3. Problem 2: Investigating a time-varying criminal network

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Analysis due Oct 27, 2021 17:29 IST Completed

In this problem, you will study a time-varying criminal network that is repeatedly disturbed by police forces. The data for this problem can be found in the `CAVIAR` directory of the data archive.

The CAVIAR investigation lasted two years and ran from 1994 to 1996. The operation brought together investigation units of the Montréal police and the Royal Canadian Mounted Police of Canada. During this two year period, 11 wiretap warrants, valid for a period of about two months each, were obtained (the 11 matrices contained in `phase1.csv`, `phase2.csv`, `...` correspond to these eleven, two month wiretap phases).

This case is interesting because, unlike other investigative strategies, the mandate of the CAVIAR project was to seize the drugs without arresting the perpetrators. During this period, imports of the trafficking network were hit by the police on eleven occasions. **The arrests took place only at the end of the investigation.** Monetary losses for traffickers were estimated at 32 million dollars. Eleven seizures took place throughout the investigation. **Some phases included no seizures, and others included multiple.** The following summarizes the 11 seizures:

Phase 4	1 seizure	$2,500,000	300 kg of marijuana
Phase 6	3 seizures	$1,300,000	2 x 15 kg of marijuana + 1 x 2 kg of cocaine
Phase 7	1 seizure	$3,500,000	401 kg of marijuana
Phase 8	1 seizure	$360,000	9 kg of cocaine
Phase 9	2 seizures	$4,300,000	2 kg of cocaine + 1 x 500 kg marijuana
Phase 10	1 seizure	$18,700,000	2200 kg of marijuana
Phase 11	2 seizures	$1,300,000	12 kg of cocaine + 11 kg of cocaine

This case offers a rare opportunity to study a criminal network in upheaval from police forces. This allows us to analyze changes in the network structure and to survey the reaction and adaptation of the participants while they were subjected to an increasing number of distressing constraints.

The network consists of 110 (numbered) players. Players 1-82 are the traffickers. Players 83-110 are the non-traffickers (financial investors; accountants; owners of various importation businesses, etc.). Initially, the investigation targeted Daniel Serero, the alleged mastermind of a drug network in downtown Montréal, who attempted to import marijuana to Canada from Morocco, transiting through Spain. After the first seizure, happening in Phase 4, traffickers reoriented to cocaine import from Colombia, transiting through the United States.

According to the police, the role of **23** of the players in the “Serero organization" are the following, listed by name (unique id):

- Daniel Serero (n1) : Mastermind of the network.
- Pierre Perlini (n3) : Principal lieutenant of Serero, he executes Serero's instructions.
- Alain (n83) and Gérard (n86) Levy : Investors and transporters of money.
- Wallace Lee (n85) : Takes care of financial affairs (accountant).
- Gaspard Lino (n6): Broker in Spain.
- Samir Rabbat (n11): Provider in Morocco.
- Lee Gilbert (n88): Trusted man of Wallace Lee (became an informer after the arrest).
- Beverly Ashton (n106): Spouse of Lino, transports money and documents.
- Antonio Iannacci (n89): Investor.

- Mohammed Echouafni (n84): Moroccan investor.
- Richard Gleeson (n5), Bruno de Quinzio (n8) and Gabrielle Casale (n76) : Charged with recuperating the marijuana.
- Roderik Janouska (n77): Individual with airport contacts.
- Patrick Lee (n87): Investor.
- Salvatore Panetta (n82): Transport arrangements manager.
- Steve Cunha (n96): Transport manager, owner of a legitimate import company (became an informer after the arrest).
- Ernesto Morales (n12): Principal organizer of the cocaine import, intermediary between the Colombians and the Serero organization.
- Oscar Nieri (n17): The handyman of Morales.
- Richard Brebner (n80): Was transporting the cocaine from the US to Montréal.
- Ricardo Negrinotti (n33): Was taking possession of the cocaine in the US to hand it to Brebner.
- Johnny Pacheco (n16): Cocaine provider.

