4 Senate Graphs with all Four Attributes**



## 7.2. Senate Attributed Graphs as Sankey Diagrams

A Sankey diagram (https://en.wikipedia.org/wiki/Sankey_diagram) is a type of flow diagram where the width of the arrows is proportional to the flow rate. The flows represent the directed edges (hyperlinks) between different attribute groups, where “source” is the starting point and “target” is the destination.  In our interactive visualizations (Holoviews), we can find the number of hyperlinks by hovering over each flow, and we can also obtain the numbers of incoming and outgoing flows by hovering over each attribute type band.

In the following graphs, we display the incumbency, party affiliation and candidacy status attributes for the full Senate candidates hyperlink graph (Gs) using Sankey diagrams.

**Fig 20-1: Sankey diagram for Senate party**

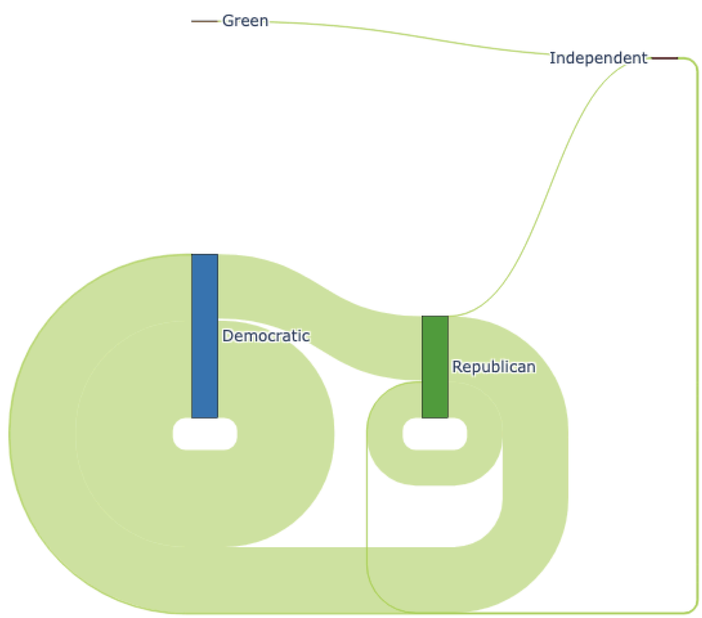


**Fig 20-2:** **Sankey diagram for Senate status**

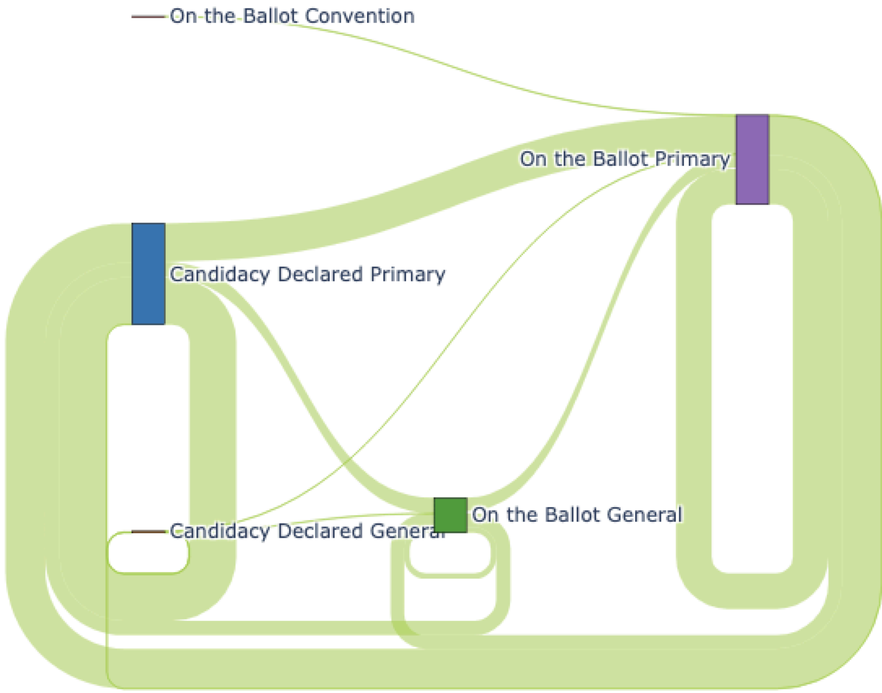
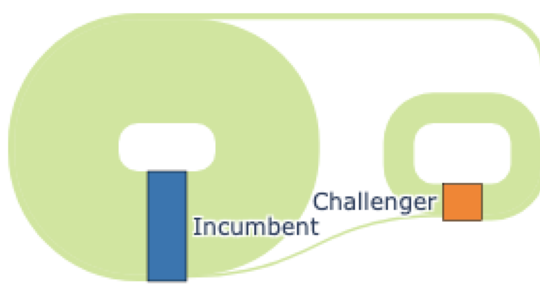



**Fig 20-3:** **Sankey diagram for Senate incumbency**

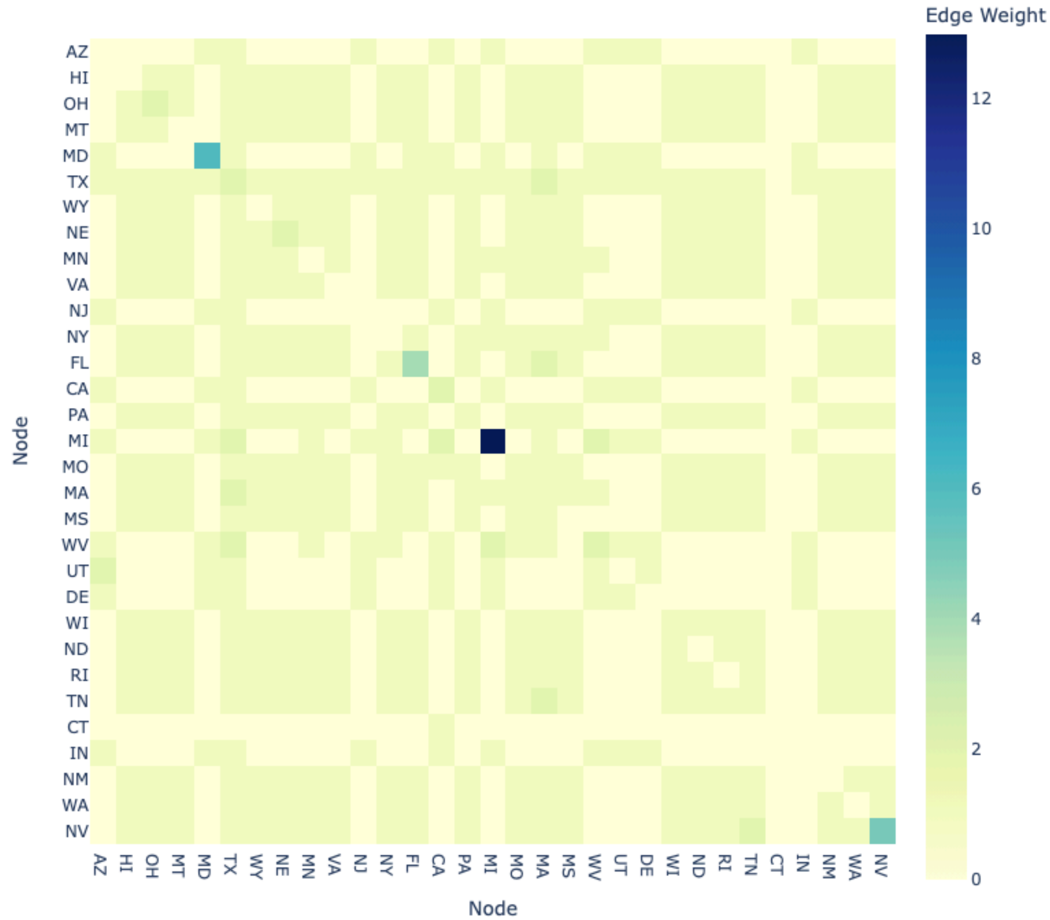



We are not including state-attributed Sankey diagrams due to the reason that the number of states in both Gs and Gh would make the graph unreadable, so we present the adjacency matrix heatmaps to visualize the relationships between candidate nodes from the state aspect.

## 7.3. State Attributed Heatmap of Senate Candidates Hyperlink Graph

Figure 21 displays the heatmap for the Senate Candidates' hyperlink graph. The edge weights are represented by the color intensity in each cell of the heatmap, meaning the weight of the edge between two states. The assortativity coefficient is a measure used to quantify the tendency of nodes in a network to connect to other nodes that are similar in some way. A higher intensity (darker color) indicates a stronger connection between two states, and a lower intensity (lighter color) indicates a weaker connection. The heatmap above allows us to obtain a clear and detailed visualization of the connectivity relationships between candidates in different states. For instance, Michigan (MI) and California (CA) exhibit relatively higher connections and assortativity. However, one limitation is that this heatmap cannot provide the direction of the assortativity between two states. This means that we cannot determine if the connections from MI to CA have higher assortativity or vice versa.

**Fig 21:** **State Attributed Senate Candidates Adjacency Matrix Heatmap**




## 7.4. House Candidate Graphs

In order to manageably visualize the attributes for the House candidates, we selected a subgraph of candidate's from the states of Colorado, Connecticut, Georgia, Illinois and Washington. The reciprocated subgraph of these states contains 52 nodes and 967 edges. Figure 22 illustrates the subgraph without attributes.

**Fig 22: Subgraph of the CO, CT, GA, IL, WA House Candidates**

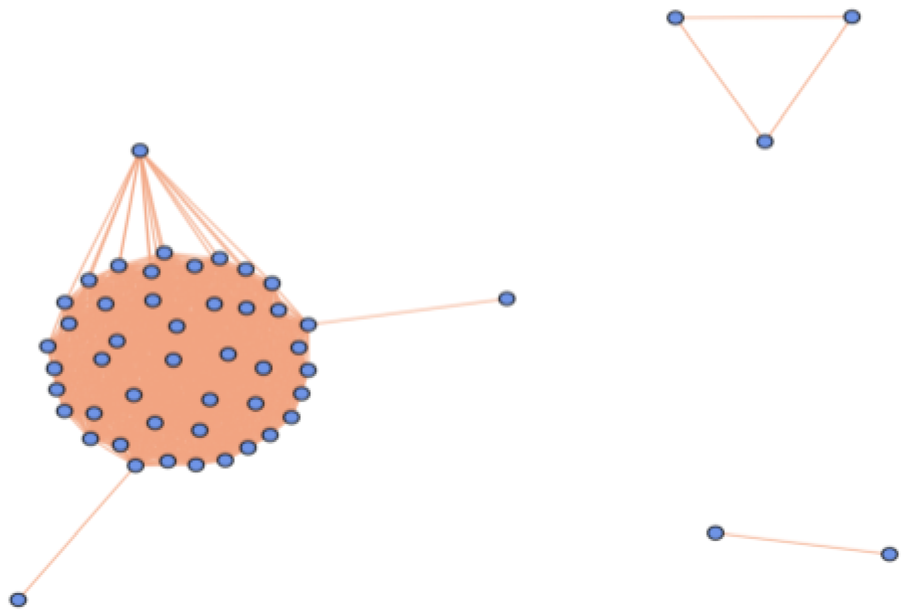
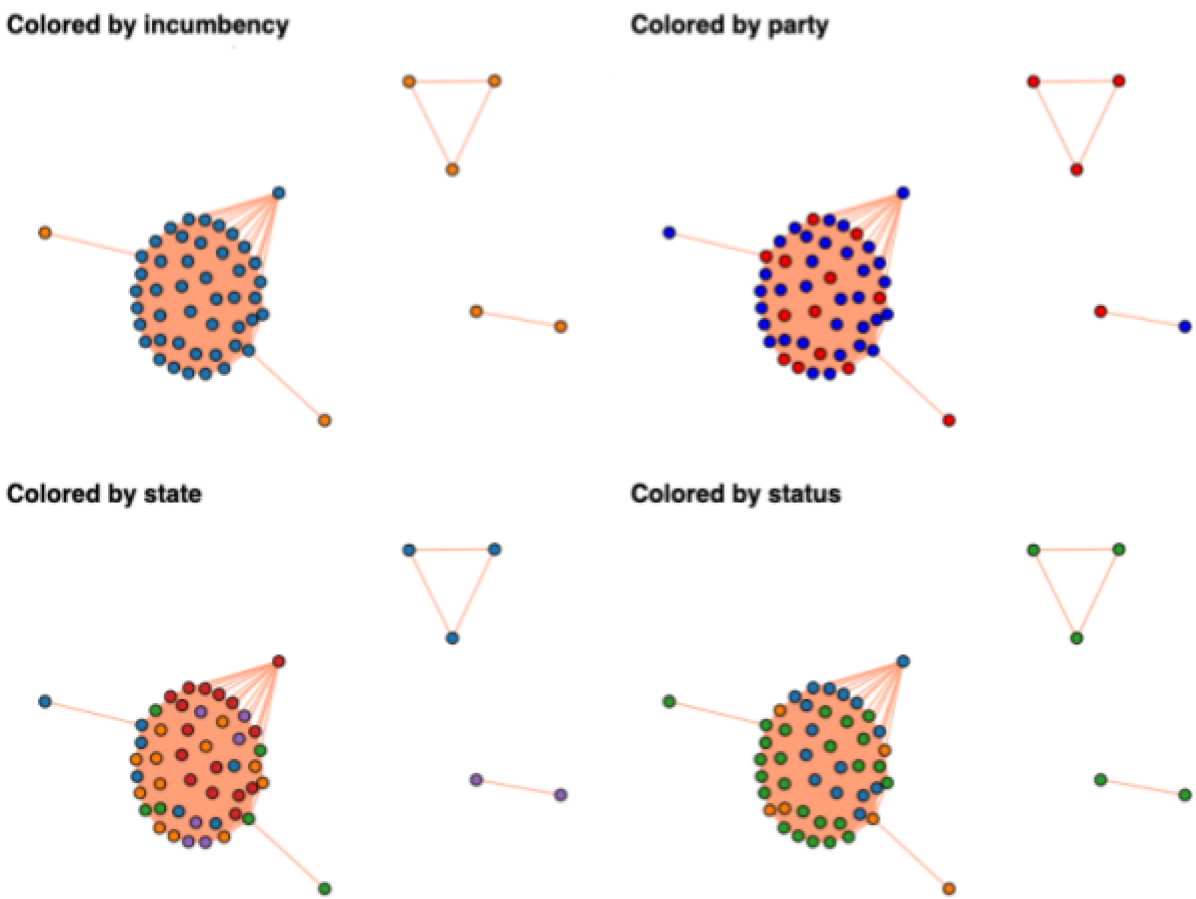


Figure 23 presents subgraphs where candidate nodes are colored based on their respective attribute values. Each of the four subgraphs highlights different attributes: incumbency, party affiliation, state, and candidacy status. In the incumbency graph, green nodes represent “Incumbents,” comprising the majority with 45 nodes and red nodes represent “Challengers,” accounting for 7 nodes. The party affiliation graph depicts “Democratic” as blue nodes, represented by 35 nodes and “Republican” as red nodes, represented by 17 nodes. The states graph colored Colorado as blue with 10 nodes, Connecticut as orange with 6 nodes, Georgia as green with 12 nodes, Illinois as red with 17 nodes and Washington as purple with 8 nodes. Lastly, the status attributed graph colored “candidacy declared primary” as blue with 6 nodes, “on the ballot general” as orange with 16 nodes and “on the ballot primary” as green with 30 nodes. Each subgraph visually emphasizes the distribution of candidates based on the specific attribute, providing a clear and comparative view of how these attributes are represented within the network of candidates.

**Fig 23: Attribute Subgraphs of the CO, CT, GA, IL, WA House Candidates**




The four attribute subgraphs of the House candidates from Colorado, Connecticut, Georgia, Illinois and Washington.

## 7.5. House Attributed Graphs as Sankey Diagrams

In the following graphs, we display the incumbency, party affiliation and candidacy status attributes for the full House candidates hyperlink graph (Gh) using Sankey diagrams.

