COVID-19 in US Counties

PHYS5116

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The Story So Far

Region-wise 7-day Rolling Average of New COVID-19 Cases per Day
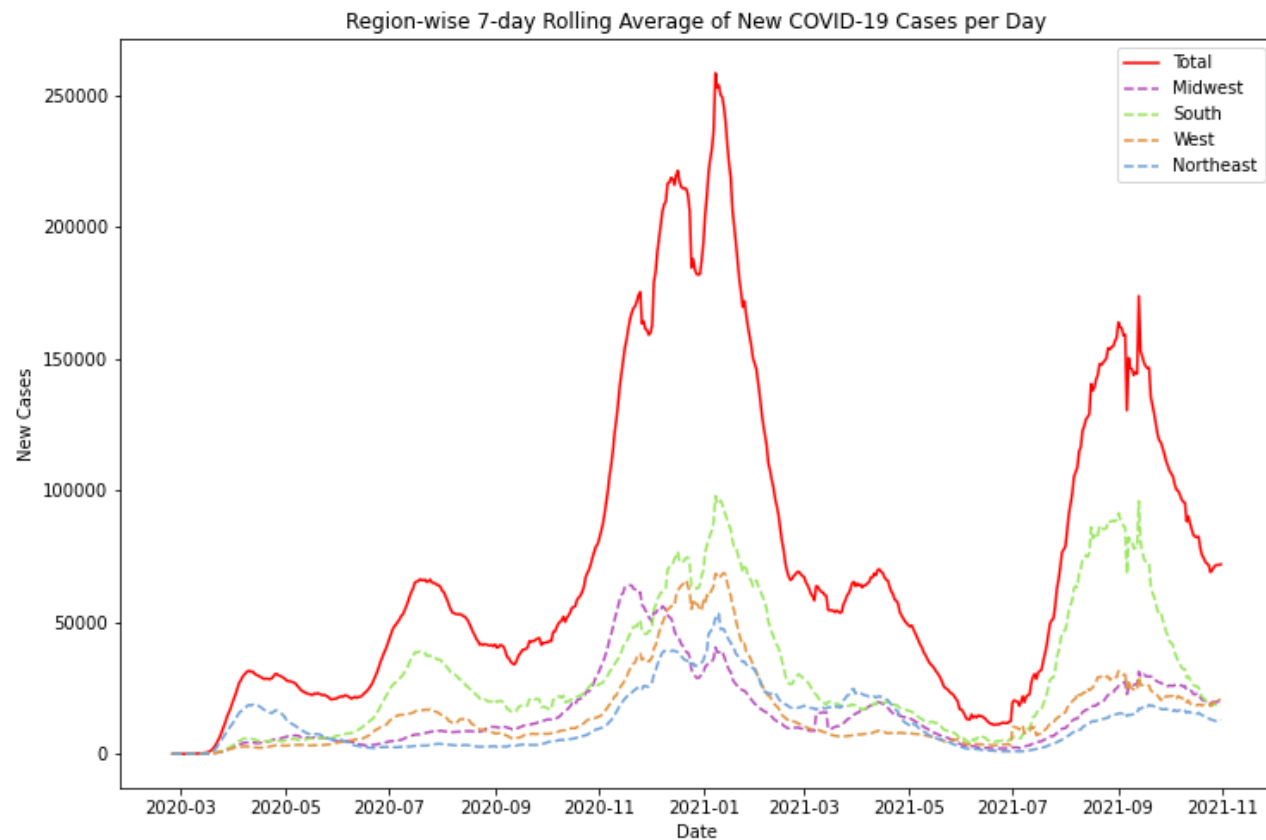
Raw Data

- COVID-19 stats: The New York Times

	Date	County	State	FIPS	Total Cases	Total Deaths
135	11-02-20	Snohomish	Washington	53061	1	0
136	11-02-20	Dane	Wisconsin	55025	1	0
137	12-02-20	Maricopa	Arizona	4013	1	0
138	12-02-20	Los Angele	California	6037	1	0
139	12-02-20	Orange	California	6059	1	0
140	12-02-20	San Diego	California	6073	1	0
141	12-02-20	San Franci	California	6075	2	0
142	12-02-20	Santa Clar	California	6085	2	0
143	12-02-20	Cook	Illinois	17031	2	0
144	12-02-20	Suffolk	Massachus	25025	1	0
145	12-02-20	Bexar	Texas	48029	1	0
146	12-02-20	Snohomish	Washington	53061	1	0
147	12-02-20	Dane	Wisconsin	55025	1	0
148	13-02-20	Maricopa	Arizona	4013	1	0
149	13-02-20	Los Angele	California	6037	1	0
150	13-02-20	Orange	California	6059	1	0
151	13-02-20	San Diego	California	6073	1	0
152	13-02-20	San Franci	California	6075	2	0

Data Processing

- Clean up names
- Add regions - Northeast, Midwest, South, West
- Calculate new cases per day for each county

COVID-19 Correlations Network

- Nodes: **Counties**
- Edges:
  - Calculate correlation coefficient of new cases from Feb 2020 to Oct 2021 between every pair of counties
  - **Connect** counties where **coefficient** is **above** a threshold value (**0.75**)
- Edge weight: correlation coefficient

- Final graph: **929 nodes**, **5566 edges**

COVID-19 Correlations Network

- But what do the edges **actually mean**?

COVID-19 Correlations Network

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- We know edges represent **high positive correlations** between counties based on new cases over 1.5 years
- This means only **counties with similar infection patterns** (increase **and** decrease) will be **connected**

COVID-19 Correlations Network

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- We know edges represent **high positive correlations** between counties based on new cases over 1.5 years
- This means only **counties with similar infection patterns** (increase **and** decrease) will be **connected**

- Our hypothesis: This network has an underlying community structure of **counties with similar infection patterns** that we can detect
- We analyse the graph to determine what the communities mean