In the data files (`phase1.csv`, `phase2.csv`, `...`), you will find matrices that report the number of wiretapped correspondences between the above players in the network, where players are identified by their unique id. You will be analyzing this time-varying network, giving a rough sketch of its shape, its evolution and the role of the actors in it.

*Paper:*https://www.researchgate.net/publication/292304919_Modeling_Verdict_Outcomes_Using_Social_Network_Measures_The_Watergate_and_Caviar_Network_Cases

You can also load this dataset directly from the internet (which is slightly more convenient when using Colab) using the following Python code:

```
import pandas as pd
import networkx as nx
phases = {}
G = {}
for i in range(1,12):
  var_name = "phase" + str(i)
  file_name = "https://raw.githubusercontent.com/ragini30/Networks-Homework/main/" + var_name +
".csv"
  phases[i] = pd.read_csv(file_name, index_col = ["players"])
  phases[i].columns = "n" + phases[i].columns
  phases[i].index = phases[i].columns
  phases[i][phases[i] > 0] = 1
  G[i] = nx.from_pandas_adjacency(phases[i])
  G[i].name = var_name
```

Note that this code also renames the actors from integer identifiers to strings of the kind “n1", “n2" etc, to be more consistent with notation. It then creates **networkx** graphs from the matrices and stores them in the `G` dictionary by their phase number.

The following questions will use undirected graphs derived from this data.

Part (a) Question 1

1.0/1.0 point (graded)

What is the size of the network at each phase? Plot the evolution of the number of node and number of edges over time, from phase 1 to 11.

Provide the number of nodes and edges for the three phases listed below:

Phase	Number of nodes	Number of edges
2	24 ✔ **Answer:** 24	28 ✔ **Answer:** 28
6	27 ✔ **Answer:** 27	47 ✔ **Answer:** 47
10	42 ✔ **Answer:** 42	50 ✔ **Answer:** 50

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Answers are displayed within the problem

Part (a) Question 2

2.0/2.0 points (graded)

Try visualizing the graph at each phase. For **networkx** you can use

```
nx.draw(g, pos=nx.drawing.nx_agraph.graphviz_layout(g), with_labels=True)
```

where the graphviz layout algorithm `graphviz_layout` has been used.

The graphviz algorithm is recommended for these complex graphs, and you will need it to answer some of these questions. You can install it on Ubuntu using

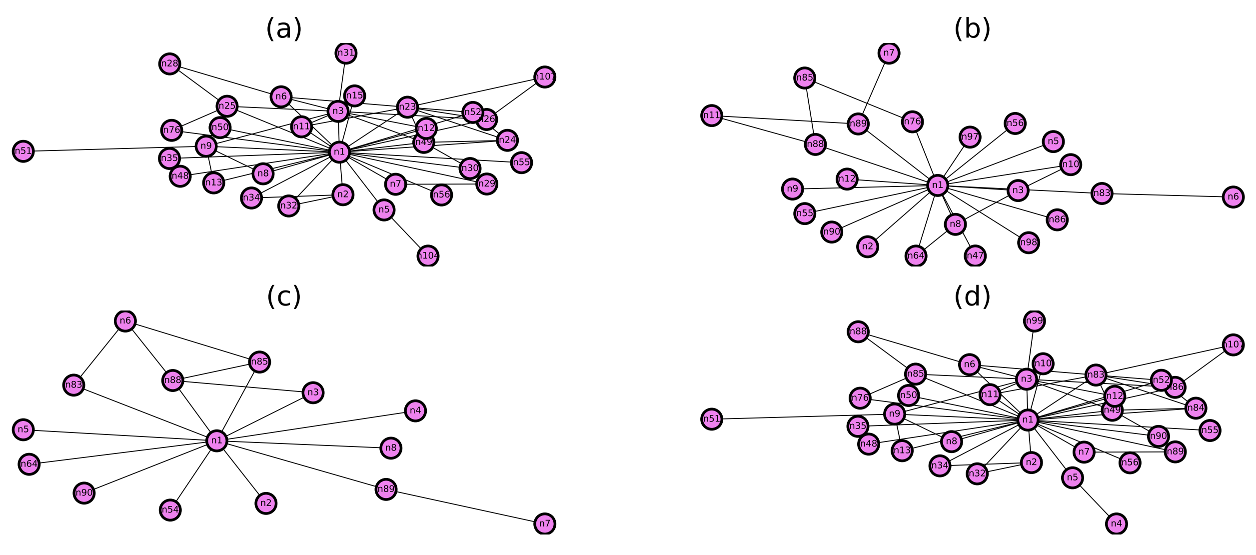
```
sudo apt-get install graphviz graphviz-dev
pip install pygraphviz
```