**Fig 24-1: Sankey Diagram of Incumbency for House Candidates**

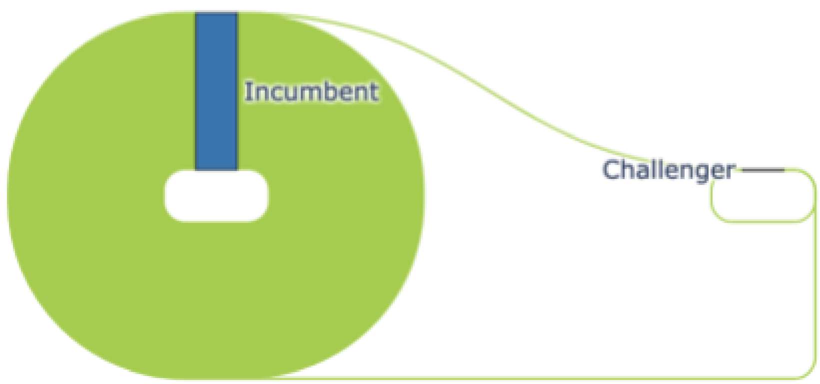



**Fig 24-2: Sankey Diagram of Party for House Candidates**

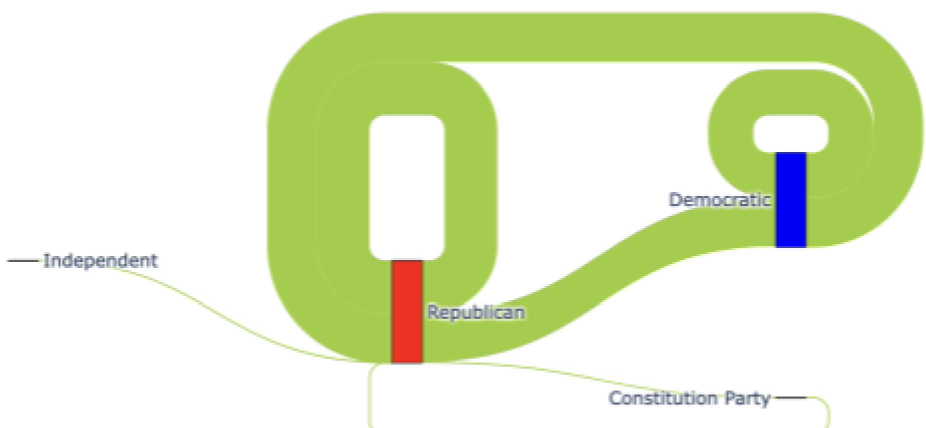
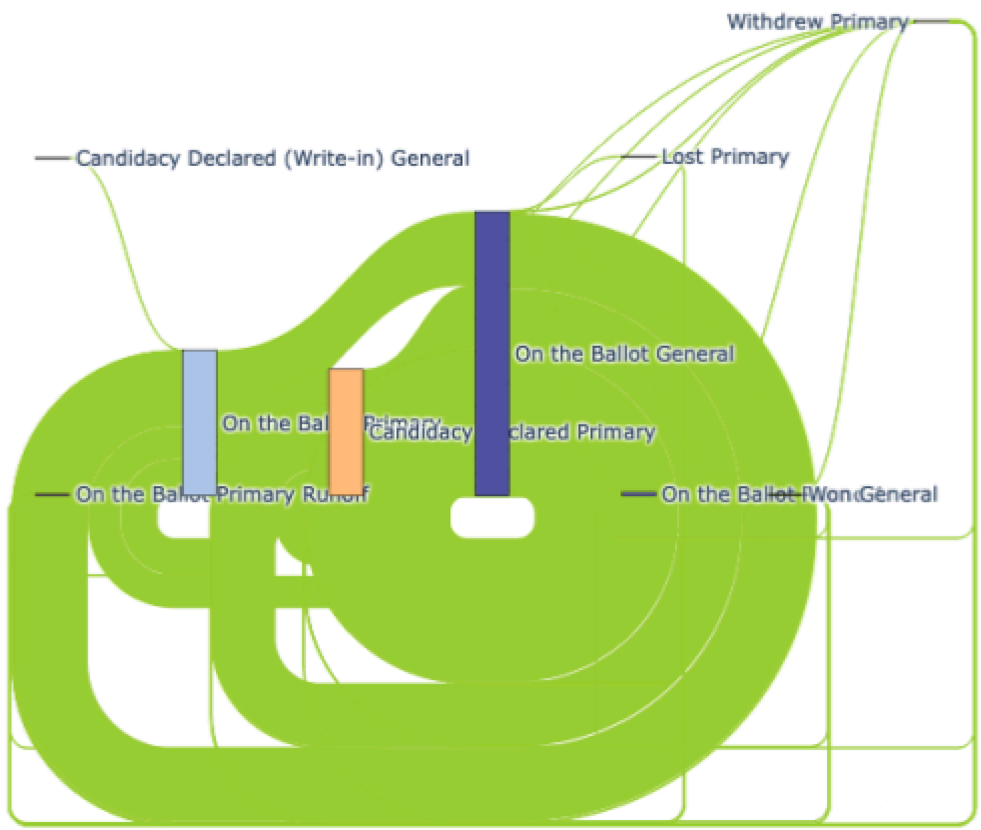


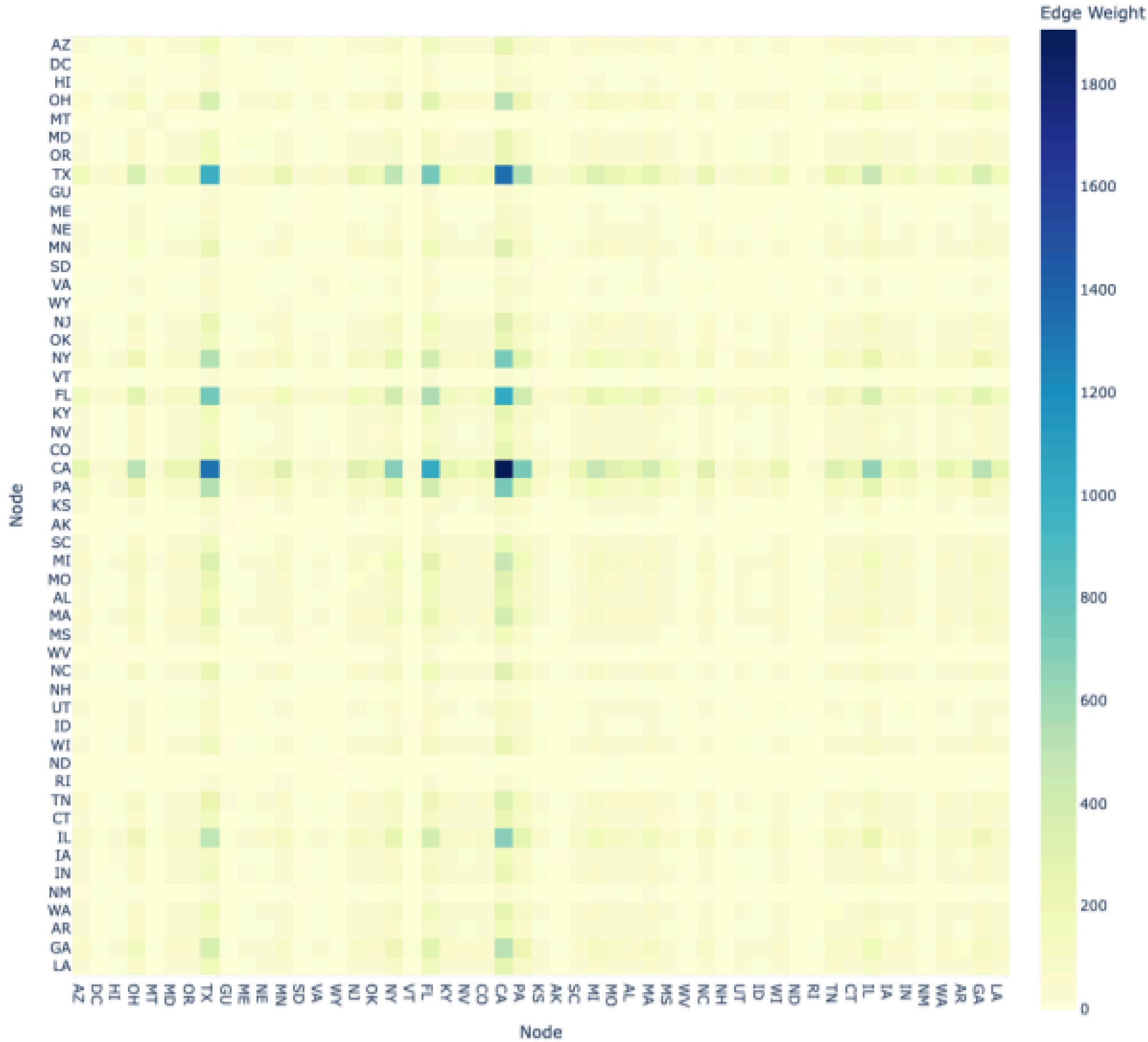
Fig 24-3: Sankey Diagram of Status for House Candidates




## 7.6. State Attributed Heatmap of House Candidates Hyperlink Graph

The heatmap below offers a detailed look at how House candidates are interconnected within the network, with the color intensity indicating the weight of the edge between the corresponding nodes. Nodes along the diagonal represent self-loops. For example, the darkest node shows California has a high connectivity to other candidate nodes also from California. There also appears to be many candidates from California and Texas connected to each other.

**Fig 25: State Attributed House Candidates Graph Adjacency Matrix Heatmap**




# 8. Nodal Centrality Indices

In this section we explore multiple centrality measures for nodes in both the Senate and House hyperlinks graph. We begin by defining the measure of centrality used in our analysis. Our calculations were performed using NetworkX's centrality functions.

- ***Out-degree centrality:*** In a directed graph, the degree centrality of a node is the number of nodes outgoing from the node divided by the total number of nodes in the graph minus one (https://networkx.org/documentation/stable/reference/algorithms/generated/networkx.algorithms.centrality.out_degree_centrality.html#networkx.algorithms.centrality.out_degree_centrality).

- ***In-degree centrality:*** In a directed graph, the degree centrality of a node is the number of nodes incoming to the node divided by the total number of nodes in the graph minus one (https://networkx.org/documentation/stable/reference/algorithms/generated/networkx.algorithms.centrality.in_degree_centrality.html#networkx.algorithms.centrality.in_degree_centrality).
- ***Degree centrality:*** In an undirected graph, the degree centrality of a node is the number of nodes adjacent to the node divided by the total number of nodes in the graph minus one (https://networkx.org/documentation/stable/reference/algorithms/generated/networkx.algorithms.centrality.degree_centrality.html).
- ***Closeness centrality:*** Closeness centrality quantifies how close a node is to all other nodes in the network by using the average shortest path distance to a node over all other reachable nodes (the exact mathematical definition is here https://networkx.org/documentation/stable/reference/algorithms/generated/networkx.algorithms.centrality.closeness_centrality.html#networkx.algorithms.centrality.closeness_centrality).
- ***Betweenness centrality:*** Betweenness centrality quantifies the importance of a node based on the number of times it acts as a bridge along the shortest path between two other nodes (the exact mathematical definition is here https://networkx.org/documentation/stable/reference/algorithms/generated/networkx.algo

rithms.centrality.betweenness_centrality.html#networkx.algorithms.centrality.betweenness_centrality).

- ***Eigenvector centrality:*** Eigenvector centrality iteratively computes the centrality of a node based on the centrality of its neighbors (the exact mathematical definition is here https://networkx.org/documentation/stable/reference/algorithms/generated/networkx.algorithms.centrality.eigenvector_centrality.html#networkx.algorithms.centrality.eigenvector_centrality).
- ***HITS:*** The HITS algorithm computes two numbers for a node- hubs and authorities. Authorities estimate the node value based on the incoming links. Hubs estimates the node value based on outgoing links (https://networkx.org/documentation/stable/reference/algorithms/generated/networkx.algorithms.link_analysis.hits_alg.hits.html#networkx.algorithms.link_analysis.hits_alg.hits).
- ***Katz centrality:*** Katz centrality measures the relative influence of a node within a network by considering the number of all paths leading to that node, while giving a diminishing weight to longer paths. It is defined using a parameter α that scales the importance of the paths and a parameter β that adds a constant to account for each node's centrality (the exact mathematical definition is here https://networkx.org/documentation/stable/reference/algorithms/generated/networkx.algorithms.centrality.katz_centrality.html#networkx.algorithms.centrality.katz_centrality).
- ***PageRank centrality:*** PageRank computes a ranking of the nodes in the graph based on the structure of the incoming links. It was originally designed as an algorithm to rank web pages (https://networkx.org/documentation/stable/reference/algorithms/generated/networkx.algorithms.link_analysis.pagerank_alg.pagerank.html#networkx.algorithms.link_analysis.pagerank_alg.pagerank).

- ***Load centrality:*** The load centrality of a node is the fraction of all shortest paths that pass through that node (https://networkx.org/documentation/stable/reference/algorithms/generated/networkx.algorithms.centrality.load_centrality.html#networkx.algorithms.centrality.load_centrality).
- ***Communicability:*** The communicability between pairs of nodes (u,v) in a graph is the sum of walks of different lengths starting at u and ending at v (https://networkx.org/documentation/stable/reference/algorithms/generated/networkx.algorithms.communicability_alg.communicability.html#networkx.algorithms.communicability_alg.communicability).

## 8.1. Centrality Measures for Reciprocated (undirected) Senate Graph

### Table 19: Centrality Measures for Reciprocated Subgraph of Senate Graph

| node | degree | closeness | betweenness | eigenvector | HITS | Katz | PageRank | load | communicability |
|---|---|---|---|---|---|---|---|---|---|
| Colin Allred | 0.261905 | 0.531646 | 0.358188 | 0.022944 | 0.004855 | 0.021787 | 0.028444 | 0.35707 | 0.470194 |
| Elizabeth Warren | 0.547619 | 0.626866 | 0.221332 | 0.221603 | 0.046895 | 0.221539 | 0.033383 | 0.218448 | 0.695074 |
| Ted Cruz | 0.5 | 0.591549 | 0.173868 | 0.218282 | 0.046192 | 0.218272 | 0.029273 | 0.173926 | 0.655624 |
| Justin Amash | 0.166667 | 0.482759 | 0.094774 | 0.035161 | 0.007441 | 0.034424 | 0.017956 | 0.095891 | 0.167885 |
| Rick Scott | 0.5 | 0.506024 | 0.092915 | 0.217709 | 0.046071 | 0.217721 | 0.032118 | 0.092915 | 0.577673 |
| David Trone | 0.238095 | 0.407767 | 0.092915 | 0.002064 | 0.000436 | 0.000812 | 0.031618 | 0.092915 | 0.137938 |
| Elissa Slotkin | 0.285714 | 0.424242 | 0.061556 | 0.003923 | 0.00083 | 0.002601 | 0.034377 | 0.06417 | 0.109371 |
| Sherrod Brown | 0.5 | 0.5 | 0.047619 | 0.217708 | 0.04607 | 0.217721 | 0.031036 | 0.047619 | 0.556273 |
| Alexander Mooney | 0.238095 | 0.403846 | 0.047619 | 0.002064 | 0.000436 | 0.000813 | 0.030796 | 0.047619 | 0.099174 |
| Angela Alsobrooks | 0.047619 | 0.295775 | 0.047619 | 0.000103 | 2.2e-05 | -0.000661 | 0.014312 | 0.047619 | 0.048019 |
| Deb Fischer | 0.5 | 0.5 | 0.047619 | 0.217708 | 0.04607 | 0.217721 | 0.031036 | 0.047619 | 0.556273 |
| Debbie Mucarsel-Powe | 0.047619 | 0.344262 | 0.047619 | 0.010878 | 0.002302 | 0.010211 | 0.012138 | 0.047619 | 0.049317 |
| Adam Schiff | 0.238095 | 0.403846 | 0.047619 | 0.002064 | 0.000436 | 0.000813 | 0.030796 | 0.047619 | 0.099174 |
| Amy Klobuchar | 0.52381 | 0.525 | 0.038753 | 0.220513 | 0.046664 | 0.220501 | 0.031213 | 0.03886 | 0.58082 |
| Kirsten Gillibrand | 0.52381 | 0.525 | 0.038753 | 0.220513 | 0.046664 | 0.220501 | 0.031213 | 0.03886 | 0.58082 |
| Don Blankenship | 0.095238 | 0.411765 | 0.0 | 0.03478 | 0.00736 | 0.034182 | 0.009314 | 0.0 | 0.031078 |
| Sheldon Whitehouse | 0.47619 | 0.494118 | 0.0 | 0.217193 | 0.045961 | 0.217234 | 0.027107 | 0.0 | 0.534634 |
| Mike Rogers | 0.071429 | 0.371681 | 0.0 | 0.00205 | 0.000434 | 0.001247 | 0.011308 | 0.0 | 0.007111 |
| Larry Hogan | 0.02381 | 0.229508 | 0.0 | 5e-06 | 1e-06 | -0.0007 | 0.009571 | 0.0 | 0.000185 |
| Alan Grayson | 0.02381 | 0.257669 | 0.0 | 0.000542 | 0.000115 | -0.000156 | 0.008647 | 0.0 | 0.000122 |
| Maria Cantwell | 0.47619 | 0.494118 | 0.0 | 0.217193 | 0.045961 | 0.217234 | 0.027107 | 0.0 | 0.534634 |
| Tim Kaine | 0.47619 | 0.494118 | 0.0 | 0.217193 | 0.045961 | 0.217234 | 0.027107 | 0.0 | 0.534634 |
| Peter Meijer | 0.071429 | 0.371681 | 0.0 | 0.00205 | 0.000434 | 0.001247 | 0.011308 | 0.0 | 0.007111 |
| Dan Osborn | 0.02381 | 0.336 | 0.0 | 0.010851 | 0.002296 | 0.010219 | 0.004745 | 0.0 | 0.001775 |
| Bernie Moreno | 0.02381 | 0.336 | 0.0 | 0.010851 | 0.002296 | 0.010219 | 0.004745 | 0.0 | 0.001775 |
| Ruben Gallego | 0.214286 | 0.4 | 0.0 | 0.002059 | 0.000435 | 0.000843 | 0.025788 | 0.0 | 0.058759 |
| Marsha Blackburn | 0.47619 | 0.494118 | 0.0 | 0.217193 | 0.045961 | 0.217234 | 0.027107 | 0.0 | 0.534634 |
| Josh Hawley | 0.47619 | 0.494118 | 0.0 | 0.217193 | 0.045961 | 0.217234 | 0.027107 | 0.0 | 0.534634 |
| Jon Tester | 0.47619 | 0.494118 | 0.0 | 0.217193 | 0.045961 | 0.217234 | 0.027107 | 0.0 | 0.534634 |
| Roger Wicker | 0.47619 | 0.494118 | 0.0 | 0.217193 | 0.045961 | 0.217234 | 0.027107 | 0.0 | 0.534634 |
| Bob Casey Jr. | 0.47619 | 0.494118 | 0.0 | 0.217193 | 0.045961 | 0.217234 | 0.027107 | 0.0 | 0.534634 |
| Jacky Rosen | 0.47619 | 0.494118 | 0.0 | 0.217193 | 0.045961 | 0.217234 | 0.027107 | 0.0 | 0.534634 |
| Mazie K. Hirono | 0.47619 | 0.494118 | 0.0 | 0.217193 | 0.045961 | 0.217234 | 0.027107 | 0.0 | 0.534634 |
| Martin Heinrich | 0.47619 | 0.494118 | 0.0 | 0.217193 | 0.045961 | 0.217234 | 0.027107 | 0.0 | 0.534634 |
| John Barrasso | 0.47619 | 0.494118 | 0.0 | 0.217193 | 0.045961 | 0.217234 | 0.027107 | 0.0 | 0.534634 |
| Kevin Cramer | 0.47619 | 0.494118 | 0.0 | 0.217193 | 0.045961 | 0.217234 | 0.027107 | 0.0 | 0.534634 |
| Tammy Baldwin | 0.47619 | 0.494118 | 0.0 | 0.217193 | 0.045961 | 0.217234 | 0.027107 | 0.0 | 0.534634 |
| Steve Garvey | 0.02381 | 0.289655 | 0.0 | 0.000103 | 2.2e-05 | -0.000626 | 0.006106 | 0.0 | 0.000459 |
| Jim Banks | 0.214286 | 0.4 | 0.0 | 0.002059 | 0.000435 | 0.000843 | 0.025788 | 0.0 | 0.058759 |
| John Curtis | 0.214286 | 0.4 | 0.0 | 0.002059 | 0.000435 | 0.000843 | 0.025788 | 0.0 | 0.058759 |
| Andrew Kim | 0.214286 | 0.4 | 0.0 | 0.002059 | 0.000435 | 0.000843 | 0.025788 | 0.0 | 0.058759 |
| Lisa Blunt Rochester | 0.214286 | 0.4 | 0.0 | 0.002059 | 0.000435 | 0.000843 | 0.025788 | 0.0 | 0.058759 |
| Jim Justice | 0.02381 | 0.289655 | 0.0 | 0.000103 | 2.2e-05 | -0.000626 | 0.006106 | 0.0 | 0.000459 |