COVID-19 Correlations Network

Correlation Network of New COVID Cases in Counties

COVID-19 Correlations Network

Correlation Network Degree Distribution
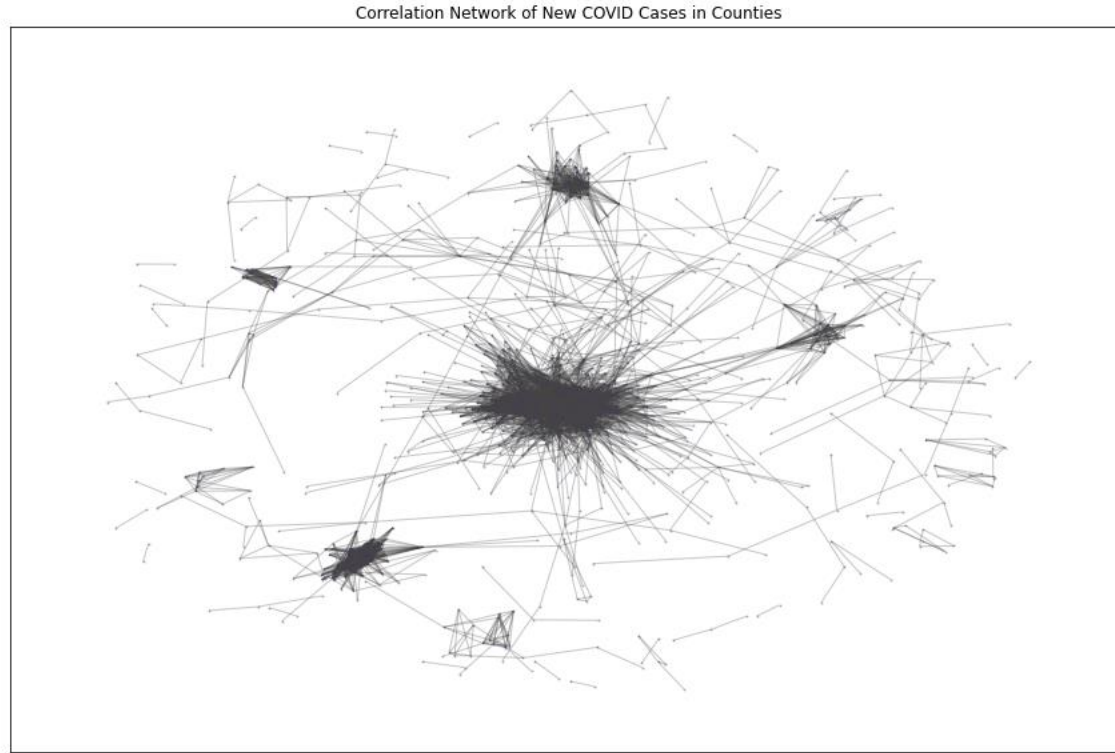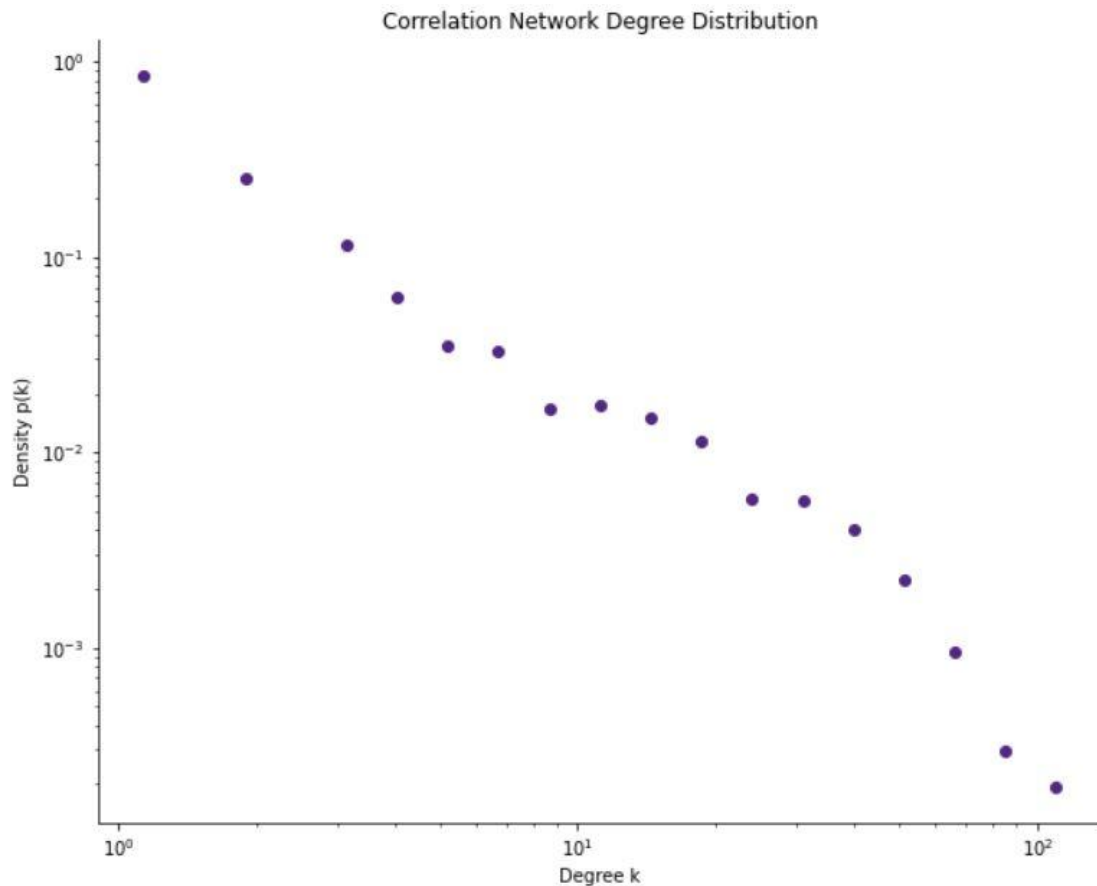
γ: 4.05

Avg. degree: 11.98
Avg. weighted degree: 9.52

Density: 0.013

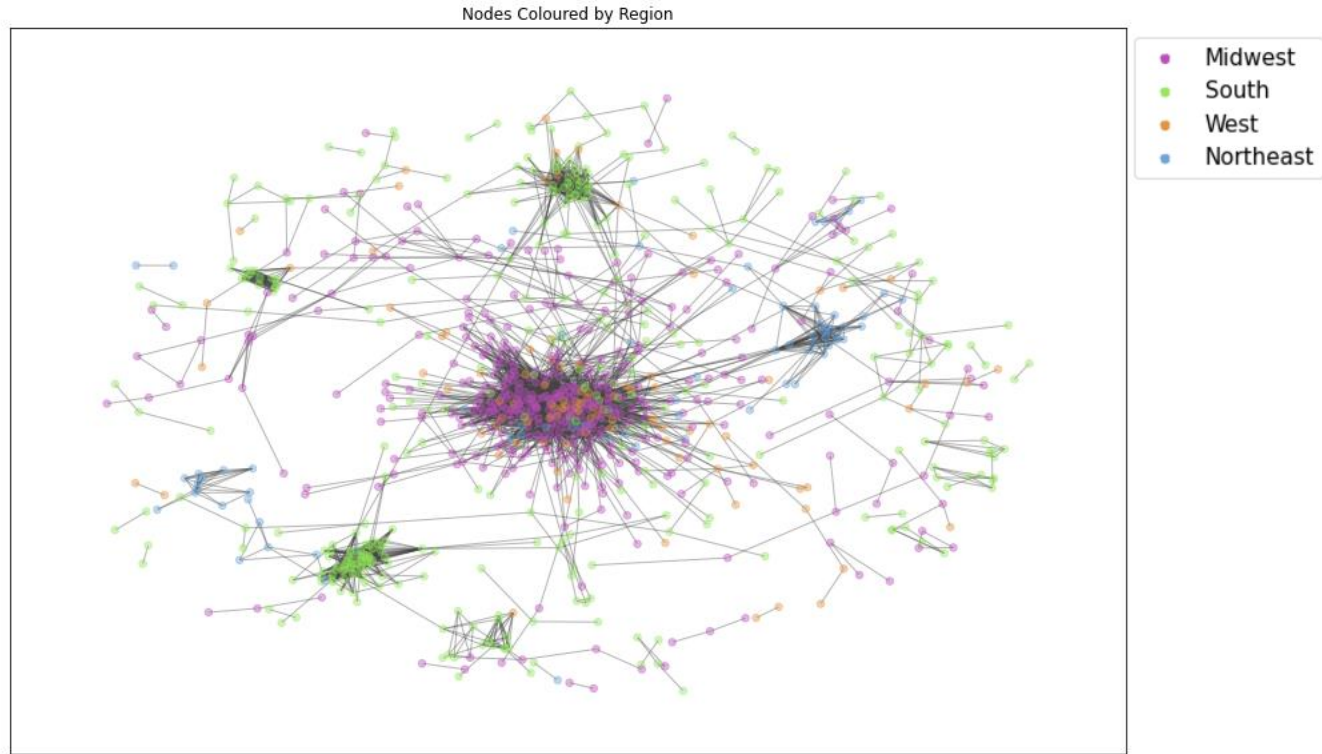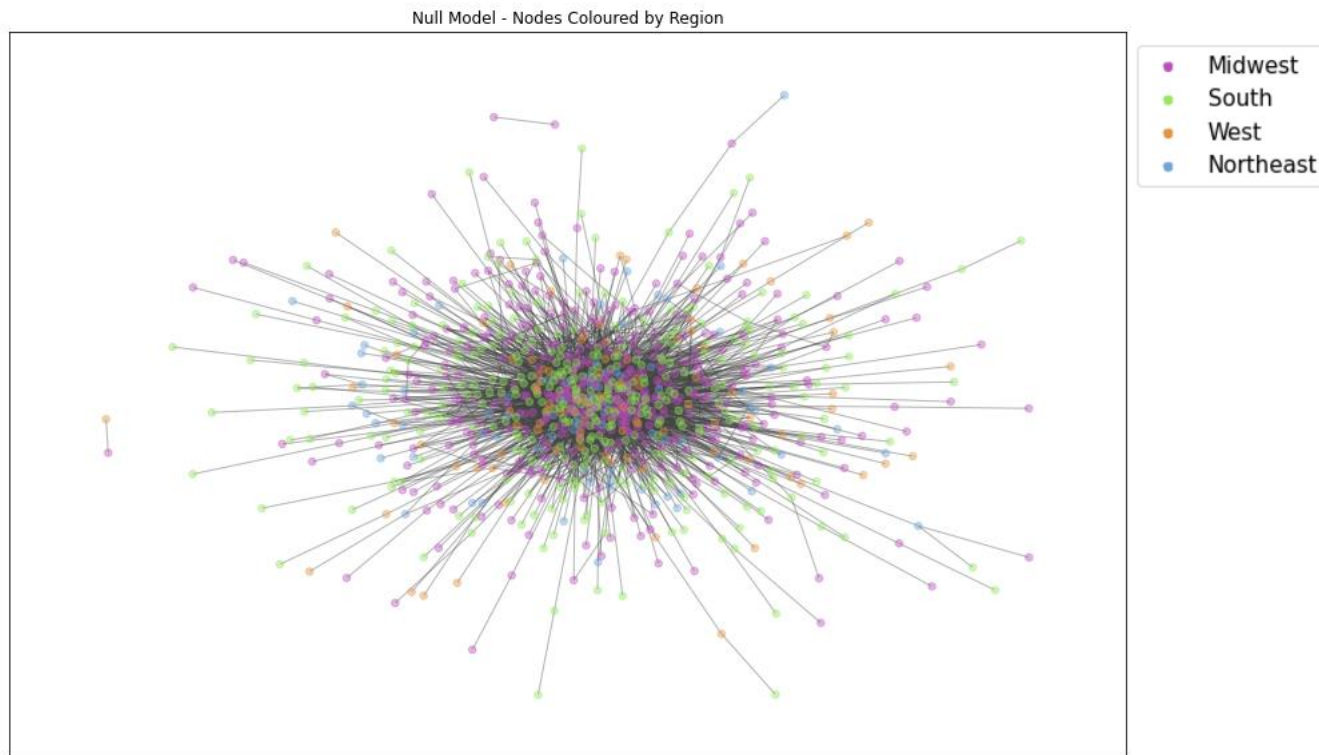Avg. clustering coefficient: 0.612
Triangles: 29,131