or you can install it on Google Colab by running the following in its own cell:

```
!apt-get install graphviz graphviz-dev
!pip install pygraphviz
```

For macOS and Windows, you can find instructions here.

Visualize the graph for **Phase 3**. Which of the following plots below correspond to **Phase 3**?



- (a)
- (b)
- (c)
- (d) ✔

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Part (b) Question 1

2.0/2.0 points (graded)

For each of the 11 phases and for each of the players under investigation **(i.e., the 23 listed above)** , compute and list the normalized degree centrality of the player.

The normalized degree centrality of node i is defined as

$$\tilde{k}_i = \frac{k_i}{n-1},$$

where k_i is the degree of node i and n is the number of nodes in the graph.

You can compute the normalized degree centrality using the **networkx** function `networkx.degree_centrality`.

Provide the degree centrality for the following four players, at the specified phases: (Provide your answer to **three significant figures**, answer graded to 1% tolerance.)

Player	Phase 3	Phase 9
n1	0.84375 ✔ **Answer:** 0.8438	0.30303030303030304 ✔ **Answer:** 0.3030
n3	0.28125 ✔ **Answer:** 0.2812	0.33333333333333337 ✔ **Answer:** 0.3333
n12	0.0625 ✔ **Answer:** 0.06250	0.24242424242424243 ✔ **Answer:** 0.2424
n83	0.25 ✔ **Answer:** 0.2500	0.030303030303030304 ✔ **Answer:** 0.03030

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Part (b) Question 2

2.0/2.0 points (graded)

For each of the 11 phases and for each of the players under investigation, compute and list the normalized betweenness centrality of the player.

For undirected graphs, the normalized betweenness centrality for node i is defined as

$$\tilde{B}_i = \frac{2}{(n-1)(n-2)} \sum_{s \neq i \neq t} \frac{n^i_{st}}{g_{st}},$$

where n^i_{st} is the number of shortest paths between s and t that pass through i and g_{st} is the total number of shortest paths between s and t. Note that this considers both orderings of each pair of nodes, so for undirected graphs, a path counts twice (as it counts both for n^i_{st} and for n^i_{ts}).

You can compute the normalized betweenness centrality using the **networkx** function `networkx.betweenness_centrality(graph, normalized = True)`

Provide the normalized betweenness centrality for the following four players, at the specified phases: (Provide your answer to **three significant figures**, answer graded to 1% tolerance.)

Player	Phase 3	Phase 9
n1	0.829502688172043 **Answer:** 0.8295	0.2490530303030303 **Answer:** 0.2490
n3	0.09549731182795697 **Answer:** 0.09550	0.5762310606060607 **Answer:** 0.5762
n12	0.0 **Answer:** 0.0000	0.3573232323232323 **Answer:** 0.3573
n83	0.046572580645161295 **Answer:** 0.04657	0.0 **Answer:** 0.0000

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Answers are displayed within the problem

Part (b) Question 3

2.0/2.0 points (graded)

For each of the 11 phases and for each of the players under investigation, compute and list the eigenvector centrality of the player.

Ensure your eigenvector centrality is normalized as

$$\sqrt{\sum_i v_i^2} = 1.$$

You can compute the eigenvector centrality with this normalization using the **networkx** function `networkx.eigenvector_centrality`.