## 8.2. Centrality Measures for Directed Senate Graph

### Table 20: Centrality Measures for Connected Subgraph of Senate Graph

| node | out_degree | in_degree | closeness | betweenness | eigenvector | HITS_hubs | HITS_auths | Katz | PageRank | load |
|---|---|---|---|---|---|---|---|---|---|---|
| Elizabeth Warren | 0.418182 | 0.472727 | 0.597826 | 0.146002 | 0.221651 | 0.045116 | 0.046927 | 0.221477 | 0.040501 | 0.131152 |
| Colin Allred | 0.2 | 0.2 | 0.478261 | 0.109852 | 0.023966 | 0.005092 | 0.005415 | 0.022661 | 0.022476 | 0.088811 |
| David Trone | 0.236364 | 0.181818 | 0.376712 | 0.108876 | 0.003016 | 0.00531 | 0.000828 | 0.001609 | 0.026388 | 0.110723 |
| Adam Schiff | 0.181818 | 0.236364 | 0.474138 | 0.088159 | 0.013447 | 0.000676 | 0.00338 | 0.011998 | 0.028643 | 0.105017 |
| Rick Scott | 0.381818 | 0.4 | 0.561224 | 0.085753 | 0.217711 | 0.044307 | 0.045742 | 0.217694 | 0.033391 | 0.09064 |
| Josh Hawley | 0.381818 | 0.4 | 0.544554 | 0.08435 | 0.217195 | 0.04436 | 0.045737 | 0.217177 | 0.031483 | 0.105665 |
| Ted Cruz | 0.381818 | 0.418182 | 0.561224 | 0.073846 | 0.220002 | 0.044429 | 0.046365 | 0.219927 | 0.032416 | 0.060216 |
| Justin Amash | 0.145455 | 0.127273 | 0.44 | 0.059054 | 0.035182 | 0.009475 | 0.007376 | 0.034357 | 0.014221 | 0.059302 |
| Alexander Mooney | 0.218182 | 0.181818 | 0.371622 | 0.057095 | 0.003016 | 0.00527 | 0.00083 | 0.00161 | 0.023432 | 0.059289 |
| Elissa Slotkin | 0.218182 | 0.236364 | 0.387324 | 0.04438 | 0.004878 | 0.001174 | 0.001581 | 0.003357 | 0.027274 | 0.046263 |
| Jacky Rosen | 0.363636 | 0.418182 | 0.495495 | 0.035017 | 0.217052 | 0.044193 | 0.045817 | 0.217025 | 0.032578 | 0.035017 |
| Debbie Mucarsel-Powell | 0.036364 | 0.036364 | 0.366667 | 0.031987 | 0.010873 | 0.00222 | 0.002271 | 0.010125 | 0.009874 | 0.031987 |
| Sherrod Brown | 0.381818 | 0.381818 | 0.486726 | 0.031987 | 0.217566 | 0.04432 | 0.045469 | 0.217618 | 0.03091 | 0.031987 |
| Deb Fischer | 0.381818 | 0.381818 | 0.486726 | 0.031987 | 0.217566 | 0.04432 | 0.045469 | 0.217618 | 0.03091 | 0.031987 |
| Angela Alsobrooks | 0.036364 | 0.036364 | 0.280612 | 0.027609 | 0.000158 | 5.3e-05 | 0.000272 | -0.000705 | 0.015787 | 0.027609 |
| Amy Klobuchar | 0.4 | 0.4 | 0.509259 | 0.023281 | 0.220371 | 0.04489 | 0.046175 | 0.220395 | 0.030855 | 0.023397 |
| Kirsten Gillibrand | 0.4 | 0.4 | 0.509259 | 0.023281 | 0.220371 | 0.04489 | 0.046175 | 0.220395 | 0.030855 | 0.023397 |
| Marsha Blackburn | 0.363636 | 0.4 | 0.491071 | 0.021044 | 0.217052 | 0.044199 | 0.045702 | 0.217063 | 0.031231 | 0.021044 |
| Shiva Ayyadurai | 0.018182 | 0.018182 | 0.018182 | 0.014478 | 0.0 | 0.002272 | 0.0 | -0.000785 | 0.004955 | 0.014478 |
| Larry Hogan | 0.018182 | 0.054545 | 0.282051 | 0.014141 | 0.000158 | 1.3e-05 | 0.000275 | -0.00074 | 0.013391 | 0.014141 |
| Bob Casey Jr. | 0.363636 | 0.381818 | 0.486726 | 0.014141 | 0.217052 | 0.04421 | 0.045475 | 0.2171 | 0.02983 | 0.014141 |
| Tammy Baldwin | 0.363636 | 0.381818 | 0.486726 | 0.014141 | 0.217052 | 0.04421 | 0.045475 | 0.2171 | 0.02983 | 0.014141 |
| Mike Rogers | 0.072727 | 0.054545 | 0.341615 | 0.000786 | 0.002101 | 0.000625 | 0.000568 | 0.001197 | 0.008359 | 0.000842 |
| Sam Brown | 0.036364 | 0.018182 | 0.018182 | 0.000168 | 0.0 | 0.00443 | 0.000114 | -0.000785 | 0.003438 | 0.000168 |
| Lucas Kunce | 0.018182 | 0.0 | 0.0 | 0.0 | 0.0 | 0.002214 | -0.0 | -0.000748 | 0.002679 | 0.0 |
| David McCormick | 0.018182 | 0.0 | 0.0 | 0.0 | 0.0 | 0.002201 | 0.0 | -0.000748 | 0.002679 | 0.0 |
| Jim Justice | 0.018182 | 0.018182 | 0.272277 | 0.0 | 0.00015 | 4e-05 | 0.000269 | -0.000668 | 0.004338 | 0.0 |
| Gloria Johnson | 0.018182 | 0.0 | 0.0 | 0.0 | 0.0 | 0.002212 | -0.0 | -0.000748 | 0.002679 | 0.0 |
| Marquita Bradshaw | 0.018182 | 0.0 | 0.0 | 0.0 | 0.0 | 0.002272 | -0.0 | -0.000748 | 0.002679 | 0.0 |
| Don Blankenship | 0.072727 | 0.072727 | 0.395683 | 0.0 | 0.034751 | 0.007099 | 0.007382 | 0.034083 | 0.00807 | 0.0 |
| Jim Marchant | 0.018182 | 0.018182 | 0.018182 | 0.0 | 0.0 | 0.002218 | 0.000114 | -0.000785 | 0.003438 | 0.0 |
| Bernie Moreno | 0.018182 | 0.018182 | 0.329341 | 0.0 | 0.010838 | 0.002201 | 0.002266 | 0.010133 | 0.00393 | 0.0 |
| Robin Ficker | 0.018182 | 0.0 | 0.0 | 0.0 | 0.0 | 1.3e-05 | 0.0 | -0.000748 | 0.002679 | 0.0 |
| Jeff Gunter | 0.054545 | 0.0 | 0.0 | 0.0 | 0.0 | 0.002229 | 0.0 | -0.000748 | 0.002679 | 0.0 |
| Peter Meijer | 0.054545 | 0.054545 | 0.341615 | 0.0 | 0.002101 | 0.000461 | 0.000576 | 0.001197 | 0.007898 | 0.0 |
| Hill Harper | 0.018182 | 0.0 | 0.0 | 0.0 | 0.0 | 7.7e-05 | 0.0 | -0.000748 | 0.002679 | 0.0 |
| Dan Osborn | 0.018182 | 0.018182 | 0.329341 | 0.0 | 0.010838 | 0.002201 | 0.002266 | 0.010133 | 0.00393 | 0.0 |
| Ruben Gallego | 0.163636 | 0.163636 | 0.369128 | 0.0 | 0.003009 | 0.000787 | 0.001057 | 0.001642 | 0.019557 | 0.0 |
| Randy Toler | 0.018182 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.0 | -0.000748 | 0.002679 | 0.0 |
| Alan Grayson | 0.018182 | 0.018182 | 0.269608 | 0.0 | 0.000542 | 0.00011 | 0.000113 | -0.000242 | 0.006875 | 0.0 |
| Lisa Blunt Rochester | 0.163636 | 0.163636 | 0.369128 | 0.0 | 0.003009 | 0.000787 | 0.001057 | 0.001642 | 0.019557 | 0.0 |
| Andrew Kim | 0.163636 | 0.163636 | 0.369128 | 0.0 | 0.003009 | 0.000787 | 0.001057 | 0.001642 | 0.019557 | 0.0 |
| John Curtis | 0.163636 | 0.163636 | 0.369128 | 0.0 | 0.003009 | 0.000787 | 0.001057 | 0.001642 | 0.019557 | 0.0 |
| Jim Banks | 0.163636 | 0.163636 | 0.369128 | 0.0 | 0.003009 | 0.000787 | 0.001057 | 0.001642 | 0.019557 | 0.0 |
| Steve Garvey | 0.018182 | 0.018182 | 0.323529 | 0.0 | 0.00067 | 0.000164 | 3.5e-05 | -0.000148 | 0.005113 | 0.0 |
| Robert Hyde | 0.018182 | 0.0 | 0.0 | 0.0 | 0.0 | 0.000164 | -0.0 | -0.000748 | 0.002679 | 0.0 |
| Kevin Cramer | 0.363636 | 0.363636 | 0.482456 | 0.0 | 0.217052 | 0.044215 | 0.045362 | 0.217136 | 0.027646 | 0.0 |
| John Barrasso | 0.363636 | 0.363636 | 0.482456 | 0.0 | 0.217052 | 0.044215 | 0.045362 | 0.217136 | 0.027646 | 0.0 |
| Martin Heinrich | 0.363636 | 0.363636 | 0.482456 | 0.0 | 0.217052 | 0.044215 | 0.045362 | 0.217136 | 0.027646 | 0.0 |
| Mazie K. Hirono | 0.363636 | 0.363636 | 0.482456 | 0.0 | 0.217052 | 0.044215 | 0.045362 | 0.217136 | 0.027646 | 0.0 |
| Roger Wicker | 0.363636 | 0.363636 | 0.482456 | 0.0 | 0.217052 | 0.044215 | 0.045362 | 0.217136 | 0.027646 | 0.0 |
| Jon Tester | 0.363636 | 0.363636 | 0.482456 | 0.0 | 0.217052 | 0.044215 | 0.045362 | 0.217136 | 0.027646 | 0.0 |
| Sheldon Whitehouse | 0.363636 | 0.363636 | 0.482456 | 0.0 | 0.217052 | 0.044215 | 0.045362 | 0.217136 | 0.027646 | 0.0 |
| Tim Kaine | 0.363636 | 0.363636 | 0.482456 | 0.0 | 0.217052 | 0.044215 | 0.045362 | 0.217136 | 0.027646 | 0.0 |
| Maria Cantwell | 0.363636 | 0.363636 | 0.482456 | 0.0 | 0.217052 | 0.044215 | 0.045362 | 0.217136 | 0.027646 | 0.0 |
| Eric Hovde | 0.018182 | 0.0 | 0.0 | 0.0 | 0.0 | 0.002201 | -0.0 | -0.000748 | 0.002679 | 0.0 |

### 8.3. Centrality Measures for Reciprocated (undirected) House Graph (subset)

We consider the same subgraph of 5 states- Colorado, Connecticut, Georgia, Illinois and Washington- that we used in the section 6 visualizations. The reciprocated subgraph has 52 vertices and 967 edges. Table 21 displays the calculated centrality measures.