Avg. path length: 3.54

Components: 60

COVID-19 Correlations Network - Coloured by Region

Nodes Coloured by Region

- Midwest
- South
- West
- Northeast

Null Model

- Expected degree graph without self-loops, edge weights are shuffled

Null Model - Nodes Coloured by Region

Legend:
- Midwest
- South
- West
- Northeast

Community Detection

- Greedy Modularity Maximisation

  Greedy modularity maximisation begins with each node in its own community and joins the pair of communities that most increases modularity until no such pair exists.

- k-Cliques (k = 5)

  A k-clique community is the union of all cliques of size k (complete subgraphs of size k) that can be reached through adjacent (sharing k-1 nodes) k-cliques.

Community Detection - Greedy Modularity Maximisation

- Communities detected:
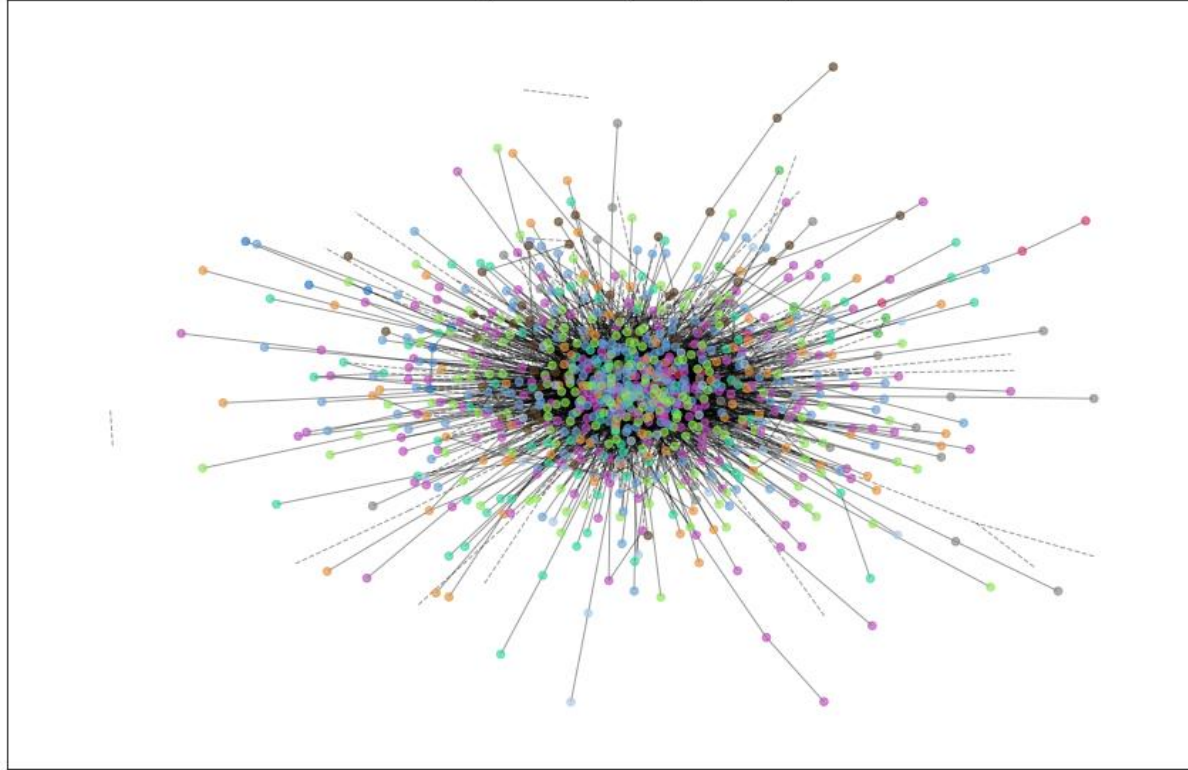 - Correlation network: 25
  - Null Model: 11

Network	Mean Size	Median Size	Std. Dev.	Max Size	Min
Correlation Network	31.72	10	57.94	290	5
Null Model	81	43	76.06	201	5

Community Detection - Greedy Modularity Maximisation
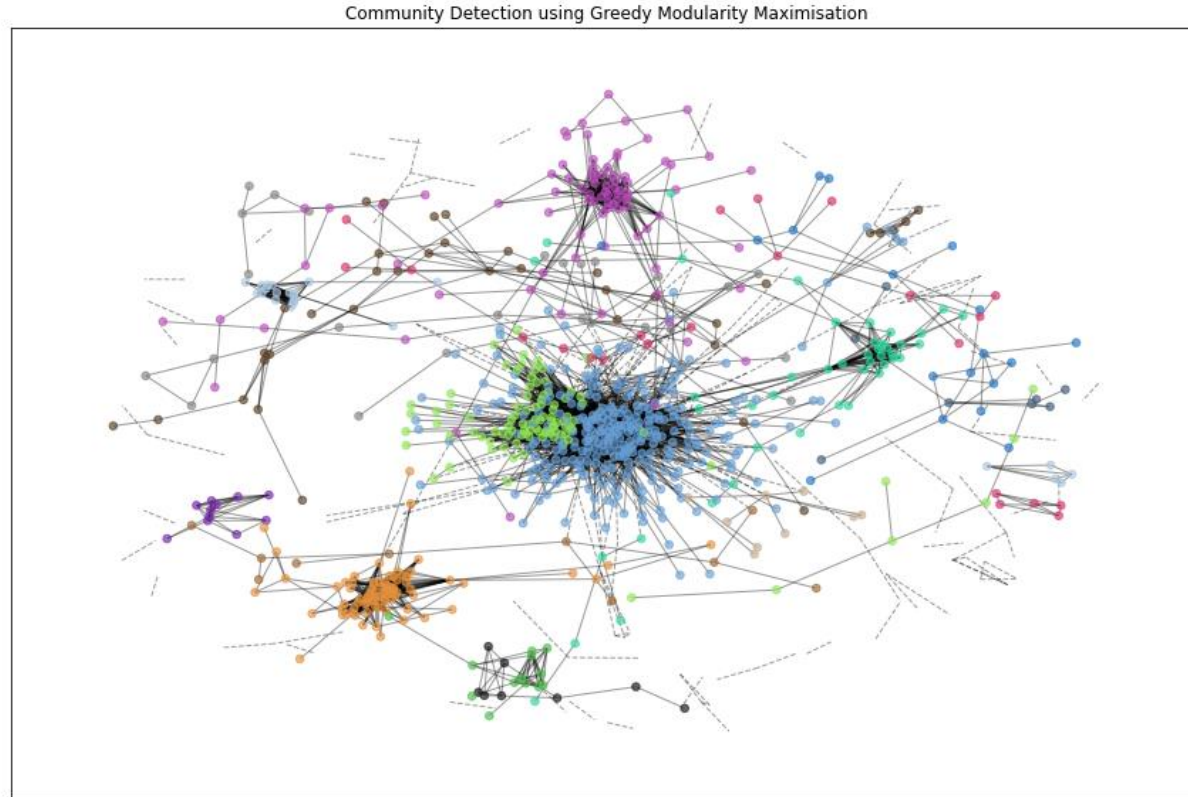
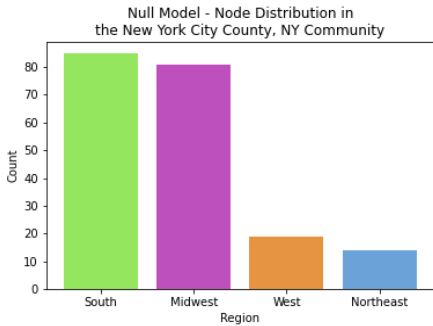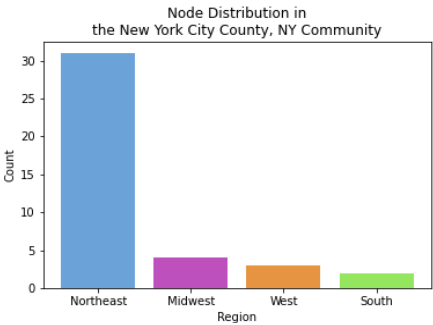Community Detection using Greedy Modularity Maximisation