Provide the eigenvector centrality for the following four players, at the specified phases: (Provide your answer to **three significant figures**, answer graded to 1% tolerance.)

Player	Phase 3	Phase 9
n1	0.5938791958045414 ✔ **Answer:** 0.5939	0.4589575176167988 ✔ **Answer:** 0.4590
n3	0.291304887672891 ✔ **Answer:** 0.2913	0.46798771473230655 ✔ **Answer:** 0.4680
n12	0.1359904690175954 ✔ **Answer:** 0.1360	0.14065936326685183 ✔ **Answer:** 0.1407
n83	0.27749730090075797 ✔ **Answer:** 0.2775	0.09178102356758049 ✔ **Answer:** 0.09178

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Answers are displayed within the problem

Part (b) Question 4

1.0/1.0 point (graded)

Recall the mathematical definition of each of these metrics, along with the algorithm that is best suited to compute it and the corresponding time complexity.

Which algorithm is the fastest for this data set?

- (●) Degree centrality
- ( ) Betweenness centrality
- ( ) Eigenvector centrality

✔

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Answers are displayed within the problem

Part (b) Question 5

3.0/3.0 points (graded)

The data from questions 1 to 3 can be used to perform different types of quantitative analyses. In this question we will look at performing one such analysis - we will determine the *temporal consistency* of a player's centrality , i.e. which players consistently remained active and central throughout most of the phases and which didn't?

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To answer this question, look at the temporal evolution of the networks and calculate the mean centrality for each of the centrality metrics, across all phases, for every player.

Note: As every actor might not be present in every phase, attach a centrality of zero (0) to an actor for the phases in which they are not present, *before* calculating these statistics, so that you take a mean over all 11 phases for all actors. (**Food for thought** , **not graded**: What are the implications of this step? What else could you do to ensure that your numbers are comparable with each other?)

For the betweenness centrality, which three players have the highest mean? (Enter an integer, eg: `1` for **n1**, `2` for **n2**, etc.)

Highest: 1 ✔ **Answer:** 1 2nd highest: 12 ✔ **Answer:** 12 3rd highest: 3 ✔ **Answer:** 3

For the eigenvector centrality, which three players have the highest mean? (Enter an integer, eg: `1` for **n1**, `2` for **n2**, etc.)

Highest: 1 ✔ **Answer:** 1 2nd highest: 3 ✔ **Answer:** 3 3rd highest: 85 ✔ **Answer:** 85

Submit You have used 1 of 3 attempts

Answers are displayed within the problem

Part (c): (2 points) Include your answer to this question in your written report. (∼100 words, 200 word limit.)

Observe the plot you made in Part (a) Question 1. The number of nodes increases sharply over the first few phases then levels out. Comment on what you think may be causing this effect. Based on your answer, should you adjust your conclusions in Part (b) Question 5?

Grading rubric:

Award one of the following:

- **(1 point)**: Gives a convincing reason for why the number of nodes increases sharply.
- **(2 points)**: Gives a convincing reason for why the number of nodes increases sharply, **and** recognizses that including the early phases in Part (b) Question 5 could bias the result.

Example solution:

Seizures did not start happening until phase 4, so police were likely using the wiretaps to grow the list of suspects during the early phases. For this reason, if players are not present in the early phases then it may be that police had not yet started wiretapping them. However, the police wiretap has no effect on the criminal enterprise, so this would bias their mean score downward. Hence, the early phases should be removed from the calculation in Part (b) Question 5.

Part (d): (5 points) Include your answer to this question in your written report. (∼300 words, 400 word limit.)

In the context of criminal networks, what would each of these metrics teach you about the importance of an actor's role in the traffic? In your own words, could you explain the limitations of degree centrality? In your opinion, which one would be most relevant to identify who is running the illegal activities of the group? Please justify.