Table 21: Centrality Measures for Reciprocated Subgraph of House Candidates

| node | degree | closeness | betweenness | eigenvector | HITS | Katz | PageRank | load |
|---|---|---|---|---|---|---|---|---|
| Lauren Boebert | 0.862745 | 0.864379 | 0.035294 | 0.150212 | 0.022475 | 0.129893 | 0.022674 | 0.035294 |
| Jahana Hayes | 0.862745 | 0.864379 | 0.035294 | 0.150212 | 0.022475 | 0.129893 | 0.022674 | 0.035294 |
| Lauren Underwood | 0.862745 | 0.864379 | 0.001621 | 0.151327 | 0.022642 | 0.134383 | 0.020393 | 0.001621 |
| Eric Sorensen | 0.862745 | 0.864379 | 0.001621 | 0.151327 | 0.022642 | 0.134383 | 0.020393 | 0.001621 |
| Robin Kelly | 0.862745 | 0.864379 | 0.001621 | 0.151327 | 0.022642 | 0.134383 | 0.020393 | 0.001621 |
| Mary Miller | 0.862745 | 0.864379 | 0.001621 | 0.151327 | 0.022642 | 0.134383 | 0.020393 | 0.001621 |
| Bill Foster | 0.862745 | 0.864379 | 0.001621 | 0.151327 | 0.022642 | 0.134383 | 0.020393 | 0.001621 |
| Delia Ramirez | 0.862745 | 0.864379 | 0.001621 | 0.151327 | 0.022642 | 0.134383 | 0.020393 | 0.001621 |
| Nikki Budzinski | 0.862745 | 0.864379 | 0.001621 | 0.151327 | 0.022642 | 0.134383 | 0.020393 | 0.001621 |
| Sean Casten | 0.862745 | 0.864379 | 0.001621 | 0.151327 | 0.022642 | 0.134383 | 0.020393 | 0.001621 |
| Darin LaHood | 0.862745 | 0.864379 | 0.001621 | 0.151327 | 0.022642 | 0.134383 | 0.020393 | 0.001621 |
| Brad Schneider | 0.862745 | 0.864379 | 0.001621 | 0.151327 | 0.022642 | 0.134383 | 0.020393 | 0.001621 |
| Jonathan Jackson | 0.862745 | 0.864379 | 0.001621 | 0.151327 | 0.022642 | 0.134383 | 0.020393 | 0.001621 |
| Raja Krishnamoorthi | 0.862745 | 0.864379 | 0.001621 | 0.151327 | 0.022642 | 0.134383 | 0.020393 | 0.001621 |
| Danny K. Davis | 0.862745 | 0.864379 | 0.001621 | 0.151327 | 0.022642 | 0.134383 | 0.020393 | 0.001621 |
| Jan Schakowsky | 0.862745 | 0.864379 | 0.001621 | 0.151327 | 0.022642 | 0.134383 | 0.020393 | 0.001621 |
| Mike Bost | 0.862745 | 0.864379 | 0.001621 | 0.151327 | 0.022642 | 0.134383 | 0.020393 | 0.001621 |
| Brittany Pettersen | 0.843137 | 0.846739 | 0.0 | 0.150133 | 0.022463 | 0.136958 | 0.019895 | 0.0 |
| Jim Himes | 0.843137 | 0.846739 | 0.0 | 0.150133 | 0.022463 | 0.136958 | 0.019895 | 0.0 |
| Rick Larsen | 0.843137 | 0.846739 | 0.0 | 0.150133 | 0.022463 | 0.136958 | 0.019895 | 0.0 |
| Mike Collins | 0.843137 | 0.846739 | 0.0 | 0.150133 | 0.022463 | 0.136958 | 0.019895 | 0.0 |
| Drew MacEwen | 0.019608 | 0.019608 | 0.0 | 0.0 | 0.0 | -0.163014 | 0.019231 | 0.0 |
| Joe Neguse | 0.843137 | 0.846739 | 0.0 | 0.150133 | 0.022463 | 0.136958 | 0.019895 | 0.0 |
| George Logan | 0.019608 | 0.446131 | 0.0 | 0.003484 | 0.000521 | -0.148369 | 0.003323 | 0.0 |
| Marilyn Strickland | 0.843137 | 0.846739 | 0.0 | 0.150133 | 0.022463 | 0.136958 | 0.019895 | 0.0 |
| Barry Loudermilk | 0.843137 | 0.846739 | 0.0 | 0.150133 | 0.022463 | 0.136958 | 0.019895 | 0.0 |
| Kim Schrier | 0.843137 | 0.846739 | 0.0 | 0.150133 | 0.022463 | 0.136958 | 0.019895 | 0.0 |
| Michael Lynch (1) | 0.039216 | 0.039216 | 0.0 | 0.0 | -0.0 | -0.172071 | 0.019231 | 0.0 |
| Suzan DelBene | 0.843137 | 0.846739 | 0.0 | 0.150133 | 0.022463 | 0.136958 | 0.019895 | 0.0 |
| Mike Quigley | 0.294118 | 0.525192 | 0.0 | 0.052641 | 0.007876 | -0.054077 | 0.008794 | 0.0 |
| Diana DeGette | 0.843137 | 0.846739 | 0.0 | 0.150133 | 0.022463 | 0.136958 | 0.019895 | 0.0 |
| Nikema Williams | 0.843137 | 0.846739 | 0.0 | 0.150133 | 0.022463 | 0.136958 | 0.019895 | 0.0 |
| Joe Courtney | 0.843137 | 0.846739 | 0.0 | 0.150133 | 0.022463 | 0.136958 | 0.019895 | 0.0 |
| Rich McCormick | 0.843137 | 0.846739 | 0.0 | 0.150133 | 0.022463 | 0.136958 | 0.019895 | 0.0 |
| Marjorie Taylor Greene | 0.843137 | 0.846739 | 0.0 | 0.150133 | 0.022463 | 0.136958 | 0.019895 | 0.0 |
| Pramila Jayapal | 0.843137 | 0.846739 | 0.0 | 0.150133 | 0.022463 | 0.136958 | 0.019895 | 0.0 |
| Jason Crow | 0.843137 | 0.846739 | 0.0 | 0.150133 | 0.022463 | 0.136958 | 0.019895 | 0.0 |
| Yadira Caraveo | 0.843137 | 0.846739 | 0.0 | 0.150133 | 0.022463 | 0.136958 | 0.019895 | 0.0 |
| Sanford Bishop Jr. | 0.843137 | 0.846739 | 0.0 | 0.150133 | 0.022463 | 0.136958 | 0.019895 | 0.0 |
| Emily Randall | 0.019608 | 0.019608 | 0.0 | 0.0 | -0.0 | -0.163014 | 0.019231 | 0.0 |
| David Scott | 0.843137 | 0.846739 | 0.0 | 0.150133 | 0.022463 | 0.136958 | 0.019895 | 0.0 |
| Hank Johnson | 0.843137 | 0.846739 | 0.0 | 0.150133 | 0.022463 | 0.136958 | 0.019895 | 0.0 |
| Dan Newhouse | 0.843137 | 0.846739 | 0.0 | 0.150133 | 0.022463 | 0.136958 | 0.019895 | 0.0 |
| Gabe Evans | 0.039216 | 0.039216 | 0.0 | 0.0 | -0.0 | -0.172071 | 0.019231 | 0.0 |
| Lucy McBath | 0.843137 | 0.846739 | 0.0 | 0.150133 | 0.022463 | 0.136958 | 0.019895 | 0.0 |
| Austin Scott | 0.843137 | 0.846739 | 0.0 | 0.150133 | 0.022463 | 0.136958 | 0.019895 | 0.0 |
| Rick Allen | 0.843137 | 0.846739 | 0.0 | 0.150133 | 0.022463 | 0.136958 | 0.019895 | 0.0 |
| Andrew Clyde | 0.843137 | 0.846739 | 0.0 | 0.150133 | 0.022463 | 0.136958 | 0.019895 | 0.0 |
| Richard Holtorf | 0.039216 | 0.039216 | 0.0 | 0.0 | -0.0 | -0.172071 | 0.019231 | 0.0 |
| John Larson | 0.843137 | 0.846739 | 0.0 | 0.150133 | 0.022463 | 0.136958 | 0.019895 | 0.0 |
| Adam Frisch | 0.019608 | 0.446131 | 0.0 | 0.003484 | 0.000521 | -0.148369 | 0.003323 | 0.0 |
| Rosa L. DeLauro | 0.843137 | 0.846739 | 0.0 | 0.150133 | 0.022463 | 0.136958 | 0.019895 | 0.0 |

Evaluating these centrality measures, we can see that most candidates are well connected to others in the reciprocated network. The high degree and closeness centrality measure of candidate nodes indicate high accessibility between candidates' Wikipedia pages. Lauren Boebert and Jahana Hayes are two candidates that stand out due to their high values in betweenness and load centrality, indicating that they serve as connectors in the network.

## 8.4. Centrality Measures for Directed House Graph (subset)

The weakly connected subgraph of the House hyperlink graph for Colorado, Connecticut, Georgia, Illinois and Washington contains 60 vertices and 1,969 edges. Table 22 displays the calculated centrality measures.

## Table 22: Centrality Measures for Connected Subgraph of House Candidates

| node | out_degree | in_degree | closeness | betweenness | eigenvector | HITS_hubs | HITS_auths | Katz | PageRank | load |
|---|---|---|---|---|---|---|---|---|---|---|
| Lauren Boebert | 0.745763 | 0.779661 | 0.787228 | 0.054062 | 0.150624 | 0.022094 | 0.022552 | 0.112178 | 0.02612 | 0.054062 |
| Jahana Hayes | 0.745763 | 0.762712 | 0.760082 | 0.027762 | 0.150624 | 0.022095 | 0.02254 | 0.119202 | 0.022029 | 0.027762 |
| Ron Hanks | 0.016949 | 0.016949 | 0.016949 | 0.013735 | 0.0 | 0.000514 | -0.0 | -0.147149 | 0.00482 | 0.013735 |
| Dan Newhouse | 0.728814 | 0.762712 | 0.760082 | 0.013442 | 0.150546 | 0.022083 | 0.02254 | 0.118918 | 0.021664 | 0.013442 |
| David Scott | 0.728814 | 0.762712 | 0.760082 | 0.013442 | 0.150546 | 0.022083 | 0.02254 | 0.118918 | 0.021664 | 0.013442 |
| Joe Courtney | 0.728814 | 0.762712 | 0.760082 | 0.013442 | 0.150546 | 0.022083 | 0.02254 | 0.118918 | 0.021664 | 0.013442 |
| Jonathan Jackson | 0.745763 | 0.745763 | 0.747199 | 0.000701 | 0.150546 | 0.022259 | 0.022524 | 0.125592 | 0.019501 | 0.000701 |
| Delia Ramirez | 0.745763 | 0.745763 | 0.747199 | 0.000701 | 0.150546 | 0.022259 | 0.022524 | 0.125592 | 0.019501 | 0.000701 |
| Raja Krishnamoorthi | 0.745763 | 0.745763 | 0.747199 | 0.000701 | 0.150546 | 0.022259 | 0.022524 | 0.125592 | 0.019501 | 0.000701 |
| Mary Miller | 0.745763 | 0.745763 | 0.747199 | 0.000701 | 0.150546 | 0.022259 | 0.022524 | 0.125592 | 0.019501 | 0.000701 |
| Eric Sorensen | 0.745763 | 0.745763 | 0.747199 | 0.000701 | 0.150546 | 0.022259 | 0.022524 | 0.125592 | 0.019501 | 0.000701 |
| Darin LaHood | 0.745763 | 0.745763 | 0.747199 | 0.000701 | 0.150546 | 0.022259 | 0.022524 | 0.125592 | 0.019501 | 0.000701 |
| Robin Kelly | 0.745763 | 0.745763 | 0.747199 | 0.000701 | 0.150546 | 0.022259 | 0.022524 | 0.125592 | 0.019501 | 0.000701 |
| Bill Foster | 0.745763 | 0.745763 | 0.747199 | 0.000701 | 0.150546 | 0.022259 | 0.022524 | 0.125592 | 0.019501 | 0.000701 |
| Nikki Budzinski | 0.745763 | 0.745763 | 0.747199 | 0.000701 | 0.150546 | 0.022259 | 0.022524 | 0.125592 | 0.019501 | 0.000701 |
| Danny K. Davis | 0.745763 | 0.745763 | 0.747199 | 0.000701 | 0.150546 | 0.022259 | 0.022524 | 0.125592 | 0.019501 | 0.000701 |
| Jan Schakowsky | 0.745763 | 0.745763 | 0.747199 | 0.000701 | 0.150546 | 0.022259 | 0.022524 | 0.125592 | 0.019501 | 0.000701 |
| Mike Bost | 0.745763 | 0.745763 | 0.747199 | 0.000701 | 0.150546 | 0.022259 | 0.022524 | 0.125592 | 0.019501 | 0.000701 |
| Lauren Underwood | 0.745763 | 0.745763 | 0.747199 | 0.000701 | 0.150546 | 0.022259 | 0.022524 | 0.125592 | 0.019501 | 0.000701 |
| Sean Casten | 0.745763 | 0.745763 | 0.747199 | 0.000701 | 0.150546 | 0.022259 | 0.022524 | 0.125592 | 0.019501 | 0.000701 |
| Brad Schneider | 0.745763 | 0.745763 | 0.747199 | 0.000701 | 0.150546 | 0.022259 | 0.022524 | 0.125592 | 0.019501 | 0.000701 |
| Barry Loudermilk | 0.728814 | 0.745763 | 0.747199 | 0.0 | 0.150546 | 0.022083 | 0.022528 | 0.125592 | 0.019493 | 0.0 |
| Mike Quigley | 0.745763 | 0.254237 | 0.46405 | 0.0 | 0.052095 | 0.022597 | 0.007716 | -0.045948 | 0.008256 | 0.0 |
| Joe Neguse | 0.728814 | 0.745763 | 0.747199 | 0.0 | 0.150546 | 0.022083 | 0.022528 | 0.125592 | 0.019493 | 0.0 |
| Kim Schrier | 0.728814 | 0.745763 | 0.747199 | 0.0 | 0.150546 | 0.022083 | 0.022528 | 0.125592 | 0.019493 | 0.0 |
| Michael Lynch (1) | 0.033898 | 0.033898 | 0.033898 | 0.0 | 0.0 | -0.0 | -0.0 | -0.155713 | 0.017368 | 0.0 |
| Mike France | 0.016949 | 0.0 | 0.0 | 0.0 | 0.0 | 0.000514 | -0.0 | -0.140142 | 0.002605 | 0.0 |
| George Logan | 0.016949 | 0.016949 | 0.408192 | 0.0 | 0.003475 | 0.000514 | 0.000511 | -0.134182 | 0.003031 | 0.0 |
| Suzan DelBene | 0.728814 | 0.745763 | 0.747199 | 0.0 | 0.150546 | 0.022083 | 0.022528 | 0.125592 | 0.019493 | 0.0 |
| Brittany Pettersen | 0.728814 | 0.745763 | 0.747199 | 0.0 | 0.150546 | 0.022083 | 0.022528 | 0.125592 | 0.019493 | 0.0 |
| Mike Collins | 0.728814 | 0.745763 | 0.747199 | 0.0 | 0.150546 | 0.022083 | 0.022528 | 0.125592 | 0.019493 | 0.0 |
| Jim Himes | 0.728814 | 0.745763 | 0.747199 | 0.0 | 0.150546 | 0.022083 | 0.022528 | 0.125592 | 0.019493 | 0.0 |
| Philip Singleton | 0.016949 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.140142 | 0.002605 | 0.0 |
| Rick Larsen | 0.728814 | 0.745763 | 0.747199 | 0.0 | 0.150546 | 0.022083 | 0.022528 | 0.125592 | 0.019493 | 0.0 |
| Marilyn Strickland | 0.728814 | 0.745763 | 0.747199 | 0.0 | 0.150546 | 0.022083 | 0.022528 | 0.125592 | 0.019493 | 0.0 |
| Drew MacEwen | 0.016949 | 0.016949 | 0.016949 | 0.0 | 0.0 | -0.0 | -0.0 | -0.147518 | 0.017368 | 0.0 |
| Nikema Williams | 0.728814 | 0.745763 | 0.747199 | 0.0 | 0.150546 | 0.022083 | 0.022528 | 0.125592 | 0.019493 | 0.0 |
| Diana DeGette | 0.728814 | 0.745763 | 0.747199 | 0.0 | 0.150546 | 0.022083 | 0.022528 | 0.125592 | 0.019493 | 0.0 |
| Rich McCormick | 0.728814 | 0.745763 | 0.747199 | 0.0 | 0.150546 | 0.022083 | 0.022528 | 0.125592 | 0.019493 | 0.0 |
| Marjorie Taylor Greene | 0.728814 | 0.745763 | 0.747199 | 0.0 | 0.150546 | 0.022083 | 0.022528 | 0.125592 | 0.019493 | 0.0 |
| Pramila Jayapal | 0.728814 | 0.745763 | 0.747199 | 0.0 | 0.150546 | 0.022083 | 0.022528 | 0.125592 | 0.019493 | 0.0 |
| Jason Crow | 0.728814 | 0.745763 | 0.747199 | 0.0 | 0.150546 | 0.022083 | 0.022528 | 0.125592 | 0.019493 | 0.0 |
| Yadira Caraveo | 0.728814 | 0.745763 | 0.747199 | 0.0 | 0.150546 | 0.022083 | 0.022528 | 0.125592 | 0.019493 | 0.0 |
| Sanford Bishop Jr. | 0.728814 | 0.745763 | 0.747199 | 0.0 | 0.150546 | 0.022083 | 0.022528 | 0.125592 | 0.019493 | 0.0 |
| Emily Randall | 0.016949 | 0.016949 | 0.016949 | 0.0 | 0.0 | -0.0 | -0.0 | -0.147518 | 0.017368 | 0.0 |
| Hank Johnson | 0.728814 | 0.745763 | 0.747199 | 0.0 | 0.150546 | 0.022083 | 0.022528 | 0.125592 | 0.019493 | 0.0 |
| Gabe Evans | 0.033898 | 0.033898 | 0.033898 | 0.0 | 0.0 | -0.0 | -0.0 | -0.155713 | 0.017368 | 0.0 |
| Jerrod Sessler | 0.016949 | 0.0 | 0.0 | 0.0 | 0.0 | 0.000514 | -0.0 | -0.140142 | 0.002605 | 0.0 |
| Mandisha Thomas | 0.0 | 0.016949 | 0.016949 | 0.0 | 0.0 | -0.0 | 0.0 | -0.147149 | 0.00482 | 0.0 |
| Lucy McBath | 0.728814 | 0.745763 | 0.747199 | 0.0 | 0.150546 | 0.022083 | 0.022528 | 0.125592 | 0.019493 | 0.0 |
| Mike Crane | 0.016949 | 0.0 | 0.0 | 0.0 | 0.0 | 0.000514 | -0.0 | -0.140142 | 0.002605 | 0.0 |
| Austin Scott | 0.728814 | 0.745763 | 0.747199 | 0.0 | 0.150546 | 0.022083 | 0.022528 | 0.125592 | 0.019493 | 0.0 |
| Dave Williams | 0.016949 | 0.0 | 0.0 | 0.0 | 0.0 | -0.0 | -0.0 | -0.140142 | 0.002605 | 0.0 |
| Rick Allen | 0.728814 | 0.745763 | 0.747199 | 0.0 | 0.150546 | 0.022083 | 0.022528 | 0.125592 | 0.019493 | 0.0 |
| Andrew Clyde | 0.728814 | 0.745763 | 0.747199 | 0.0 | 0.150546 | 0.022083 | 0.022528 | 0.125592 | 0.019493 | 0.0 |
| Joe Kent | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.0 | -0.0 | -0.140142 | 0.002605 | 0.0 |
| Richard Holtorf | 0.033898 | 0.033898 | 0.033898 | 0.0 | 0.0 | -0.0 | -0.0 | -0.155713 | 0.017368 | 0.0 |
| John Larson | 0.728814 | 0.745763 | 0.747199 | 0.0 | 0.150546 | 0.022083 | 0.022528 | 0.125592 | 0.019493 | 0.0 |
| Adam Frisch | 0.016949 | 0.016949 | 0.415894 | 0.0 | 0.003475 | 0.000514 | 0.000511 | -0.134533 | 0.00311 | 0.0 |
| Rosa L. DeLauro | 0.728814 | 0.745763 | 0.747199 | 0.0 | 0.150546 | 0.022083 | 0.022528 | 0.125592 | 0.019493 | 0.0 |

# 9. Attribute Assortativity Coefficients

Assortative mixing in a graph quantifies the tendency of nodes to connect with other ‘similar’ nodes over ‘dissimilar’ nodes (see Newman https://arxiv.org/pdf/cond-mat/0209450). The assortativity coefficient of a graph is a measure of the extent to which assortative mixing among nodes occurs in a graph. The range of the assortativity coefficient of a graph is between −1 and 1. Assortativity coefficients close to 1 indicate that there is a very high likelihood of two nodes sharing the same property to be adjacent (assortative graph). Assortativity coefficients close to −1 indicate that there is very low likelihood of two nodes sharing the same property to be adjacent (disassortative graph). Graphs with assortativity coefficients close to zero are indeterminate in terms of their assortative mixing (neutral assortative graph).

Here we consider cases of assortative mixing corresponding to the attributes of our candidates’ graphs. In this section, we evaluate the assortativity for the Senate and House graphs based on the attributes we described in Section 5. The assortativity coefficients were calculated using NetworkX’s attribute_assortativity_coefficient function (https://networkx.org/documentation/stable/reference/algorithms/generated/networkx.algorithms.assortativity.attribute_assortativity_coefficient.html#networkx.algorithms.assortativity.attribute_assortativity_coefficient).