Community Detection - Greedy Modularity Maximisation
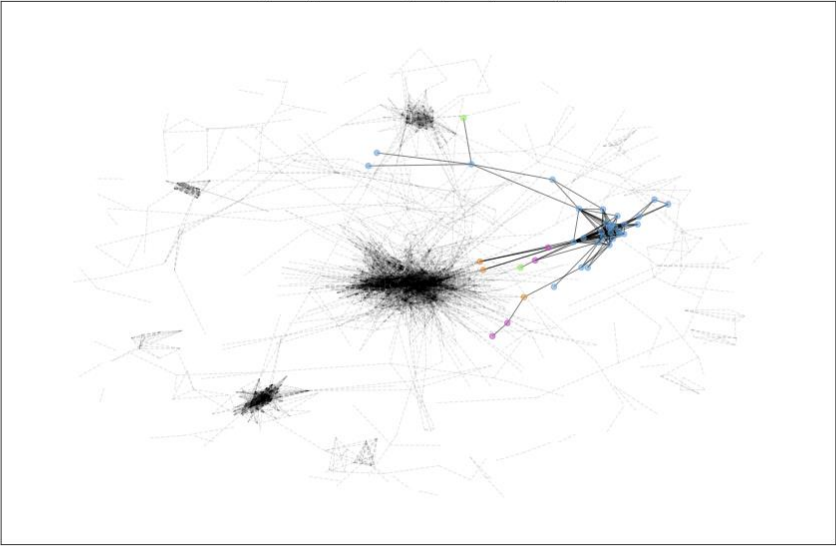

Null Model - Community Detection using Greedy Modularity Maximisation

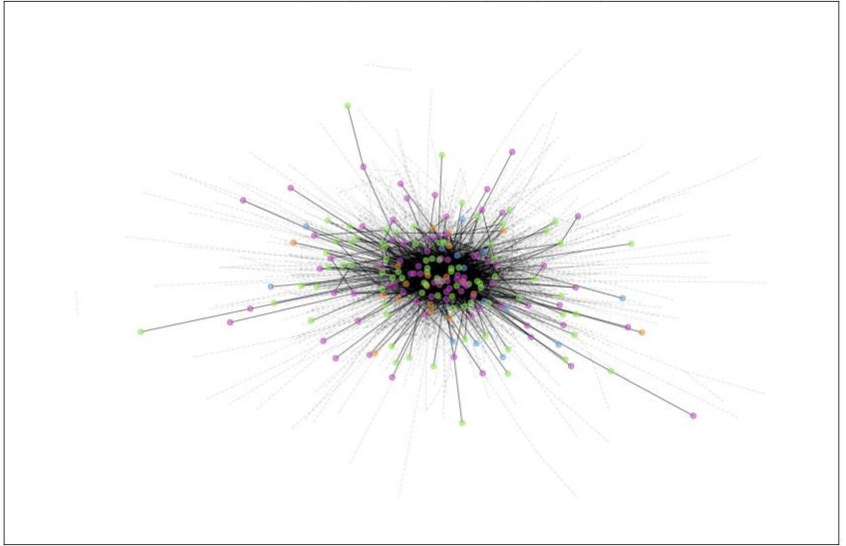# Community Detection - Greedy Modularity Maximisation

Node Distribution in
the New York City County, NY Community

Null Model - Node Distribution in
the New York City County, NY Community

New York City County, NY Community using Greedy Modularity Maximisation

Null Model - New York City County, NY Community using Greedy Modularity Maximisation

Community: ['Mercer County, NJ', 'Boundary County, ID', 'Lehigh County, PA', 'Somerset County, NJ', 'Monroe County, PA', 'Luzerne County, PA', 'Union County, NJ', 'Dawson County, MT', 'Suffolk County, NY', 'Page County, VA', 'Ulster County, NY', 'Ocean County, NJ', 'Passaic County, NJ', 'Dutchess County, NY', 'Seneca County, NY', 'Hudson County, NJ', 'Sussex County, NJ', 'Ransom County, ND', 'New York City County, NY', 'Monmouth County, NJ', 'Custer County, MT', 'Burlington County, NJ', 'Camden County, NJ', 'Westchester County, NY', 'Lee County, KY', 'Morris County, NJ', 'Guernsey County, OH', 'Rockland County, NY', 'Racine County, WI', 'Middlesex County, NJ', 'Pike County, PA', 'Warren County, NJ', 'Nassau County, NY', 'Essex County, NJ', 'Bergen County, NJ', 'Putnam County, NY', 'Northampton County, PA', 'Schenectady County, NY', 'Orange County, NY', 'Wayne County, MI']
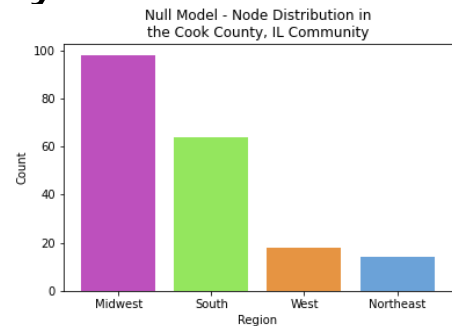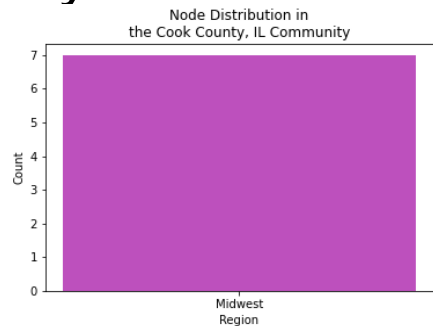Community size: 40

Correlation network community
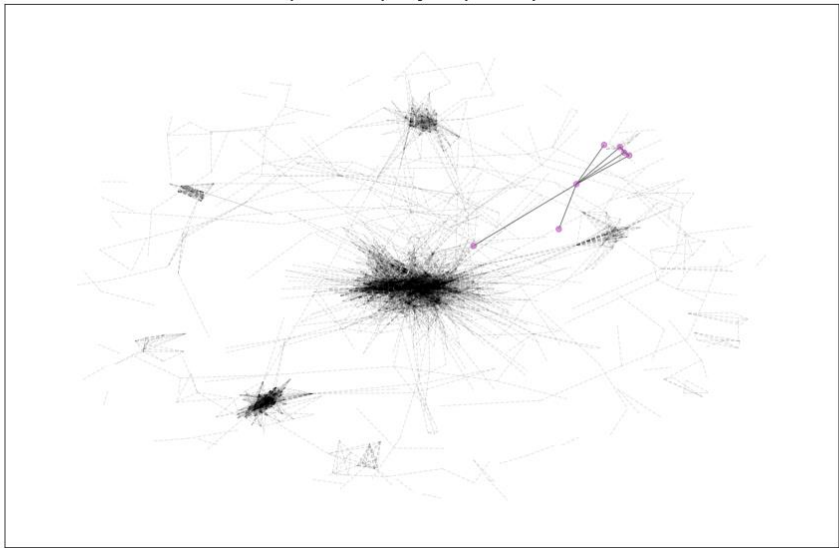
Null model community

Community: ['Sumner County, KS', 'Dickinson County, MI', 'Jackson County, SD', 'San Diego County, CA', 'Langlade County, WI', 'Vermilion County, LA', 'Jasper County, MO', 'Oconee County, SC', 'Aurora County, SD', 'New Hanover County, NC', 'Clark County, NV', 'Franklin County, FL', 'Chilton County, AL', 'Acadia County, LA', 'Polk County, WI', 'Miami County, KS', 'Brown County, KS', 'Ozaukee County, WI', 'Custer County, MT', 'Poinsett County, AR', 'Osceola County, FL', 'Stephens County, TX', 'Scott County, VA', 'Itasca County, MN', 'Ashland County, WI', 'Jefferson County, KY', 'Bartow County, GA', 'Turner County, SD', 'San Luis Obispo County, CA', 'Hampden County, MA', 'Lenawee County, MI', 'Lancaster County, NE', 'Williams County, OH', 'Wasatch County, UT', 'Marshall County, WV', 'Dale County, AL', 'Rogers County, OK', 'Montcalm County, MI', 'Taylor County, WI', 'Hardin County, KY', 'Wayne County, KY', 'Dakota County, MN', 'Cass County, ND', 'Newton County, GA', 'Newport News city County, VA', 'Weston County, WY', 'Iredell County, NC', 'Lee County, IL', 'Delaware County, OH', 'Crisp County, GA', 'Douglas County, CO', 'Fayette County, GA', 'Upshur County, WV', 'Allen County, OH', 'New York City County, NY', 'Clare County, MI', 'Will County, IL', 'Grant County, SD', 'Bottineau County, ND', 'Seward County, NE', 'Muscogee County, GA', 'Sarpy County, NE', 'Lemhi County, ID', 'Knox County, TN', 'Huntington County, IN', 'Hamilton County, IN', 'Dodge County, GA', 'Ballard County, KY', 'Granville County, NC', 'Middlesex County, CT', 'Cleveland County, OK', 'Chattooga County, GA', 'Tattnall County, GA', 'St. Mary County, LA', 'Lawrence County, IL', 'Adams County, WI', 'Essex County, MA', 'Weakley County, TN', 'Wood County, WI', 'Logan County, OK', 'Braxton County, WV', 'Henry County, MO', 'Catawba County, NC', 'Essex County, NJ', 'Rice County, KS', 'DeKalb County, IN', 'DuPage County, IL', 'Allegan County, MI', 'Rush County, KS', 'Ramsey County, MN', 'Walsh County, ND', 'Lane County, OR', 'Westmoreland County, PA', 'Watauga County, NC', 'Washington County, AL', 'Chippewa County, WI', 'Cocke County, TN', 'Vernon County, WI', 'Barrow County, GA', 'Page County, VA', 'Lewis and Clark County, MT', 'Amherst County, VA', 'Oklahoma County, OK', 'Elliott County, KY', 'Dutchess County, NY', 'Ellis County, KS', 'Florence County, SC', 'Buffalo County, WI', 'Jones County, IA', 'Noble County, OH', 'Lee County, GA', 'Newaygo County, MI', 'Floyd County, KY', 'Moniteau County, MO', 'Anderson County, TN', 'Becker County, MN', 'Floyd County, GA', 'Franklin County, VA', 'Orleans County, LA', 'Gladwin County, MI', 'Oglala Lakota County, SD', 'Benton County, IA', 'Davis County, UT', 'Lee County, IA', 'Kenosha County, WI', 'Cass County, IA', 'Solano County, CA', 'Reno County, KS', 'Darlington County, SC', 'Pinellas County, FL', 'Delaware County, IN', 'Philadelphia County, PA', 'Kendall County, TX', 'Clay County, FL', 'Gulf County, FL', 'Madison County, GA', 'Cass County, MI', 'St. Landry County, LA', 'Campbell County, VA', 'Benton County, WA', 'Schley County, GA', 'Stanislaus County, CA', 'Orange County, NY', 'Natrona County, WY', 'Green County, WI', 'Williamson County, TN', 'Allegany County, NY', 'Dooly County, GA', 'Barber County, KS', 'Medina County, OH', 'Butts County, GA', 'Erath County, TX', 'Shelby County, AL', 'York County, NE', 'Orange County, CA', 'Upson County, GA', 'Manitowoc County, WI', 'Dubuque County, IA', 'Red Willow County, NE', 'Bedford County, VA', 'Cherokee County, GA', 'Polk County, IA', 'Phelps County, MO', 'Shelby County, IL', 'Wise County, TX', 'Roane County, TN', 'Vernon County, LA', 'Monmouth County, NJ', 'Hillsborough County, FL', 'Jerome County, ID', 'Eau Claire County, WI', 'Peoria County, IL', 'Auglaize County, OH', 'Crow Wing County, MN', 'Lewis County, NY', 'Caldwell County, NC', 'Bonneville County, ID', 'Summers County, WV', 'Madison County, OH', 'Coffee County, GA', 'Manatee County, FL', 'Sumner County, TN', 'St. Johns County, FL', 'Ouachita County, LA', 'Clay County, MN', 'Oconee County, GA', 'Jasper County, IN', 'Warren County, NJ', 'Dawson County, GA', 'Multnomah County, OR', 'Delta County, MI', 'Ellis County, TX', 'Worcester County, MA', 'Montgomery County, OH', 'Talbot County, GA', 'Glynn County, GA', 'Clayton County, IA', 'Marion County, KY', 'Charles Mix County, SD']
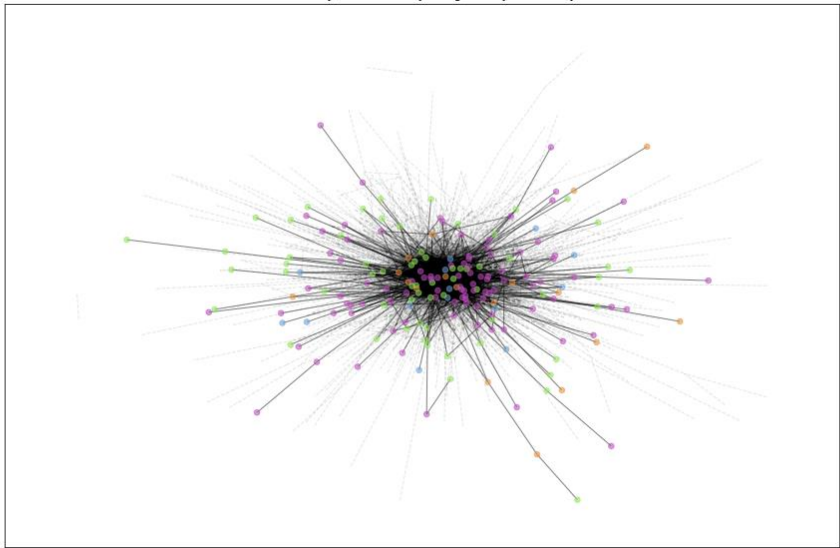Community size: 199

Community Detection - Greedy Modularity Maximisation

Node Distribution in
the Cook County, IL Community

Null Model - Node Distribution in
the Cook County, IL Community

Cook County, IL Community using Greedy Modularity Maximisation

Null Model - Cook County, IL Community using Greedy Modularity Maximisation

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Community: ['Stephenson County, IL', 'Lake County, IL', 'DuPage County, IL', 'Will County, IL', 'Kane County, IL',
'McHenry County, IL', 'Cook County, IL']
Community size: 7
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Correlation network community