## 9.1. Attribute Assortativity for Senate Candidate Graphs

The incumbency-attributed Senate graph, having 58 vertices and 581 edges, has a corresponding incumbency assortativity coefficient of 0.823, which is strongly assortative. This indicates that candidates of the same type of incumbency tend to be linked together.

Nevertheless, the party-attributed Senate candidates graph has a negative party assortativity coefficient of -0.044, i.e. this graph is rather neutral assortative. In addition, the status-attributed Senate candidates graph is neutral assortative too, having a small status assortativity coefficient of 0.02. Finally, the state-attributed Senate candidates graph is also neutral assortative with a very low coefficient of 0.04. Therefore, although in terms of incumbency, the graph is assortative, we cannot conclude the same in terms of party affiliation, status, or state.

## 9.2. Attribute Assortativity for House Candidate Graphs

The incumbency-attributed graph, with an incumbency assortativity coefficient of 0.346, displays a moderate tendency for assortativity, i.e, House candidates tend to connect with others sharing the same incumbency status. This is visually supported by the Sankey diagram in Figure 24-1 from Section 7.5, which shows incumbents and challengers linking predominantly within their groups.

In contrast, the party-attributed graph exhibits a party assortativity coefficient of -0.00179, indicating that connections are nearly random with respect to party affiliation. This suggests that candidates are equally likely to connect with members of their own party as they are with members of other parties.

Similarly, the state-attributed graph has a state assortativity coefficient of 0.00014, implying almost no assortative mixing based on state. This means that there is no apparent tendency for candidates to preferentially connect with others from either the same state or different states.

The status-attributed graph shows a smallest status assortativity coefficient, at 0.00001, further reinforcing the notion of random connectivity. The negligible value suggests that candidate connections are uniformly distributed across various statuses.

Wondering about the found neutral assortativity of the party, state and status attributes, we looked into a further evaluation of candidate Wikipedia pages. Thus we found that at the bottom of most pages a table containing hyperlinks to all current Senators or House members was included (respectively). This inclusion of comprehensive link tables likely contributes to the random neutral mixing observed in the party, state, and status-attributed graphs, as it creates a baseline level of connectivity that is not influenced by these attributes.

# 10. Graph Partition Communities

In this section, we examine various community partition algorithms applied to both the Senate and House hyperlink graphs. We start by defining the community partition algorithms utilized in our analysis. The calculations were conducted using NetworkX functions.

- ***Girvan-Newman algorithm:*** Detects communities by progressively removing edges from the original network. The connected components of the remaining network are the communities (applied to any graph type https://en.wikipedia.org/wiki/Girvan%E2%80%93Newman_algorithm).
- ***Louvain communities:*** Two step method for detecting communities: first small communities are found by optimizing modularity (https://en.wikipedia.org/wiki/Modularity_(networks)) locally on all nodes, then each small community is grouped into one node and the first step is repeated (applies to any graph type https://en.wikipedia.org/wiki/Louvain_method).
- ***Leiden communities:*** A method for detecting communities in large networks that improves upon the Louvain algorithm, offering better accuracy and faster performance by refining community partitions more effectively (only for undirected graphs https://en.wikipedia.org/wiki/Leiden_algorithm).

- ***Label propagation algorithm (LPA):*** A community detection algorithm where each node adopts the label (community) that most of its neighbors belong to, iteratively updating labels until a consensus is reached (only for undirected graphs https://en.wikipedia.org/wiki/Label_propagation_algorithm).
- ***Asynchronous label propagation algorithm:*** A variation of the label propagation algorithm where nodes update their labels one at a time in a random order, which can help avoid oscillations and speed up convergence (applied to any graph https://networkx.org/documentation/stable/reference/algorithms/generated/networkx.algorithms.community.label_propagation.asyn_lpa_communities.html#r40d53c2ae55e-1).
- ***Fluid communities:*** A dynamic community detection algorithm that simulates the movement of fluid particles within the network, allowing communities to adapt and change fluidly based on the network's structure (only for connected simple undirected graphs https://networkx.org/documentation/stable/reference/algorithms/generated/networkx.algorithms.community.asyn_fluid.asyn_fluidc.html).

## 10.1. Community Partitions of Senate Candidates Graph

The Senate candidates' graph (Gs) has 4 Girvan-Newman communities, 6 Louvain communities and 5 Asynchronous LPA communities. Table 23 presents a breakdown of the community partitions for the four attribute categories along with the Gini index to represent the sparsity of the attributed graph (see Goswami for the use of Gini index as a sparsity measure for network graph https://www.sciencedirect.com/science/article/pii/S0020025518304158). A Gini index greater than 0.4 is highlighted in the tables. Note that the counts for the attribute lists represent the alphabetically ordered attribute values. For example, the incumbency value

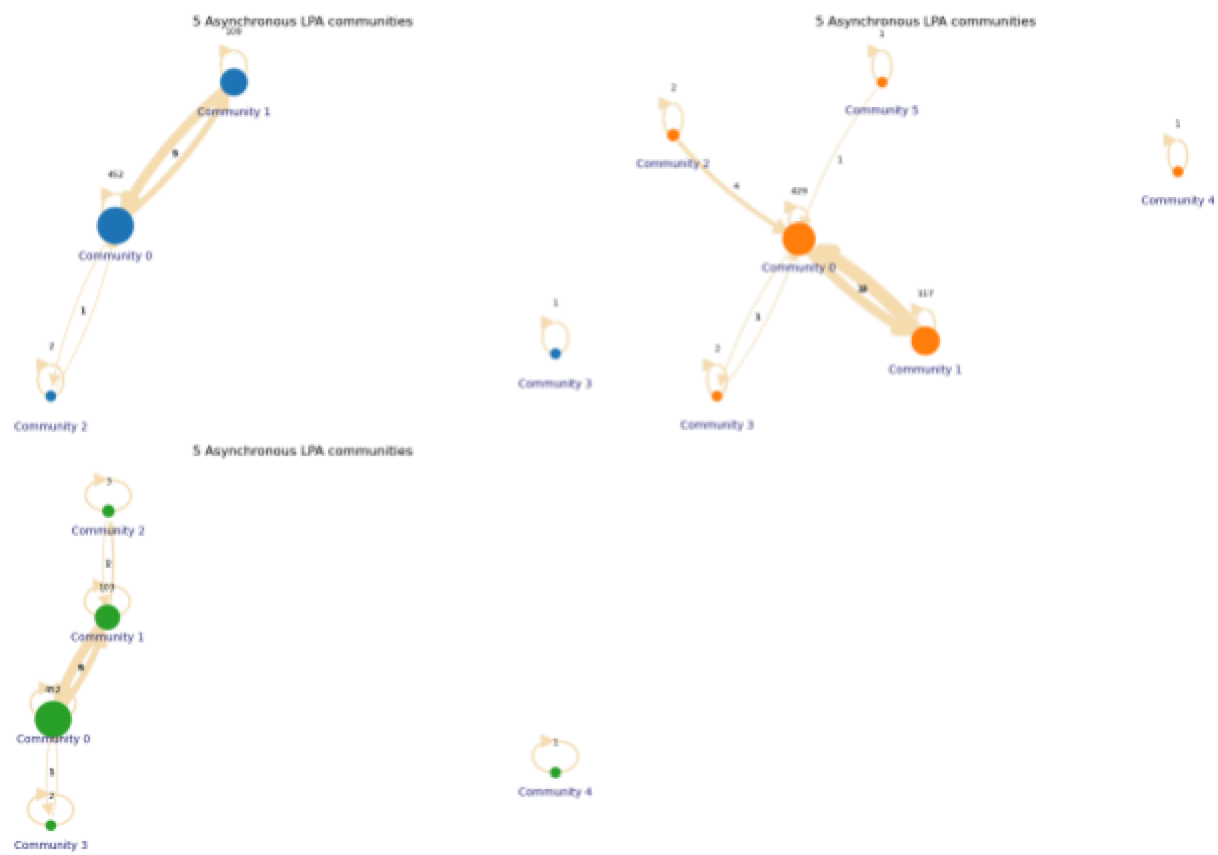
[14,21] represents 14 ‘challengers’ and 21 ‘incumbents.’ Figure 26 displays the three community image graphs.

**Table 23: Community Partitions by Attributes for the Senate Candidates' Hyperlink Graph**

| Community | incumbency | incumbency Gini index | party | party Gini index | state | state Gini index | status | status Gini index |
|---|---|---|---|---|---|---|---|---|
| Girvan-Newman community 0 | [14, 21] | 0.1 | [17, 1, 2, 15] | 0.435714 | [0, 0, 0, 0, 2, 1, 0, 2, 0, 1, 1, 2, 1, 1, 1, 2, 0, 1, 4, 1, 2, 2, 1, 3, 1, 0, 1, 1, 2, 1, 1] | 0.43318 | [3, 13, 0, 4, 15] | 0.457143 |
| Girvan-Newman community 1 | [19, 0] | 0.5 | [9, 0, 1, 9] | 0.460526 | [1, 2, 1, 1, 0, 0, 1, 0, 4, 4, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 1, 1, 0, 0, 0, 2, 0] | 0.75382 | [1, 6, 0, 3, 9] | 0.484211 |
| Girvan-Newman community 2 | [2, 0] | 0.5 | [2, 0, 0, 0] | 0.75 | [0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.967742 | [0, 2, 0, 0, 0] | 0.8 |
| Girvan-Newman community 3 | [2, 0] | 0.5 | [0, 0, 0, 2] | 0.75 | [1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0] | 0.935484 | [0, 0, 1, 0, 1] | 0.6 |
| Louvain community 0 | [7, 21] | 0.25 | [16, 0, 1, 11] | 0.517857 | [0, 0, 0, 0, 1, 1, 0, 1, 0, 0, 1, 2, 1, 1, 1, 2, 0, 1, 1, 1, 2, 2, 1, 3, 1, 0, 1, 1, 2, 0, 1] | 0.449309 | [1, 12, 0, 4, 11] | 0.485714 |
| Louvain community 1 | [21, 0] | 0.5 | [10, 0, 1, 10] | 0.464286 | [1, 2, 1, 1, 0, 0, 1, 0, 4, 5, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 1, 1, 0, 0, 0, 3, 0] | 0.768049 | [1, 7, 0, 3, 10] | 0.495238 |
| Louvain community 2 | [3, 0] | 0.5 | [0, 0, 0, 3] | 0.75 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.967742 | [0, 0, 0, 0, 3] | 0.8 |
| Louvain community 3 | [2, 0] | 0.5 | [2, 0, 0, 0] | 0.75 | [0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.967742 | [0, 2, 0, 0, 0] | 0.8 |
| Louvain community 4 | [2, 0] | 0.5 | [0, 0, 0, 2] | 0.75 | [1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0] | 0.935484 | [0, 0, 1, 0, 1] | 0.6 |
| Louvain community 5 | [2, 0] | 0.5 | [0, 1, 1, 0] | 0.5 | [0, 0, 0, 0, 1, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.935484 | [2, 0, 0, 0, 0] | 0.8 |
| Asynchronous label propagation | [14, 21] | 0.1 | [17, 1, 2, 15] | 0.435714 | [0, 0, 0, 0, 2, 1, 0, 2, 0, 1, 1, 2, 1, 1, 1, 2, 0, 1, 4, 1, 2, 2, 1, 3, 1, 0, | 0.43318 | [3, 13, 0, 4, 15] | 0.457143 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| community 0 | | | | | 1, 1, 2, 1, 1] | | | |
| Asynchronous label propagation community 1 | [16, 0] | 0.5 | [8, 0, 1, 7] | 0.46875 | [1, 2, 1, 1, 0, 0, 1, 0, 1, 4, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 1, 1, 0, 0, 0, 2, 0] | 0.733871 | [1, 6, 0, 3, 6] | 0.425 |
| Asynchronous label propagation community 2 | [3, 0] | 0.5 | [1, 0, 0, 2] | 0.583333 | [0, 0, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.967742 | [0, 0, 0, 0, 3] | 0.8 |
| Asynchronous label propagation community 3 | [2, 0] | 0.5 | [2, 0, 0, 0] | 0.75 | [0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.967742 | [0, 2, 0, 0, 0] | 0.8 |

**Fig 26: Communities Image Graphs for the Senate Graph**



## 10.2. Community Partitions of Reciprocated Senate Candidates Graph

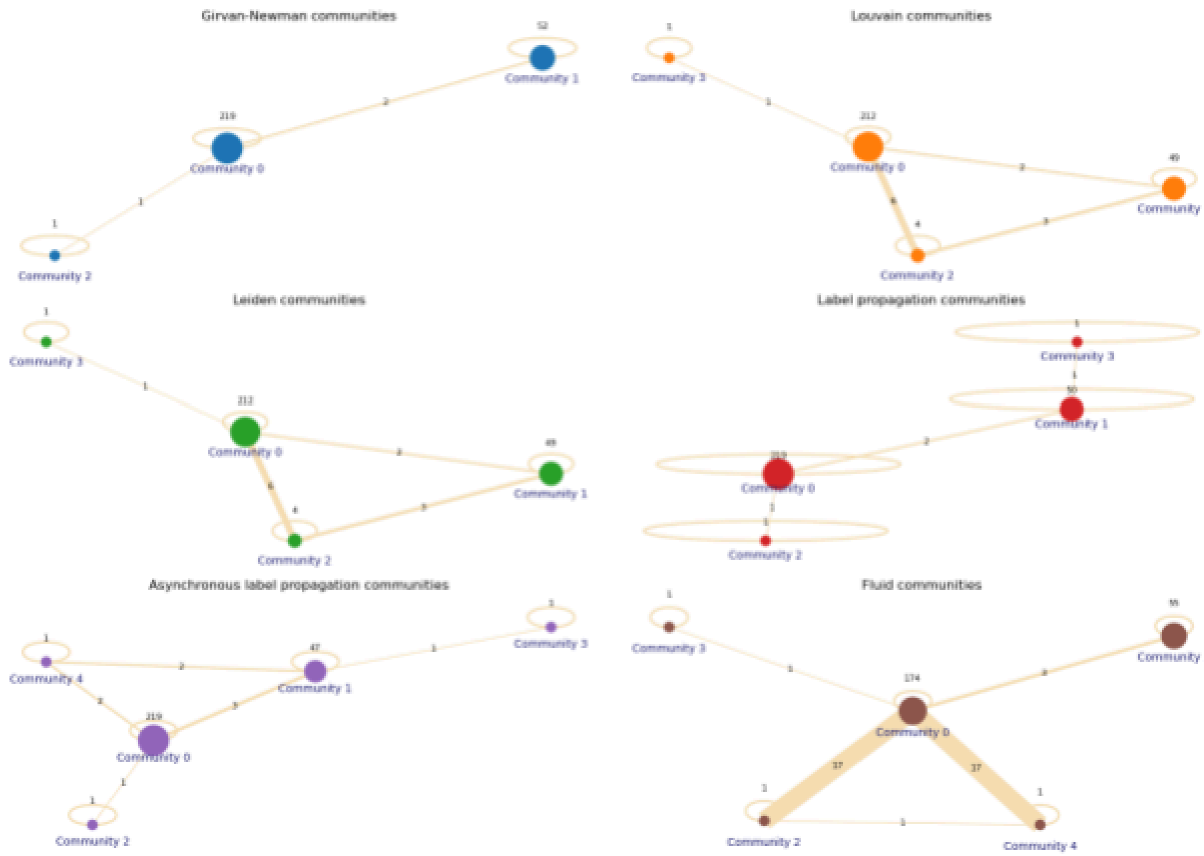
The reciprocated Senate candidates' graph (recGh) has 3 Girvan-Newman communities, 4 Louvain communities, 4 Leiden communities, 4 LPA communities, 5 Asynchronous LPA communities and 5 Fluid communities. Table 24 presents a breakdown of the community partitions for each of the four attributes along with their Gini index. Figure 27 displays the six community image graphs.