Null model community

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Community: ['Mercer County, NJ', 'Yuma County, AZ', 'Moultrie County, IL', 'Hinds County, MS', 'Newton County, MO',
'Washington County, MN', 'Tioga County, NY', 'St. Joseph County, MI', 'Wright County, MO', 'Burleigh County, ND', '
La Salle County, TX', 'Douglas County, IL', 'Rock County, WI', 'Butler County, PA', 'Camden County, NJ', 'Columbia
County, WI', 'Providence County, RI', 'Aitkin County, MN', 'Meade County, SD', 'Pike County, KY', 'Jessamine Count
y, KY', 'Shawano County, WI', 'Charlotte County, FL', 'Wabash County, IN', 'Summit County, OH', 'Hubbard County, MN
', 'Wood County, OH', 'Green Lake County, WI', 'Texas County, MO', 'Warrick County, IN', 'Adams County, IL', 'Hawki
ns County, TN', 'Marathon County, WI', 'Vilas County, WI', 'Ness County, KS', 'Lumpkin County, GA', 'Coffee County,
TN', 'Newton County, TX', 'Callaway County, MO', 'Ulster County, NY', 'Cook County, IL', 'Hinsdale County, CO', 'Bo
one County, IL', 'Aiken County, SC', 'Arapahoe County, CO', 'LaSalle County, IL', 'Calhoun County, MI', 'Stanton Co
unty, NE', 'Linn County, IA', 'McHenry County, IL', 'Scioto County, OH', 'Sauk County, WI', 'Gwinnett County, GA',
'Duval County, FL', 'Bibb County, GA', 'Fond du Lac County, WI', 'Fulton County, AR', 'Hamilton County, IA', 'Burli
ngton County, NJ', 'Houston County, AL', 'Bates County, MO', 'Licking County, OH', 'Goodhue County, MN', 'Cobb Coun
ty, GA', 'Champaign County, IL', 'Barnstable County, MA', 'Fremont County, ID', 'Athens County, OH', 'Guernsey Coun
ty, OH', 'Rockland County, NY', 'Caribou County, ID', 'DeKalb County, GA', 'Ogle County, IL', 'Jefferson County, CO
', 'Harding County, SD', 'Hill County, MT', 'Chesapeake city County, VA', 'Gibson County, IN', 'Beaufort County, SC
', 'Larimer County, CO', 'Wakulla County, FL', 'Wheeler County, TX', 'Muskegon County, MI', 'Macon County, IL', 'Va
lencia County, NM', 'Cumberland County, TN', 'Allegheny County, PA', 'Putnam County, OH', 'Florence County, WI', 'M
onroe County, GA', 'Sheboygan County, WI', 'Okaloosa County, FL', 'Gonzales County, TX', 'Pulaski County, AR', 'St.
Bernard County, LA', 'Bay County, MI', 'Lynchburg city County, VA', 'Lawrence County, IN', 'Hayes County, NE', 'Pal
m Beach County, FL', 'Marion County, FL', 'Luce County, MI', 'Edgefield County, SC', 'Adams County, ID', 'Twin Fall
s County, ID', 'Clearwater County, MN', 'Story County, IA', 'Pottawatomie County, KS', 'Kerr County, TX', 'Obion Co
unty, TN', 'Mesa County, CO', 'Morgan County, GA', 'York County, SC', 'Crawford County, OH', 'Southampton County, V
A', 'Modoc County, CA', 'Kewaunee County, WI', 'Hennepin County, MN', 'Vanderburgh County, IN', 'Washington County,
VA', 'Effingham County, IL', 'Stoddard County, MO', 'Carroll County, TN', 'Ottawa County, MI', 'Benton County, AR',
'Clayton County, GA', 'Bacon County, GA', 'Minnehaha County, SD', 'Coles County, IL', 'Johnson County, TX', 'Jasper
County, TX', 'Wyoming County, PA', 'Butte County, SD', 'Johnson County, IA', 'Suwannee County, FL', 'Jackson Count
y, OH', 'Box Butte County, NE', 'Roanoke County, VA', 'Muskingum County, OH', 'Boundary County, ID', 'Thurston Coun
ty, NE', 'Lake County, IL', 'Greene County, OH', 'Gibson County, TN', 'Madison County, MO', 'McDuffie County, GA',
'Saginaw County, MI', 'Chaves County, NM', 'Cheyenne County, NE', 'Davison County, SD', 'Monroe County, WI', 'Richl
and County, WI', 'Hamilton County, OH', 'Park County, WY', 'Tift County, GA', 'Bulloch County, GA', 'Genesee Count
y, MI', 'Winnebago County, IL', 'Fulton County, IL', 'Roseau County, MN', 'Presque Isle County, MI', 'Cullman Count
y, AL', 'Kaufman County, TX', 'Hernando County, FL', 'Traill County, ND', 'White County, AR', 'Houston County, GA',
'Tangipahoa County, LA', 'Morgan County, MO', 'Blount County, AL', 'Morris County, NJ', 'Doña Ana County, NM', 'Ric
hmond County, GA', 'Lewis County, TN', 'Washington County, GA', 'Iowa County, WI', 'Meriwether County, GA', 'Brule
County, SD', 'Kingman County, KS', 'Pike County, IL', 'Pike County, PA', 'Treasure County, MT', 'Kalamazoo County,
MI', 'Menominee County, WI', 'Dane County, WI', 'Oneida County, WI', 'Highland County, OH', 'Washington County, RI
', 'Burke County, GA', 'St. Tammany County, LA', 'Angelina County, TX', 'Douglas County, MN', 'Laurens County, SC',
'Paulding County, OH']
Community size: 194
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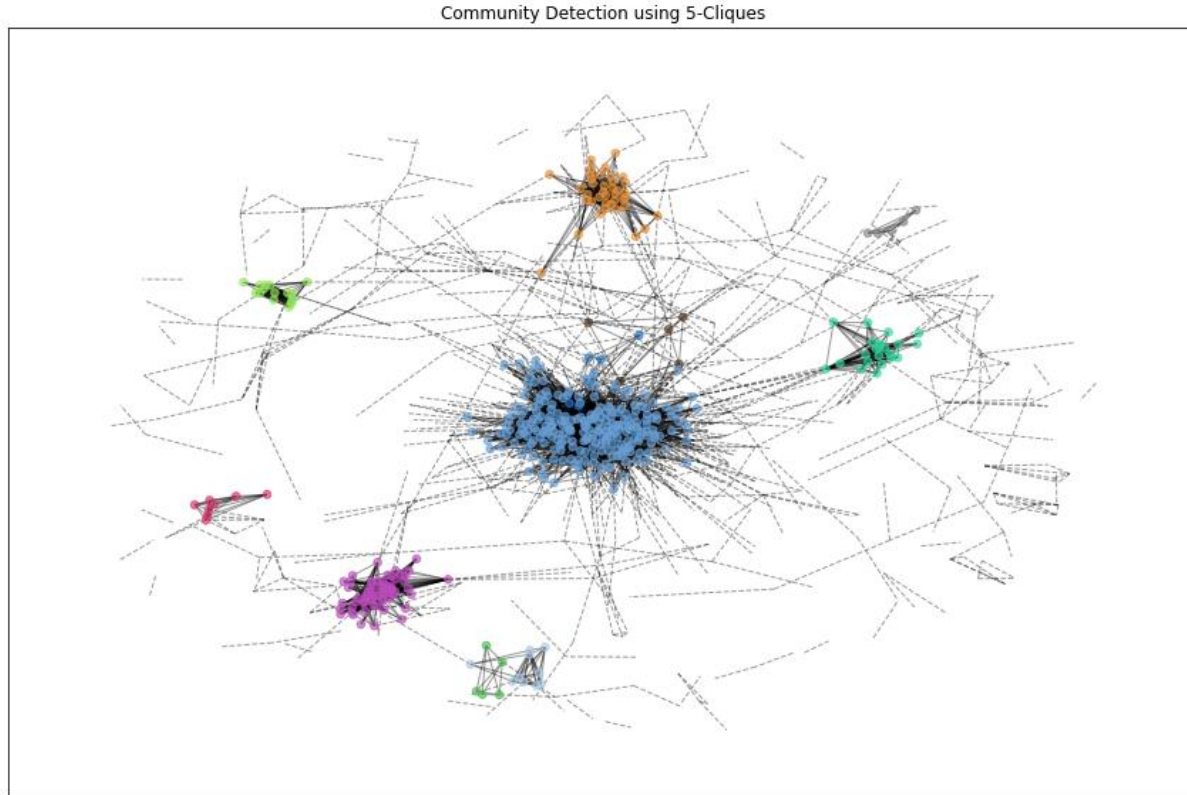
Community Detection - 5-cliques

- Communities detected:
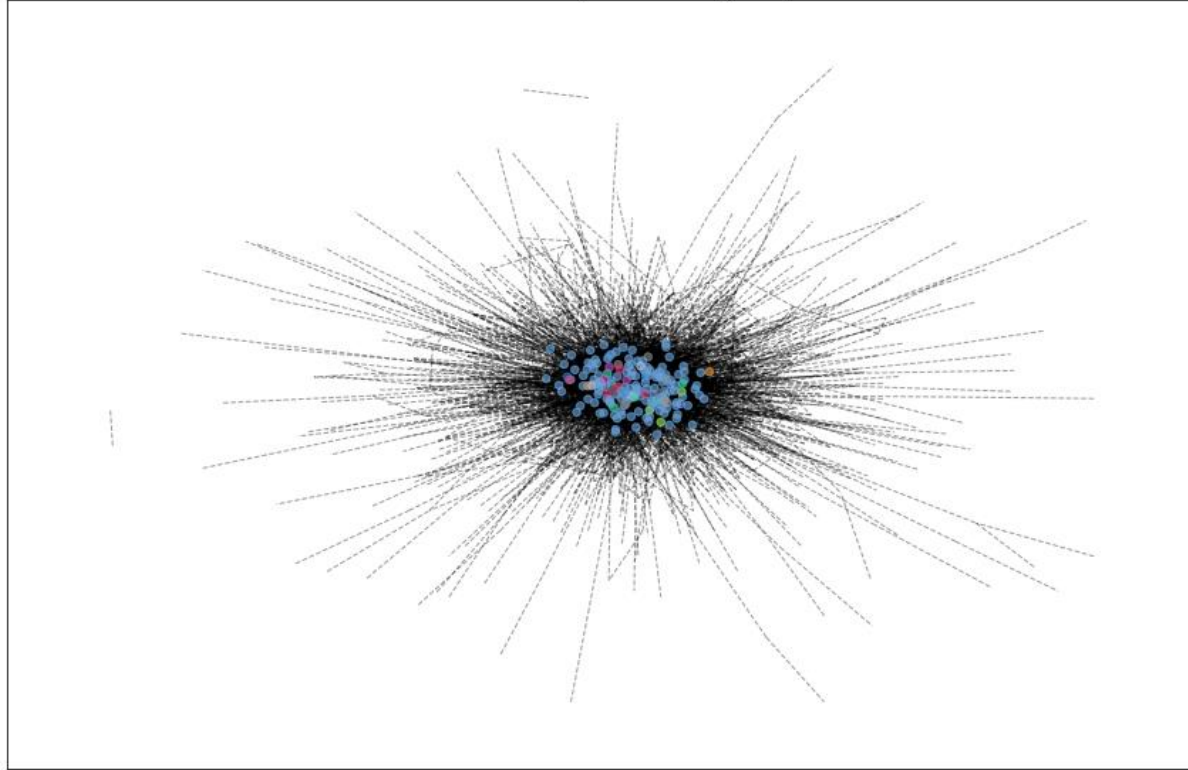   - Correlation network: 11
    - Null Model: 10

Network	Mean Size	Median Size	Std. Dev.	Max Size	Min
Correlation Network	38.54	10	67.87	246	5
Null Model	21.1	5	47.97	165	5

Community Detection - 5-cliques

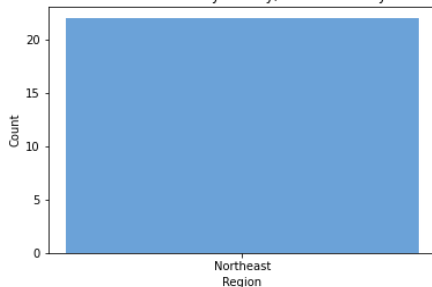
Community Detection using 5-Cliques

Community Detection - 5-cliques

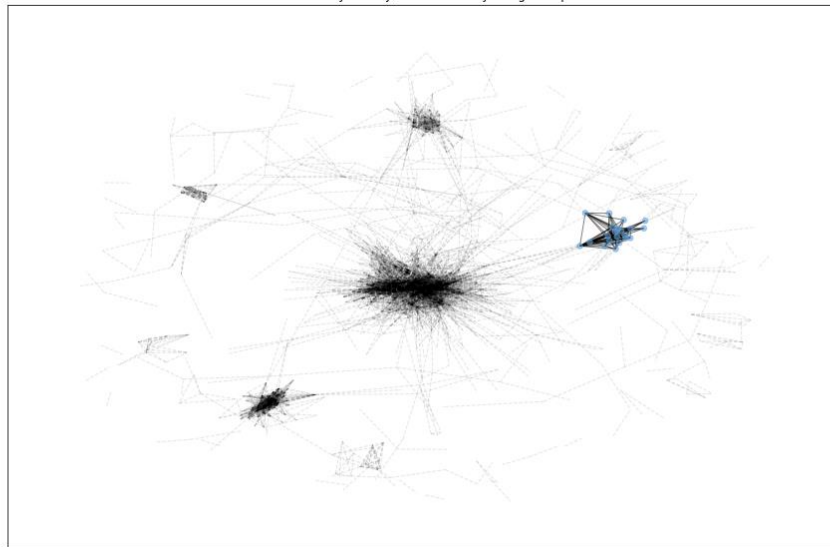Null Model - Community Detection using 5-Cliques

Community Detection - 5-cliques

Node Distribution in
the New York City County, NY Community

New York City County, NY Community using 5-Cliques

Null Model: no 5-clique community for New York City

Community: ['Mercer County, NJ', 'Lehigh County, PA', 'Somerset County, NJ', 'Westchester County, NY', 'Monroe County, PA', 'Morris County, NJ', 'Union County, NJ', 'Suffolk County, NY', 'Rockland County, NY', 'Passaic County, NJ', 'Dutchess County, NY', 'Hudson County, NJ', 'Middlesex County, NJ', 'Pike County, PA', 'Nassau County, NY', 'Essex County, NJ', 'Sussex County, NJ', 'Warren County, NJ', 'New York City County, NY', 'Bergen County, NJ', 'Monmouth County, NJ', 'Orange County, NY']
Community size: 22

Community Detection - 5-cliques

Correlation Network: no 5-clique
community for Cook County, IL

Null Model - Node Distribution in
the Cook County, IL Community

Null Model - Cook County, IL Community using 5-Cliques
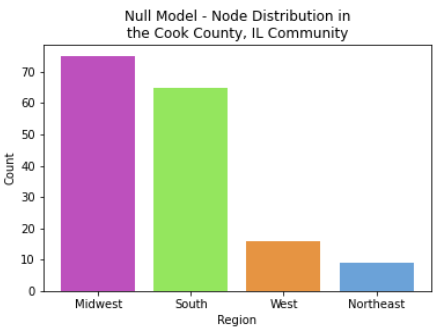
Community: ['Jackson County, SD', 'Langlade County, WI', 'Moultrie County, IL', 'Bradford County, PA', 'Franklin County, MA', 'Hinds County, MS', 'Cuyahoga County, OH', 'Tioga County, NY', 'Wagoner County, OK', 'Lake County, IN', 'Martin County, KY', 'Chilton County, AL', 'Rock County, WI', 'Pennington County, SD', 'Brown County, KS', 'Colquitt County, GA', 'Mitchell County, NC', 'Osceola County, FL', 'Putnam County, FL', 'Aransas County, TX', 'Berkeley County, WV', 'San Luis Obispo County, CA', 'Jessamine County, KY', 'Mercer County, ND', 'Marshall County, WV', 'Nash County, NC', 'Broome County, NY', 'Kootenai County, ID', 'Wells County, ND', 'Hardin County, KY', 'Dakota County, MN', 'Lumpkin County, GA', 'Ness County, KS', 'Newton County, TX', 'Lawrence County, OH', 'Cass County, NE', 'Limestone County, AL', 'Ulster County, NY', 'Delaware County, OH', 'Passaic County, NJ', 'Crisp County, GA', 'Garvin County, OK', 'Cook County, IL', 'St. Lucie County, FL', 'Douglas County, CO', 'Scioto County, OH', 'Stanton County, NE', 'Allen County, OH', 'Morris County, KS', 'Bibb County, GA', 'Berkeley County, SC', 'Okfuskee County, OK', 'Grant County, SD', 'Concho County, TX', 'Bottineau County, ND', 'Sarpy County, NE', 'Atascosa County, TX', 'Culberson County, TX', 'Johnson County, MO', 'Madison County, IN', 'Lemhi County, ID', 'Knox County, TN', 'Dodge County, GA', 'Goodhue County, MN', 'Midland County, MI', 'Champaign County, IL', 'Wichita County, KS', 'Granville County, NC', 'Madison County, IL', 'Middlesex County, CT', 'Marshall County, KS', 'Adams County, WI', 'Volusia County, FL', 'Des Moines County, IA', 'Weakley County, TN', 'Jefferson County, CO', 'Gallatin County, MT', 'Hill County, MT', 'Otter Tail County, MN', 'Larimer County, CO', 'Wakulla County, FL', 'Nelson County, KY', 'Muskegon County, MI', 'Florence County, WI', 'Lane County, OR', 'Chippewa County, WI', 'Cleveland County, NC', 'Westmoreland County, PA', 'Williamson County, IL', 'Lynchburg city County, VA', 'Vernon County, WI', 'Cascade County, MT', 'Oklahoma County, OK', 'Edgefield County, SC', 'Florence County, SC', 'Atkinson County, GA', 'Buffalo County, WI', 'Sangamon County, IL', 'Pottawatomie County, KS', 'Lowndes County, GA', 'Floyd County, GA', 'Wabasha County, MN', 'Benton County, IA', 'Buchanan County, IA', 'Columbia County, GA', 'Spalding County, GA', 'Solano County, CA', 'Darlington County, SC', 'Benton County, AR', 'Rockdale County, GA', 'Philadelphia County, PA', 'Madison County, GA', 'Coles County, IL', 'Schley County, GA', 'Gilliam County, OR', 'Madison County, NC', 'Fall River County, SD', 'Natrona County, WY', 'Marion County, IA', 'Carlton County, MN', 'Cheyenne County, KS', 'McDuffie County, GA', 'Barber County, KS', 'Butts County, GA', 'Lawrence County, SD', 'Vermilion County, IL', 'Platte County, WY', 'Marshall County, MN', 'Park County, WY', 'Jerauld County, SD', 'Lawrence County, TN', 'Columbia County, FL', 'Lavaca County, TX', 'Cherokee County, GA', 'Shelby County, IL', 'Presque Isle County, MI', 'Brown County, WI', 'Kiowa County, CO', 'Douglas County, NE', 'Roane County, TN', 'Hernando County, FL', 'Posey County, IN', 'Eau Claire County, WI', 'Houston County, GA', 'Travis County, TX', 'Walton County, FL', 'Andrew County, MO', 'Iowa County, WI', 'Brule County, SD', 'Terrell County, TX', 'Racine County, WI', 'Clay County, MN', 'Oconee County, GA', 'Pike County, IL', 'Montgomery County, TN', 'Barry County, MO', 'Wadena County, MN', 'Dane County, WI', 'Jasper County, IN', 'Orangeburg County, SC', 'Harper County, KS', 'St. Tammany County, LA', 'Clayton County, IA', 'Paulding County, OH', 'Sedgwick County, KS']
Community size: 165
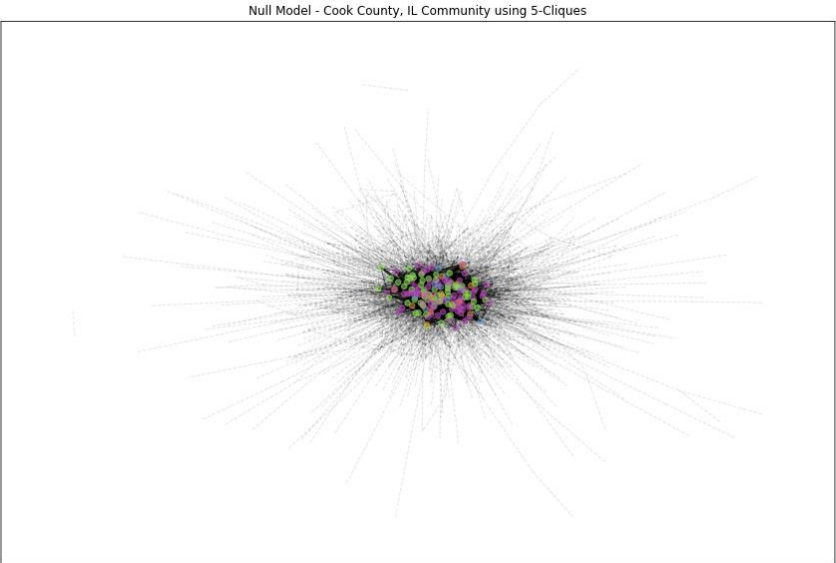
Conclusion