**Table 24: Community Partitions by Attributes for the Reciprocated Senate Candidates' Hyperlink Graph**

| Community | incumbency | incumbency Gini index | party | party Gini index | state | state Gini index | status | status Gini index |
|---|---|---|---|---|---|---|---|---|
| Girvan-Newman community 0 | [4, 21] | 0.34 | [14, 1, 10] | 0.346667 | [0, 0, 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1, 2, 0, 1, 1, 1, 2, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1] | 0.289333 | [1, 11, 4, 9] | 0.35 |
| Girvan-Newman community 1 | [16, 0] | 0.5 | [8, 0, 8] | 0.333333 | [1, 2, 1, 0, 0, 1, 0, 3, 3, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 1, 1, 0, 0, 0, 2, 0] | 0.75 | [0, 5, 3, 8] | 0.40625 |
| Girvan-Newman community 2 | [2, 0] | 0.5 | [2, 0, 0] | 0.666667 | [0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.966667 | [0, 2, 0, 0] | 0.75 |
| Louvain community 0 | [2, 21] | 0.413043 | [13, 1, 9] | 0.347826 | [0, 0, 0, 1, 1, 0, 1, 0, 0, 1, 1, 1, 1, 1, 2, 0, 1, 1, 1, 2, 1, 1, 1, 1, 0, 1, 1, 1, 0, 1] | 0.355072 | [1, 10, 4, 8] | 0.336957 |
| Louvain community 1 | [14, 0] | 0.5 | [8, 0, 6] | 0.380952 | [1, 2, 1, 0, 0, 1, 0, 3, 1, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 1, 1, 0, 0, 0, 2, 0] | 0.738095 | [0, 3, 3, 8] | 0.428571 |
| Louvain community 2 | [4, 0] | 0.5 | [1, 0, 3] | 0.5 | [0, 0, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0] | 0.95 | [0, 3, 0, 1] | 0.625 |
| Louvain community 3 | [2, 0] | 0.5 | [2, 0, 0] | 0.666667 | [0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.966667 | [0, 2, 0, 0] | 0.75 |
| Leiden community 0 | [2, 21] | 0.413043 | [13, 1, 9] | 0.347826 | [0, 0, 0, 1, 1, 0, 1, 0, 0, 1, 1, 1, 1, 1, 2, 0, 1, 1, 1, 2, 1, 1, 1, 1, 0, 1, 1, 1, 0, 1] | 0.355072 | [1, 10, 4, 8] | 0.336957 |
| Leiden community 1 | [14, 0] | 0.5 | [8, 0, 6] | 0.380952 | [1, 2, 1, 0, 0, 1, 0, 3, 1, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 1, 1, 0, 0, 0, 2, 0] | 0.738095 | [0, 3, 3, 8] | 0.428571 |
| Leiden community 2 | [4, 0] | 0.5 | [1, 0, 3] | 0.5 | [0, 0, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0] | 0.95 | [0, 3, 0, 1] | 0.625 |
| Leiden community 3 | [2, 0] | 0.5 | [2, 0, 0] | 0.666667 | [0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.966667 | [0, 2, 0, 0] | 0.75 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Label propagation community 0 | [4, 21] | 0.34 | [14, 1, 10] | 0.346667 | [0, 0, 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1, 2, 0, 1, 1, 1, 2, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1] | 0.289333 | [1, 11, 4, 9] | 0.35 |
| Label propagation community 1 | [14, 0] | 0.5 | [7, 0, 7] | 0.333333 | [1, 2, 1, 0, 0, 1, 0, 1, 3, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 1, 1, 0, 0, 0, 2, 0] | 0.738095 | [0, 5, 3, 6] | 0.357143 |
| Label propagation community 2 | [2, 0] | 0.5 | [2, 0, 0] | 0.666667 | [0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.966667 | [0, 2, 0, 0] | 0.75 |
| Label propagation community 3 | [2, 0] | 0.5 | [1, 0, 1] | 0.333333 | [0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.966667 | [0, 0, 0, 2] | 0.75 |
| Asynchronous label propagation community 0 | [4, 21] | 0.34 | [14, 1, 10] | 0.346667 | [0, 0, 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1, 2, 0, 1, 1, 1, 2, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1] | 0.289333 | [1, 11, 4, 9] | 0.35 |
| Asynchronous label propagation community 1 | [12, 0] | 0.5 | [7, 0, 5] | 0.388889 | [1, 2, 1, 0, 0, 1, 0, 1, 1, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 1, 1, 0, 0, 0, 2, 0] | 0.711111 | [0, 3, 3, 6] | 0.375 |
| Asynchronous label propagation community 2 | [2, 0] | 0.5 | [2, 0, 0] | 0.666667 | [0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.966667 | [0, 2, 0, 0] | 0.75 |
| Asynchronous label propagation community 3 | [2, 0] | 0.5 | [1, 0, 1] | 0.333333 | [0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.966667 | [0, 0, 0, 2] | 0.75 |
| Asynchronous label propagation community 4 | [2, 0] | 0.5 | [0, 0, 2] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.966667 | [0, 2, 0, 0] | 0.75 |
| Fluid community 0 | [3, 20] | 0.369565 | [14, 1, 8] | 0.376812 | [0, 0, 0, 3, 1, 0, 1, 0, 0, 1, 1, 1, 1, 1, 2, 0, 1, 1, 1, 0, 1, 1, 1, 1, 0, 1, 1, 1, 0, 1] | 0.413043 | [1, 12, 2, 8] | 0.423913 |
| Fluid community 1 | [11, 0] | 0.5 | [7, 0, 4] | 0.424242 | [1, 1, 1, 0, 0, 1, 0, 1, 1, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 1, 1, 0, 0, 0, 2, 0] | 0.693939 | [0, 3, 2, 6] | 0.431818 |
| Fluid community 2 | [4, 0] | 0.5 | [1, 0, 3] | 0.5 | [0, 0, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0] | 0.95 | [0, 3, 0, 1] | 0.625 |
| Fluid community 3 | [3, 0] | 0.5 | [1, 0, 2] | 0.444444 | [0, 1, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.944444 | [0, 0, 1, 2] | 0.583333 |
| Fluid community 4 | [1, 1] | 0 | [1, 0, 1] | 0.333333 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.966667 | [0, 0, 2, 0] | 0.75 |

**Fig 27: Communities Image Graphs for the Senate Reciprocated Graph**




## 10.3. Community Partitions of House Candidates Graph

The House candidates' graph (Gh) has 9 Girvan-Newman communities, 24 Louvain communities and 18 Asynchronous LPA communities. Table 25 presents a breakdown of the community partitions for each of the four attributes along with their Gini index. Figure 28 displays the three community image graphs and Figure 29 shows an alternative view of the community image graphs that will also display the attribute breakdown for each community when viewed as an interactive (html) rendering.

Table 25: Community Partitions by Attributes for the House Candidates' Hyperlink Graph

| Community | incumbency | incumbency Gini index | party | party Gini index | state | state Gini index | status | status Gini index |
|---|---|---|---|---|---|---|---|---|
| Girvan-Newman community 0 | [79, 343] | 0.312796 | [1, 206, 1, 214] | 0.5 | [2, 6, 4, 12, 52, 9, 7, 1, 26, 13, 1, 2, 5, 3, 16, 8, 4, 7, 7, 9, 7, 4, 12, 9, 9, 4, 6, 7, 1, 5, 1, 7, 2, 5, 19, 13, 5, 8, 19, 1, 8, 1, 9, 34, 3, 11, 1, 8, 7, 1, 1] | 0.476257 | [1, 91, 1, 193, 128, 2, 4, 1, 1] | 0.701422 |
| Girvan-Newman community 1 | [5, 0] | 0.5 | [0, 0, 0, 5] | 0.75 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0] | 0.964706 | [0, 0, 0, 0, 5, 0, 0, 0, 0] | 0.888889 |
| Girvan-Newman community 2 | [3, 0] | 0.5 | [0, 0, 0, 3] | 0.75 | [0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 0, 0, 0, 3, 0, 0, 0, 0] | 0.888889 |
| Girvan-Newman community 3 | [2, 0] | 0.5 | [0, 1, 0, 1] | 0.5 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 0, 0, 2, 0, 0, 0, 0, 0] | 0.888889 |
| Girvan-Newman community 4 | [2, 0] | 0.5 | [0, 1, 0, 1] | 0.5 | [0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 0, 0, 2, 0, 0, 0, 0, 0] | 0.888889 |
| Girvan-Newman community 5 | [2, 0] | 0.5 | [0, 1, 0, 1] | 0.5 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0] | 0.980392 | [0, 0, 0, 0, 2, 0, 0, 0, 0] | 0.888889 |
| Girvan-Newman community 6 | [2, 0] | 0.5 | [0, 2, 0, 0] | 0.75 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 0, 0, 0, 2, 0, 0, 0, 0] | 0.888889 |
| Girvan-Newman community 7 | [2, 0] | 0.5 | [0, 0, 0, 2] | 0.75 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 0, 0, 0, 2, 0, 0, 0, 0] | 0.888889 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Girvan-Newman community 8 | [2, 0] | 0.5 | [0, 1, 0, 1] | 0.5 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 0, 0, 0, 2, 0, 0, 0, 0] | 0.888889 |
| Louvain community 0 | [14, 259] | 0.448718 | [1, 121, 0, 151] | 0.524725 | [0, 5, 4, 1, 9, 5, 5, 1, 25, 13, 1, 2, 3, 3, 16, 0, 2, 7, 0, 9, 7, 1, 10, 7, 6, 4, 0, 7, 0, 2, 1, 7, 0, 4, 3, 13, 5, 3, 17, 1, 4, 1, 9, 32, 3, 1, 1, 6, 5, 1, 1] | 0.549738 | [0, 53, 0, 136, 80, 1, 1, 1, 1] | 0.722833 |
| Louvain community 1 | [4, 32] | 0.388889 | [0, 31, 0, 5] | 0.680556 | [0, 0, 0, 1, 33, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0] | 0.973856 | [0, 0, 0, 33, 3, 0, 0, 0, 0] | 0.87037 |
| Louvain community 2 | [24, 6] | 0.3 | [0, 15, 0, 15] | 0.5 | [0, 1, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 9, 0, 0, 3, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 10, 0, 1, 2, 0, 0] | 0.908497 | [0, 2, 0, 4, 24, 0, 0, 0, 0] | 0.82963 |
| Louvain community 3 | [9, 13] | 0.090909 | [0, 6, 0, 16] | 0.613636 | [2, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 8, 0, 0, 7, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0] | 0.926916 | [0, 9, 1, 8, 3, 1, 0, 0, 0] | 0.676768 |
| Louvain community 4 | [2, 14] | 0.375 | [0, 12, 0, 4] | 0.625 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 16, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 16, 0, 0, 0, 0, 0, 0, 0] | 0.888889 |
| Louvain community 5 | [7, 3] | 0.2 | [0, 6, 0, 4] | 0.55 | [0, 0, 0, 0, 10, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 0, 0, 10, 0, 0, 0, 0, 0] | 0.888889 |
| Louvain community 6 | [5, 5] | 0 | [0, 2, 1, 7] | 0.55 | [0, 0, 0, 9, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.976471 | [1, 0, 0, 0, 9, 0, 0, 0, 0] | 0.866667 |
| Louvain community 7 | [3, 1] | 0.25 | [0, 1, 0, 3] | 0.625 | [0, 0, 0, 0, 0, 4, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, | 0.980392 | [0, 0, 0, 0, 4, 0, 0, 0, 0] | 0.888889 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | | | |
| Louvain community 8 | [3, 1] | 0.25 | [0, 0, 0, 4] | 0.75 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 4, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 0, 0, 0, 4, 0, 0, 0, 0] | 0.888889 |
| Louvain community 9 | [2, 2] | 0 | [0, 3, 0, 1] | 0.625 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.960784 | [0, 2, 0, 0, 2, 0, 0, 0, 0] | 0.777778 |
| Louvain community 10 | [3, 1] | 0.25 | [0, 3, 0, 1] | 0.625 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 4, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 0, 0, 0, 4, 0, 0, 0, 0] | 0.888889 |
| Louvain community 11 | [2, 1] | 0.166667 | [0, 1, 0, 2] | 0.583333 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 0, 0, 0, 0, 0, 3, 0, 0] | 0.888889 |
| Louvain community 12 | [2, 1] | 0.166667 | [0, 3, 0, 0] | 0.75 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 3, 0, 0, 0, 0, 0, 0, 0] | 0.888889 |
| Louvain community 13 | [3, 0] | 0.5 | [0, 0, 0, 3] | 0.75 | [0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 0, 0, 0, 3, 0, 0, 0, 0] | 0.888889 |
| Louvain community 14 | [1, 1] | 0 | [0, 2, 0, 0] | 0.75 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 2, 0, 0, 0, 0, 0, 0, 0] | 0.888889 |
| Louvain community 15 | [2, 0] | 0.5 | [0, 1, 0, 1] | 0.5 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 0, 0, 2, 0, 0, 0, 0, 0] | 0.888889 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Louvain community 16 | [1, 1] | 0 | [0, 1, 0, 1] | 0.5 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 0, 0, 0, 2, 0, 0, 0, 0] | 0.888889 |
| Louvain community 17 | [2, 0] | 0.5 | [0, 1, 0, 1] | 0.5 | [0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 0, 0, 2, 0, 0, 0, 0, 0] | 0.888889 |
| Louvain community 18 | [1, 1] | 0 | [0, 0, 0, 2] | 0.75 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 2, 0, 0, 0, 0, 0, 0, 0] | 0.888889 |
| Louvain community 19 | [2, 0] | 0.5 | [0, 1, 0, 1] | 0.5 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0] | 0.980392 | [0, 0, 0, 0, 2, 0, 0, 0, 0] | 0.888889 |
| Louvain community 20 | [1, 1] | 0 | [0, 1, 0, 1] | 0.5 | [0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 2, 0, 0, 0, 0, 0, 0, 0] | 0.888889 |
| Louvain community 21 | [2, 0] | 0.5 | [0, 0, 0, 2] | 0.75 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 0, 0, 0, 2, 0, 0, 0, 0] | 0.888889 |
| Louvain community 22 | [2, 0] | 0.5 | [0, 1, 0, 1] | 0.5 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 0, 0, 0, 2, 0, 0, 0, 0] | 0.888889 |
| Louvain community 23 | [2, 0] | 0.5 | [0, 0, 0, 2] | 0.75 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 0, 0, 2, 0, 0, 0, 0, 0] | 0.888889 |
| Asynchronous label propagation community 0 | [59, 343] | 0.353234 | [1, 192, 1, 208] | 0.504975 | [2, 6, 4, 12, 45, 9, 7, 1, 26, 13, 1, 2, 5, 3, 16, 8, 4, 7, 7, 9, 7, 4, 12, 8, 9, 4, 3, | 0.476149 | [1, 90, 1, 184, 118, 2, 4, 1, 1] | 0.698729 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | 7, 1, 5, 1, 7, 2, 5, 19, 13, 5, 8, 17, 1, 8, 1, 9, 34, 3, 4, 1, 8, 7, 1, 1] | | | |
| Asynchronous label propagation community 1 | [7, 0] | 0.5 | [0, 6, 0, 1] | 0.678571 | [0, 0, 0, 0, 7, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 0, 0, 7, 0, 0, 0, 0, 0] | 0.888889 |
| Asynchronous label propagation community 2 | [3, 0] | 0.5 | [0, 3, 0, 0] | 0.75 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 0, 0, 0, 3, 0, 0, 0, 0] | 0.888889 |
| Asynchronous label propagation community 3 | [3, 0] | 0.5 | [0, 0, 0, 3] | 0.75 | [0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 0, 0, 0, 3, 0, 0, 0, 0] | 0.888889 |
| Asynchronous label propagation community 4 | [3, 0] | 0.5 | [0, 0, 0, 3] | 0.75 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 0, 0, 0, 3, 0, 0, 0, 0] | 0.888889 |
| Asynchronous label propagation community 5 | [3, 0] | 0.5 | [0, 2, 0, 1] | 0.583333 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 0, 0, 0, 3, 0, 0, 0, 0] | 0.888889 |
| Asynchronous label propagation community 6 | [2, 0] | 0.5 | [0, 1, 0, 1] | 0.5 | [0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 0, 0, 2, 0, 0, 0, 0, 0] | 0.888889 |
| Asynchronous label propagation community 7 | [2, 0] | 0.5 | [0, 1, 0, 1] | 0.5 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 0, 0, 0, 2, 0, 0, 0, 0] | 0.888889 |
| Asynchronous label propagation community 8 | [2, 0] | 0.5 | [0, 1, 0, 1] | 0.5 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 0, 0, 0, 2, 0, 0, 0, 0] | 0.888889 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Asynchronous label propagation community 9 | [2, 0] | 0.5 | [0, 0, 0, 2] | 0.75 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 0, 0, 0, 2, 0, 0, 0, 0] | 0.888889 |
| Asynchronous label propagation community 10 | [2, 0] | 0.5 | [0, 0, 0, 2] | 0.75 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 0, 0, 0, 2, 0, 0, 0, 0] | 0.888889 |
| Asynchronous label propagation community 11 | [2, 0] | 0.5 | [0, 1, 0, 1] | 0.5 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 0, 0, 2, 0, 0, 0, 0, 0] | 0.888889 |
| Asynchronous label propagation community 12 | [2, 0] | 0.5 | [0, 2, 0, 0] | 0.75 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 0, 0, 0, 2, 0, 0, 0, 0] | 0.888889 |
| Asynchronous label propagation community 13 | [2, 0] | 0.5 | [0, 0, 0, 2] | 0.75 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 0, 0, 2, 0, 0, 0, 0, 0] | 0.888889 |
| Asynchronous label propagation community 14 | [2, 0] | 0.5 | [0, 1, 0, 1] | 0.5 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0] | 0.980392 | [0, 0, 0, 0, 2, 0, 0, 0, 0] | 0.888889 |
| Asynchronous label propagation community 15 | [1, 0] | 0.5 | [0, 1, 0, 0] | 0.75 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 1, 0, 0, 0, 0, 0, 0, 0] | 0.888889 |
| Asynchronous label propagation community 16 | [1, 0] | 0.5 | [0, 0, 0, 1] | 0.75 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.980392 | [0, 0, 0, 0, 1, 0, 0, 0, 0] | 0.888889 |
| Asynchronous label propagation community 17 | [1, 0] | 0.5 | [0, 1, 0, 0] | 0.75 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, | 0.980392 | [0, 0, 0, 0, 1, 0, 0, 0, 0] | 0.888889 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0] | | | |