- Communities in the correlation network correspond to geographical regions
- Communities in the null model have no such relationship

- Communities in the correlation network have geographical proximity at a county level
- Communities in the null model do not

- There are fewer communities detected by both algorithms in the null model (GMM: 25 v 11, KC: 11 v 10)

Appendix - Correlation Network

Betweenness Centrality Distribution
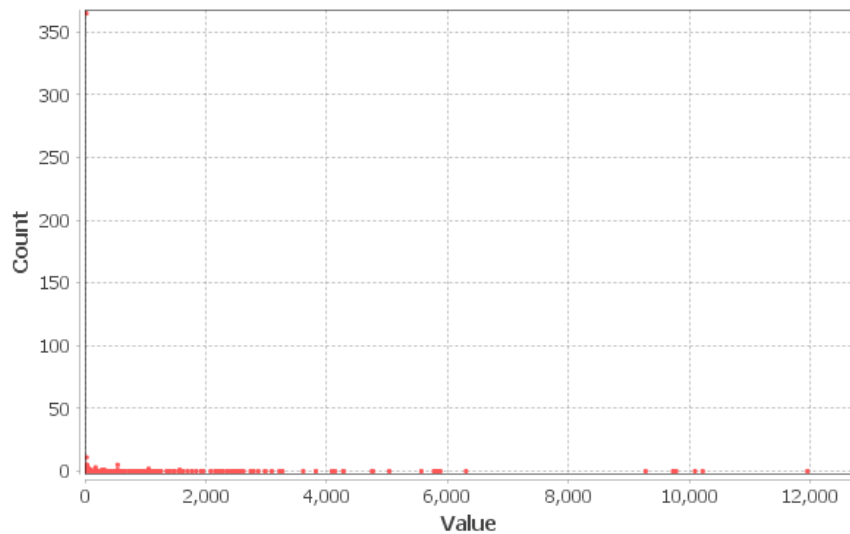
Clustering Coefficient Distribution
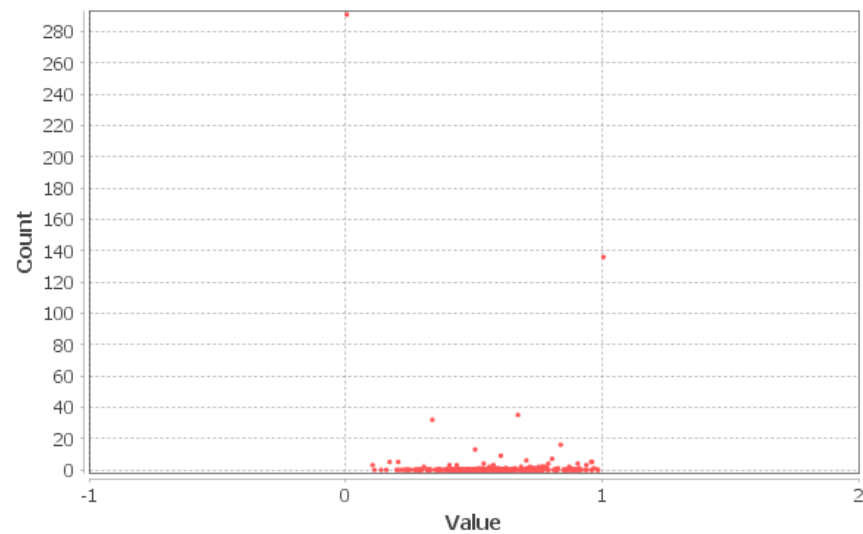
Appendix - Null Model

γ: 4.05

Avg. degree: 12.03 (11.98)
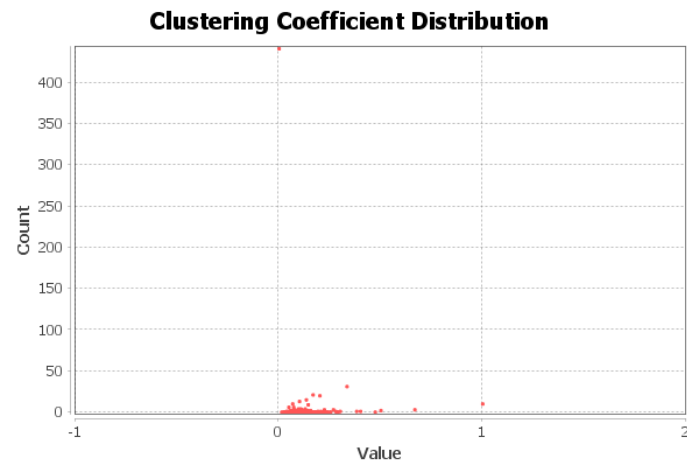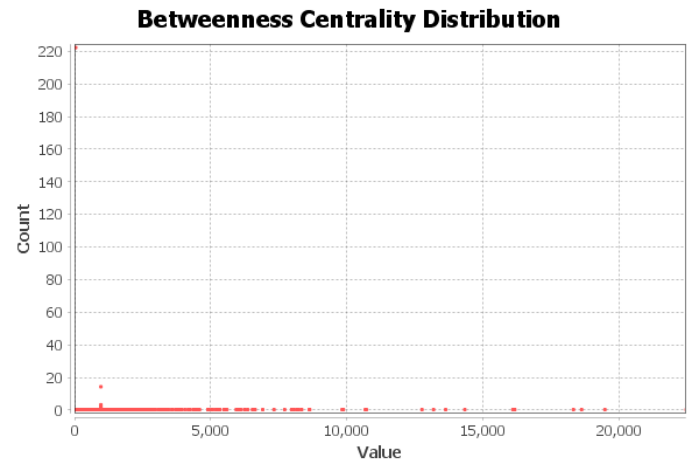Avg. weighted degree: 9.1 (9.52)

Density: 0.013

Avg. clustering coefficient: 0.115 (0.612)
Triangles: 7,911 (29,131)

Avg. path length: 3.17 (3.54)

Components: 3 (60)

[Correlation network stats from slide 10 in braces]

Betweenness Centrality Distribution

Clustering Coefficient Distribution

Thank You