**Fig 28: Communities Image Graphs for the House Candidates' Graph**

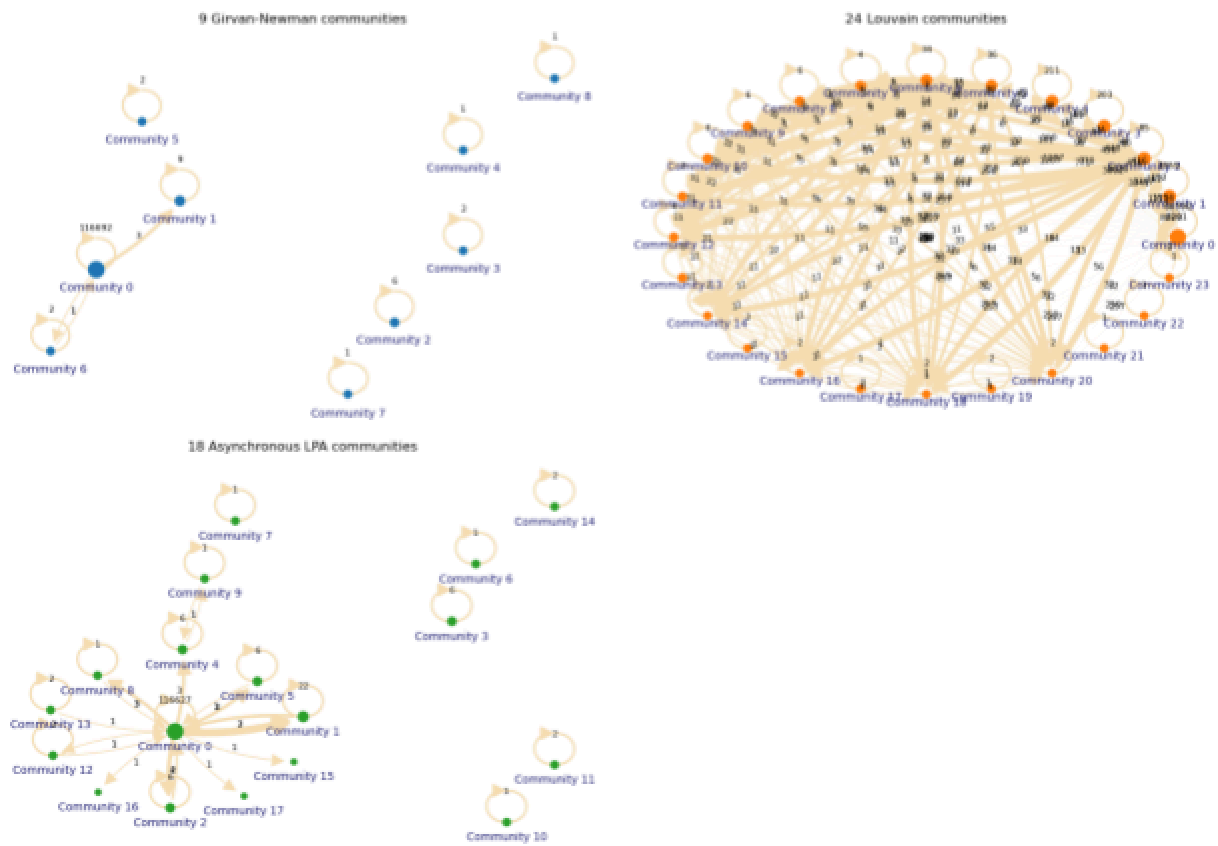
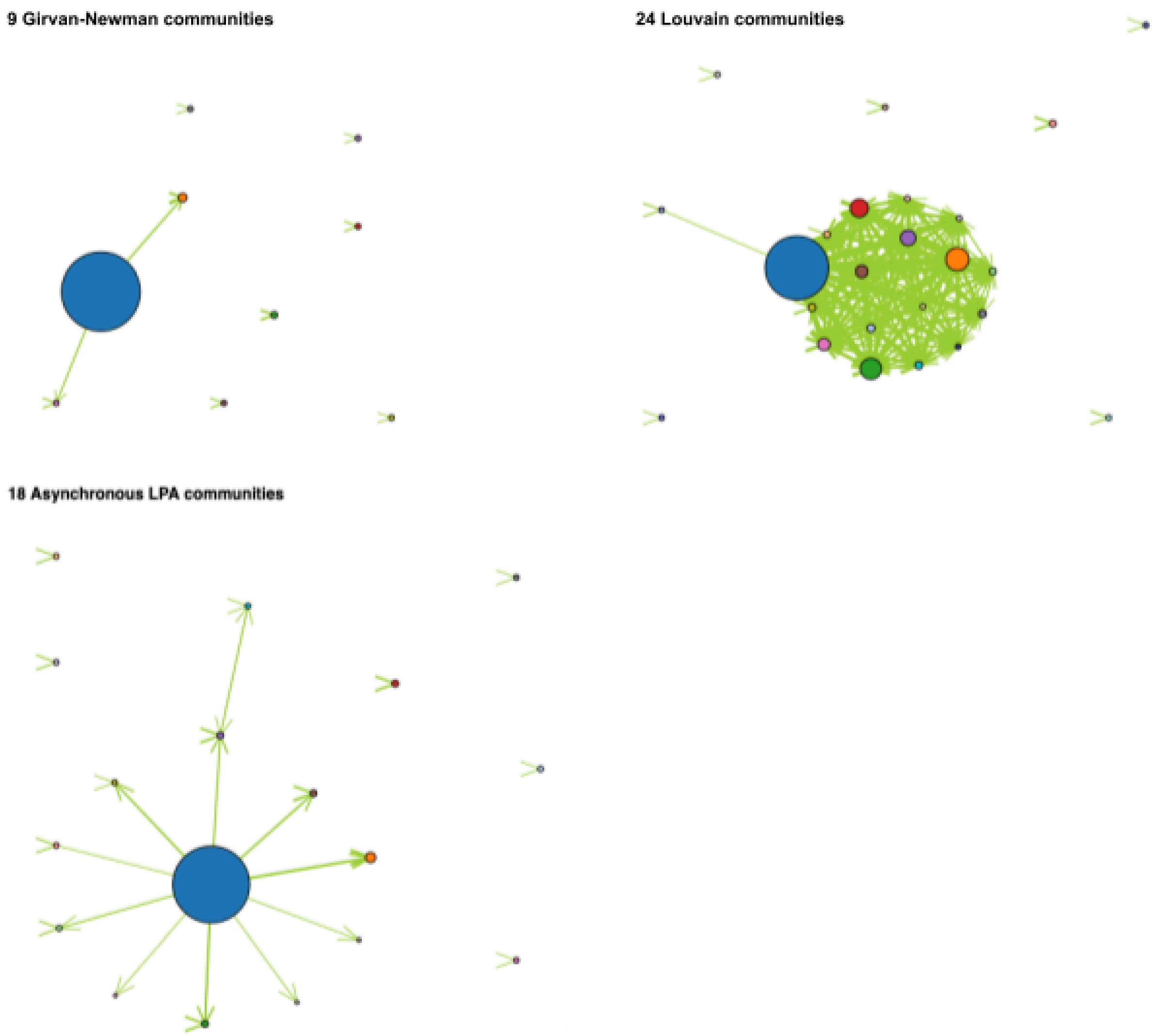


**Fig 29: Attributed House Candidates' Community Partitions**




## 10.4. Community Partitions of Reciprocated House Candidates Graph

The reciprocated House candidates' graph (recGh) has 11 Girvan-Newman communities, 37 Louvain communities, 37 Leiden communities, 13 LPA communities and 13 Asynchronous LPA communities. Note that, unlike the reciprocated Senate graph, recGh is disconnected and thus Fluid communities cannot be calculated for this graph. Table 26 presents a breakdown of the community partitions for each of the four attributes along with their Gini index. Figures 30-31 display alternative views for the five community image graphs.

**Table 26: Community Partitions by Attributes for the Reciprocated House Candidates' Hyperlink Graph**

| Community | incumbency | incumbency Gini index | party | party Gini index | state | state Gini index | status | status Gini index |
|---|---|---|---|---|---|---|---|---|
| Girvan-Newman community 0 | [33, 342] | 0.412 | [1, 183, 191] | 0.337778 | [2, 6, 4, 8, 46, 7, 6, 1, 25, 12, 1, 2, 5, 3, 16, 8, 4, 7, 7, 9, 5, 2, 12, 8, 8, 4, 3, 7, 5, 1, 7, 2, 4, 17, 12, 5, 10, 17, 1, 6, 1, 8, 32, 3, 2, 1, 6, 5, 1, 1] | 0.483893 | [84, 1, 181, 104, 1, 2, 1, 1] | 0.675 |
| Girvan-Newman community 1 | [5, 0] | 0.5 | [0, 4, 1] | 0.533333 | [0, 0, 0, 0, 5, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 5, 0, 0, 0, 0, 0] | 0.875 |
| Girvan-Newman community 2 | [4, 0] | 0.5 | [0, 0, 4] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0] | 0.97 | [0, 0, 0, 4, 0, 0, 0, 0] | 0.875 |
| Girvan-Newman community 3 | [3, 0] | 0.5 | [0, 3, 0] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 3, 0, 0, 0, 0] | 0.875 |
| Girvan-Newman community 4 | [3, 0] | 0.5 | [0, 0, 3] | 0.666667 | [0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 3, 0, 0, 0, 0] | 0.875 |
| Girvan-Newman community 5 | [3, 0] | 0.5 | [0, 2, 1] | 0.444444 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 3, 0, 0, 0, 0] | 0.875 |
| Girvan-Newman community 6 | [2, 0] | 0.5 | [0, 1, 1] | 0.333333 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 2, 0, 0, 0, 0, 0] | 0.875 |
| Girvan-Newman community 7 | [2, 0] | 0.5 | [0, 0, 2] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 2, 0, 0, 0, 0] | 0.875 |
| Girvan-Newman community 8 | [2, 0] | 0.5 | [0, 1, 1] | 0.333333 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 1, 0, 1, 0, 0, 0] | 0.75 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Girvan-Newman community 9 | [2, 0] | 0.5 | [0, 1, 1] | 0.333333 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0] | 0.98 | [0, 0, 0, 2, 0, 0, 0, 0] | 0.875 |
| Girvan-Newman community 10 | [2, 0] | 0.5 | [0, 0, 2] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 2, 0, 0, 0, 0, 0] | 0.875 |
| Louvain community 0 | [0, 217] | 0.5 | [0, 93, 124] | 0.380952 | [0, 5, 4, 1, 8, 5, 4, 1, 23, 12, 1, 2, 3, 1, 0, 0, 2, 5, 0, 8, 5, 2, 10, 6, 6, 4, 0, 7, 2, 1, 7, 0, 4, 2, 12, 5, 3, 17, 1, 4, 1, 8, 7, 3, 2, 1, 5, 5, 1, 1] | 0.505714 | [49, 0, 91, 73, 0, 2, 1, 1] | 0.660714 |
| Louvain community 1 | [1, 31] | 0.46875 | [0, 27, 5] | 0.5625 | [0, 0, 0, 0, 32, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 32, 0, 0, 0, 0, 0] | 0.875 |
| Louvain community 2 | [1, 24] | 0.46 | [0, 8, 17] | 0.453333 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 25, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 24, 0, 1, 0, 0, 0] | 0.865 |
| Louvain community 3 | [3, 17] | 0.35 | [0, 14, 6] | 0.466667 | [0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0, 0, 15, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.964 | [16, 0, 1, 3, 0, 0, 0, 0] | 0.8125 |
| Louvain community 4 | [0, 17] | 0.5 | [0, 14, 3] | 0.54902 | [0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 16, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.977647 | [0, 0, 17, 0, 0, 0, 0, 0] | 0.875 |
| Louvain community 5 | [3, 5] | 0.125 | [0, 1, 7] | 0.583333 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 8, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 1, 7, 0, 0, 0, 0, 0] | 0.84375 |
| Louvain community 6 | [1, 6] | 0.357143 | [0, 2, 5] | 0.47619 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 7, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [7, 0, 0, 0, 0, 0, 0, 0] | 0.875 |
| Louvain community 7 | [1, 4] | 0.3 | [0, 0, 5] | 0.666667 | [0, 0, 0, 5, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 5, 0, 0, 0, 0] | 0.875 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Louvain community 8 | [5, 0] | 0.5 | [0, 4, 1] | 0.533333 | [0, 0, 0, 0, 5, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 5, 0, 0, 0, 0, 0] | 0.875 |
| Louvain community 9 | [3, 1] | 0.25 | [0, 0, 4] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 4, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 4, 0, 0, 0, 0] | 0.875 |
| Louvain community 10 | [3, 1] | 0.25 | [0, 4, 0] | 0.666667 | [0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0, 0] | 0.97 | [0, 0, 1, 3, 0, 0, 0, 0] | 0.8125 |
| Louvain community 11 | [4, 0] | 0.5 | [0, 0, 4] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0] | 0.97 | [0, 0, 0, 4, 0, 0, 0, 0] | 0.875 |
| Louvain community 12 | [3, 1] | 0.25 | [0, 3, 1] | 0.5 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 4, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 4, 0, 0, 0, 0] | 0.875 |
| Louvain community 13 | [2, 1] | 0.166667 | [0, 2, 1] | 0.444444 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 3, 0, 0, 0, 0, 0] | 0.875 |
| Louvain community 14 | [3, 0] | 0.5 | [0, 0, 3] | 0.666667 | [0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 3, 0, 0, 0, 0] | 0.875 |
| Louvain community 15 | [3, 0] | 0.5 | [0, 2, 1] | 0.444444 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 3, 0, 0, 0, 0] | 0.875 |
| Louvain community 16 | [1, 1] | 0 | [0, 1, 1] | 0.333333 | [0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 2, 0, 0, 0, 0] | 0.875 |
| Louvain community 17 | [1, 1] | 0 | [0, 1, 1] | 0.333333 | [0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 2, 0, 0, 0, 0, 0] | 0.875 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Louvain community 18 | [1, 1] | 0 | [0, 2, 0] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [2, 0, 0, 0, 0, 0, 0, 0] | 0.875 |
| Louvain community 19 | [2, 0] | 0.5 | [0, 1, 1] | 0.333333 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 2, 0, 0, 0, 0, 0] | 0.875 |
| Louvain community 20 | [1, 1] | 0 | [0, 1, 1] | 0.333333 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 2, 0, 0, 0, 0] | 0.875 |
| Louvain community 21 | [1, 1] | 0 | [0, 1, 1] | 0.333333 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 1, 1, 0, 0, 0, 0] | 0.75 |
| Louvain community 22 | [1, 1] | 0 | [0, 0, 2] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 2, 0, 0, 0, 0] | 0.875 |
| Louvain community 23 | [1, 1] | 0 | [0, 1, 1] | 0.333333 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 2, 0, 0, 0, 0] | 0.875 |
| Louvain community 24 | [1, 1] | 0 | [0, 2, 0] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [2, 0, 0, 0, 0, 0, 0, 0] | 0.875 |
| Louvain community 25 | [2, 0] | 0.5 | [0, 1, 1] | 0.333333 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 1, 0, 1, 0, 0, 0] | 0.75 |
| Louvain community 26 | [1, 1] | 0 | [0, 1, 1] | 0.333333 | [0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 2, 0, 0, 0, 0, 0] | 0.875 |
| Louvain community 27 | [1, 1] | 0 | [0, 0, 2] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [2, 0, 0, 0, 0, 0, 0, 0] | 0.875 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Louvain community 28 | [1, 1] | 0 | [0, 2, 0] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [2, 0, 0, 0, 0, 0, 0, 0] | 0.875 |
| Louvain community 29 | [2, 0] | 0.5 | [0, 1, 1] | 0.333333 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0] | 0.98 | [0, 0, 0, 2, 0, 0, 0, 0] | 0.875 |
| Louvain community 30 | [1, 1] | 0 | [0, 1, 1] | 0.333333 | [0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [2, 0, 0, 0, 0, 0, 0, 0] | 0.875 |
| Louvain community 31 | [1, 1] | 0 | [0, 1, 1] | 0.333333 | [0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 2, 0, 0, 0, 0] | 0.875 |
| Louvain community 32 | [1, 1] | 0 | [0, 1, 1] | 0.333333 | [2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [2, 0, 0, 0, 0, 0, 0, 0] | 0.875 |
| Louvain community 33 | [1, 1] | 0 | [1, 0, 1] | 0.333333 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 2, 0, 0, 0, 0] | 0.875 |
| Louvain community 34 | [1, 1] | 0 | [0, 2, 0] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0] | 0.96 | [0, 0, 0, 2, 0, 0, 0, 0] | 0.875 |
| Louvain community 35 | [2, 0] | 0.5 | [0, 0, 2] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 2, 0, 0, 0, 0, 0] | 0.875 |
| Louvain community 36 | [1, 1] | 0 | [0, 1, 1] | 0.333333 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 2, 0, 0, 0, 0] | 0.875 |
| Leiden community 0 | [0, 217] | 0.5 | [0, 93, 124] | 0.380952 | [0, 5, 4, 1, 8, 5, 4, 1, 23, 12, 1, 2, 3, 1, 0, 0, 2, 5, 0, 8, 5, 2, 10, 6, 6, 4, 0, 7, 2, 1, 7, 0, 4, 2, 12, 5, 3, 17, 1, 4, 1, 8, 7, 3, 2, 1, 5, 5, 1, 1] | 0.505714 | [49, 0, 91, 73, 0, 2, 1, 1] | 0.660714 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Leiden community 1 | [1, 31] | 0.46875 | [0, 27, 5] | 0.5625 | [0, 0, 0, 0, 32, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 32, 0, 0, 0, 0, 0] | 0.875 |
| Leiden community 2 | [1, 24] | 0.46 | [0, 8, 17] | 0.453333 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 25, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 24, 0, 1, 0, 0, 0] | 0.865 |
| Leiden community 3 | [3, 16] | 0.342105 | [0, 13, 6] | 0.45614 | [0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0, 0, 14, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.963158 | [15, 0, 1, 3, 0, 0, 0, 0] | 0.809211 |
| Leiden community 4 | [0, 18] | 0.5 | [0, 15, 3] | 0.555556 | [0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 16, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.973333 | [1, 0, 17, 0, 0, 0, 0, 0] | 0.861111 |
| Leiden community 5 | [3, 5] | 0.125 | [0, 1, 7] | 0.583333 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 8, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 1, 7, 0, 0, 0, 0, 0] | 0.84375 |
| Leiden community 6 | [1, 6] | 0.357143 | [0, 2, 5] | 0.47619 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 7, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [7, 0, 0, 0, 0, 0, 0, 0] | 0.875 |
| Leiden community 7 | [1, 4] | 0.3 | [0, 0, 5] | 0.666667 | [0, 0, 0, 5, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 5, 0, 0, 0, 0] | 0.875 |
| Leiden community 8 | [5, 0] | 0.5 | [0, 4, 1] | 0.533333 | [0, 0, 0, 0, 5, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 5, 0, 0, 0, 0, 0] | 0.875 |
| Leiden community 9 | [3, 1] | 0.25 | [0, 0, 4] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 4, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 4, 0, 0, 0, 0] | 0.875 |
| Leiden community 10 | [3, 1] | 0.25 | [0, 4, 0] | 0.666667 | [0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0] | 0.97 | [0, 0, 1, 3, 0, 0, 0, 0] | 0.8125 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Leiden community 11 | [4, 0] | 0.5 | [0, 0, 4] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0] | 0.97 | [0, 0, 0, 4, 0, 0, 0, 0] | 0.875 |
| Leiden community 12 | [3, 1] | 0.25 | [0, 3, 1] | 0.5 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 4, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 4, 0, 0, 0, 0] | 0.875 |
| Leiden community 13 | [2, 1] | 0.166667 | [0, 2, 1] | 0.444444 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 3, 0, 0, 0, 0, 0] | 0.875 |
| Leiden community 14 | [3, 0] | 0.5 | [0, 0, 3] | 0.666667 | [0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 3, 0, 0, 0, 0] | 0.875 |
| Leiden community 15 | [3, 0] | 0.5 | [0, 2, 1] | 0.444444 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 3, 0, 0, 0, 0] | 0.875 |
| Leiden community 16 | [1, 1] | 0 | [0, 1, 1] | 0.333333 | [0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 2, 0, 0, 0, 0] | 0.875 |
| Leiden community 17 | [1, 1] | 0 | [0, 1, 1] | 0.333333 | [0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 2, 0, 0, 0, 0, 0] | 0.875 |
| Leiden community 18 | [1, 1] | 0 | [0, 2, 0] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [2, 0, 0, 0, 0, 0, 0, 0] | 0.875 |
| Leiden community 19 | [2, 0] | 0.5 | [0, 1, 1] | 0.333333 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 2, 0, 0, 0, 0, 0] | 0.875 |
| Leiden community 20 | [1, 1] | 0 | [0, 1, 1] | 0.333333 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 2, 0, 0, 0, 0] | 0.875 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Leiden community 21 | [1, 1] | 0 | [0, 1, 1] | 0.333333 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 1, 1, 0, 0, 0, 0] | 0.75 |
| Leiden community 22 | [1, 1] | 0 | [0, 0, 2] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 2, 0, 0, 0, 0] | 0.875 |
| Leiden community 23 | [1, 1] | 0 | [0, 1, 1] | 0.333333 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 2, 0, 0, 0, 0] | 0.875 |
| Leiden community 24 | [1, 1] | 0 | [0, 2, 0] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [2, 0, 0, 0, 0, 0, 0, 0] | 0.875 |
| Leiden community 25 | [2, 0] | 0.5 | [0, 1, 1] | 0.333333 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 1, 0, 1, 0, 0, 0] | 0.75 |
| Leiden community 26 | [1, 1] | 0 | [0, 1, 1] | 0.333333 | [0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 2, 0, 0, 0, 0, 0] | 0.875 |
| Leiden community 27 | [1, 1] | 0 | [0, 0, 2] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [2, 0, 0, 0, 0, 0, 0, 0] | 0.875 |
| Leiden community 28 | [1, 1] | 0 | [0, 2, 0] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [2, 0, 0, 0, 0, 0, 0, 0] | 0.875 |
| Leiden community 29 | [2, 0] | 0.5 | [0, 1, 1] | 0.333333 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0] | 0.98 | [0, 0, 0, 2, 0, 0, 0, 0] | 0.875 |
| Leiden community 30 | [1, 1] | 0 | [0, 1, 1] | 0.333333 | [0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [2, 0, 0, 0, 0, 0, 0, 0] | 0.875 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Leiden community 31 | [1, 1] | 0 | [0, 1, 1] | 0.333333 | [0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 2, 0, 0, 0, 0] | 0.875 |
| Leiden community 32 | [1, 1] | 0 | [0, 1, 1] | 0.333333 | [2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [2, 0, 0, 0, 0, 0, 0, 0] | 0.875 |
| Leiden community 33 | [1, 1] | 0 | [1, 0, 1] | 0.333333 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 2, 0, 0, 0, 0] | 0.875 |
| Leiden community 34 | [1, 1] | 0 | [0, 2, 0] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0] | 0.96 | [0, 0, 0, 2, 0, 0, 0, 0] | 0.875 |
| Leiden community 35 | [2, 0] | 0.5 | [0, 0, 2] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 2, 0, 0, 0, 0, 0] | 0.875 |
| Leiden community 36 | [1, 1] | 0 | [0, 1, 1] | 0.333333 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 2, 0, 0, 0, 0] | 0.875 |
| Label propagation community 0 | [29, 342] | 0.421833 | [1, 179, 191] | 0.34142 | [2, 6, 4, 8, 46, 7, 6, 1, 25, 12, 1, 2, 5, 3, 16, 8, 4, 7, 7, 9, 5, 2, 12, 8, 8, 4, 3, 7, 3, 1, 7, 2, 4, 17, 12, 5, 8, 17, 1, 6, 1, 8, 32, 3, 2, 1, 6, 5, 1, 1] | 0.487278 | [84, 1, 179, 102, 1, 2, 1, 1] | 0.674191 |
| Label propagation community 1 | [5, 0] | 0.5 | [0, 4, 1] | 0.533333 | [0, 0, 0, 0, 5, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 5, 0, 0, 0, 0, 0] | 0.875 |
| Label propagation community 2 | [4, 0] | 0.5 | [0, 0, 4] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0] | 0.97 | [0, 0, 0, 4, 0, 0, 0, 0] | 0.875 |
| Label propagation community 3 | [3, 0] | 0.5 | [0, 3, 0] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 3, 0, 0, 0, 0] | 0.875 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Label propagation community 4 | [3, 0] | 0.5 | [0, 0, 3] | 0.666667 | [0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 3, 0, 0, 0, 0] | 0.875 |
| Label propagation community 5 | [3, 0] | 0.5 | [0, 2, 1] | 0.444444 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 3, 0, 0, 0, 0] | 0.875 |
| Label propagation community 6 | [2, 0] | 0.5 | [0, 2, 0] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 2, 0, 0, 0, 0, 0] | 0.875 |
| Label propagation community 7 | [2, 0] | 0.5 | [0, 1, 1] | 0.333333 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 2, 0, 0, 0, 0, 0] | 0.875 |
| Label propagation community 8 | [2, 0] | 0.5 | [0, 2, 0] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 2, 0, 0, 0, 0] | 0.875 |
| Label propagation community 9 | [2, 0] | 0.5 | [0, 0, 2] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 2, 0, 0, 0, 0, 0] | 0.875 |
| Label propagation community 10 | [2, 0] | 0.5 | [0, 0, 2] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 2, 0, 0, 0, 0] | 0.875 |
| Label propagation community 11 | [2, 0] | 0.5 | [0, 1, 1] | 0.333333 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 1, 0, 1, 0, 0, 0] | 0.75 |
| Label propagation community 12 | [2, 0] | 0.5 | [0, 1, 1] | 0.333333 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0] | 0.98 | [0, 0, 0, 2, 0, 0, 0, 0] | 0.875 |
| Asynchronous label propagation community 0 | [29, 342] | 0.421833 | [1, 179, 191] | 0.34142 | [2, 6, 4, 8, 46, 7, 6, 1, 25, 12, 1, 2, 5, 3, 16, 8, 4, 7, 7, 9, 5, 2, 12, 8, 8, 4, 3, 7, 3, 1, 7, 2, 4, 17, 12, 5, 8, 17, 1, 6, 1, 8, 32, 3, 2, 1, 6, 5, 1, 1] | 0.487278 | [84, 1, 179, 102, 1, 2, 1, 1] | 0.674191 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Asynchronous label propagation community 1 | [5, 0] | 0.5 | [0, 4, 1] | 0.533333 | [0, 0, 0, 0, 5, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 5, 0, 0, 0, 0, 0] | 0.875 |
| Asynchronous label propagation community 2 | [4, 0] | 0.5 | [0, 0, 4] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0] | 0.97 | [0, 0, 0, 4, 0, 0, 0, 0] | 0.875 |
| Asynchronous label propagation community 3 | [3, 0] | 0.5 | [0, 3, 0] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 3, 0, 0, 0, 0] | 0.875 |
| Asynchronous label propagation community 4 | [3, 0] | 0.5 | [0, 0, 3] | 0.666667 | [0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 3, 0, 0, 0, 0] | 0.875 |
| Asynchronous label propagation community 5 | [3, 0] | 0.5 | [0, 2, 1] | 0.444444 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 3, 0, 0, 0, 0] | 0.875 |
| Asynchronous label propagation community 6 | [2, 0] | 0.5 | [0, 2, 0] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 2, 0, 0, 0, 0, 0] | 0.875 |
| Asynchronous label propagation community 7 | [2, 0] | 0.5 | [0, 1, 1] | 0.333333 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 2, 0, 0, 0, 0, 0] | 0.875 |
| Asynchronous label propagation community 8 | [2, 0] | 0.5 | [0, 2, 0] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 2, 0, 0, 0, 0] | 0.875 |
| Asynchronous label propagation community 9 | [2, 0] | 0.5 | [0, 0, 2] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 2, 0, 0, 0, 0, 0] | 0.875 |
| Asynchronous label propagation community 10 | [2, 0] | 0.5 | [0, 0, 2] | 0.666667 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 0, 2, 0, 0, 0, 0] | 0.875 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Asynchronous label propagation community 11 | [2, 0] | 0.5 | [0, 1, 1] | 0.333333 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0] | 0.98 | [0, 0, 1, 0, 1, 0, 0, 0] | 0.75 |
| Asynchronous label propagation community 12 | [2, 0] | 0.5 | [0, 1, 1] | 0.333333 | [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0] | 0.98 | [0, 0, 0, 2, 0, 0, 0, 0] | 0.875 |

**Fig 30: Reciprocated House Candidates' Community Partitions**

**Fig 31: Communities Image Graphs for the House Reciprocated Graph**

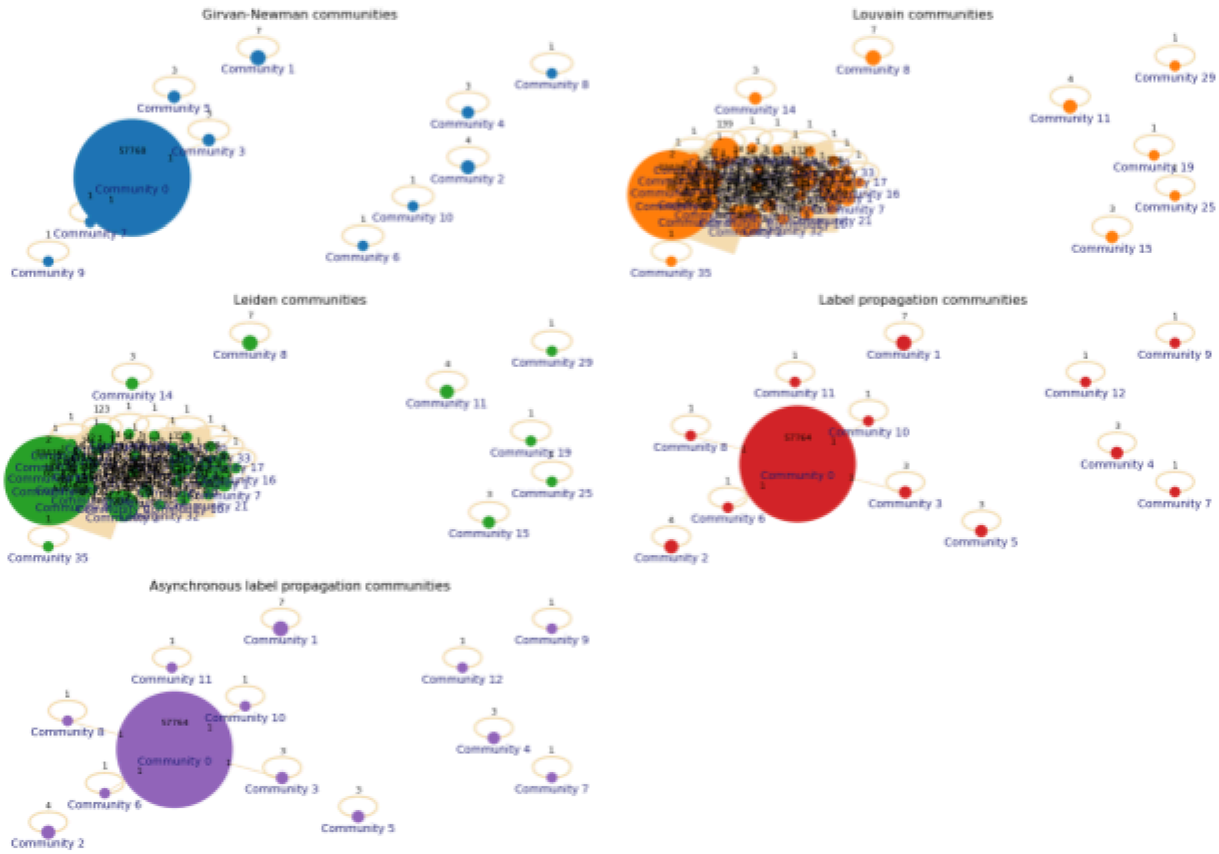
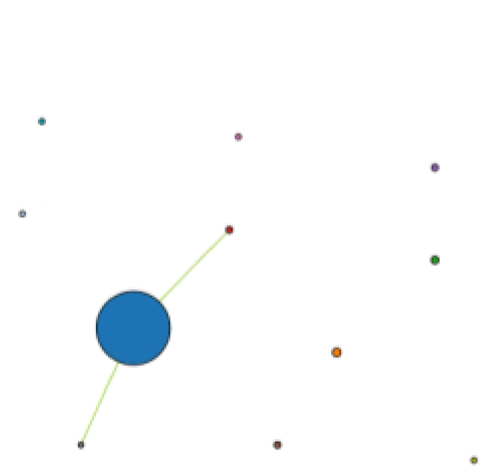
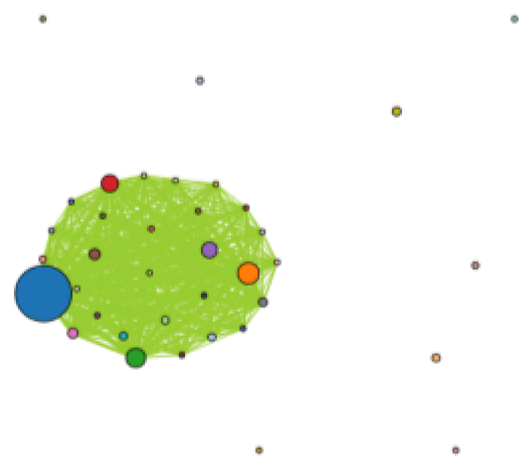


**Fig 32: Attributed Reciprocated House Candidates' Community Partitions**

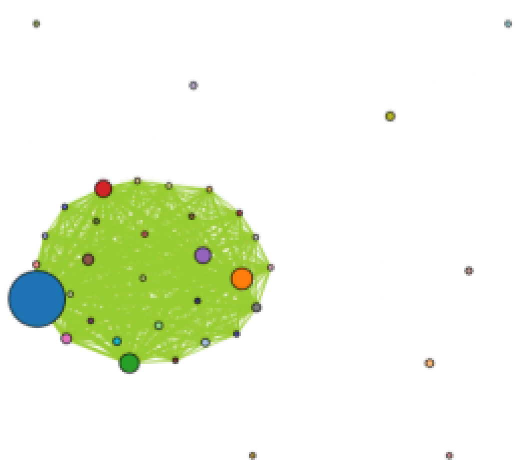
**11 Girvan-Newman communities**



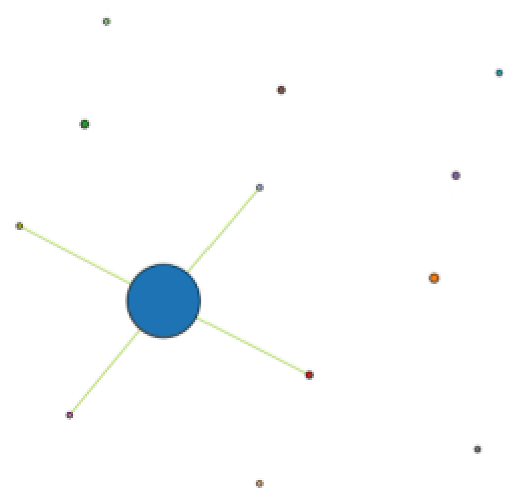
**37 Louvain communities**



**37 Leiden communities**



**13 Label propagation communities**



**13 Asynchronous LPA communities**