Grading rubric:

Award each of the following according to whether the requirement is met:

- **(1 point)**: Provides an explanation of degree centrality **within the context of a criminal network.**
- **(1 point)**: Provides an explanation of betweenness centrality **within the context of a criminal network.**
- **(1 point)**: Provides an explanation of eigenvector centrality **within the context of a criminal network.**
- **(1 point)**: Based on these explanations, gives a convincing argument for why one of these metrics is the most relevant for the identification of who is running the illegal activities of the group.
- **(1 point)**: Additionally identifies a secondary metric, and provides a reason for using this secondary metric.

Example solution:

Degree centrality measures the number of players a person is connected to. In a hierarchical organization such as this, a person is likely receiving order from just one person, so the degree likely measures how many people they manage or give orders to. Although this seems like a good way to recognize a leader, it can run foul in certain situations. For example, the mastermind could act exclusively through their lieutenant, in which case they would have a degree of one and would rank low on this centrality. Or an important information courier may transmit information between only two or three people, and so may not rank very highly by this metric.

Betweenness centrality measures how vital a person is as a link in the network — i.e. it helps understand whose removal from the network could break the network apart. If a person scores high on this metric, they are likely to be a key link in the distribution of information in the criminal network and their absence could disrupt the illegal activities of the group.

Eigenvector centrality measures how important a person is based on the players that they are connected to. For example, an important advisor would not score highly on the previous two metrics, but as they are connected to an important leader, they will score well on the eigenvector centrality. We can see this in the results of Part (b) Question 5. n12 is ranked high in the betweenness centrality, while n85 takes their place in the eigenvector centrality. n85 is the enterprises accountant, and so they act as an important advisor. n12, on the other hand, is a leader in their own right, and serves as an important distributor of information.

The eigenvector centrality would be most likely to reveal the key players in the criminal network, as it can identify important advisors that may be turned, as well as leaders that hide behind a lieutenant. The betweenness centrality should still be used as a secondary metric, as it can reveal important avenues of information. If the betweenness centrality identifies a relatively unimportant player who acts only as an information carrier, they would make a good target for further surveillance.

Part (e): (3 points) Include your answer to this question in your written report. ($\sim$100 words, 200 word limit)

In real life, the police need to effectively use all the information they have gathered, to identify who is responsible for running the illegal activities of the group. Armed with a qualitative understanding of the centrality metrics from Part (d) and the quantitative analysis from part Part (b) Question 5, integrate and interpret the information you have to identify which players were most central (or important) to the operation.

Hint: Note that the definition of a player's "importance" (i.e. how central they are) can vary based on the question you are trying to answer. Begin by defining what makes a player important to the group (in your opinion) ; use your answers from Part (d) to identify which metric(s) are relevant based on your definition and *then*, use your quantitative analysis to identify the central and peripheral traffickers. You may also perform a different quantitative analysis, if your definition of importance requires it.

Grading rubric:

Award one of the following:

- **(1 point)**: Identifies that n1 and n3 are important without explanation.

- **(1 point)**: Identifies that n1 and n3 are important without explanation.
- **(2 points)**: Gives at least two actors, and provides a convincing reason for why they are important.
- **(3 points)**: Gives at least two actors, provides a convincing reason for why they are important, and uses the metrics from Part (d) to infer what kind of role these actors might have.

Example solution:

Central leaders: n1, n3 These actors rank highly on both the betweenness centrality and eigenvector centrality. They are likely part of the central leadership for the criminal operation.

Additional leaders: n12, n85, n76 n12 ranks highly on betweenness centrality, while n85 ranks highly on eigenvector centrality. This suggests that both have an important, but distinct role. n12 likely distributes orders and coordinates low-ranked subordinates for the operation, as n12's correspondingly lower eigenvector centrality suggests that they do not deal with important actors. The high eigenvector centrality but lower betweenness centrality of n85 suggests that they perform some kind of advisory or support role. n76 ranks fourth on both the betweenness and eigenvector centrality, so this actor might perform similar duties to n1 and n3 but to a limited extent.

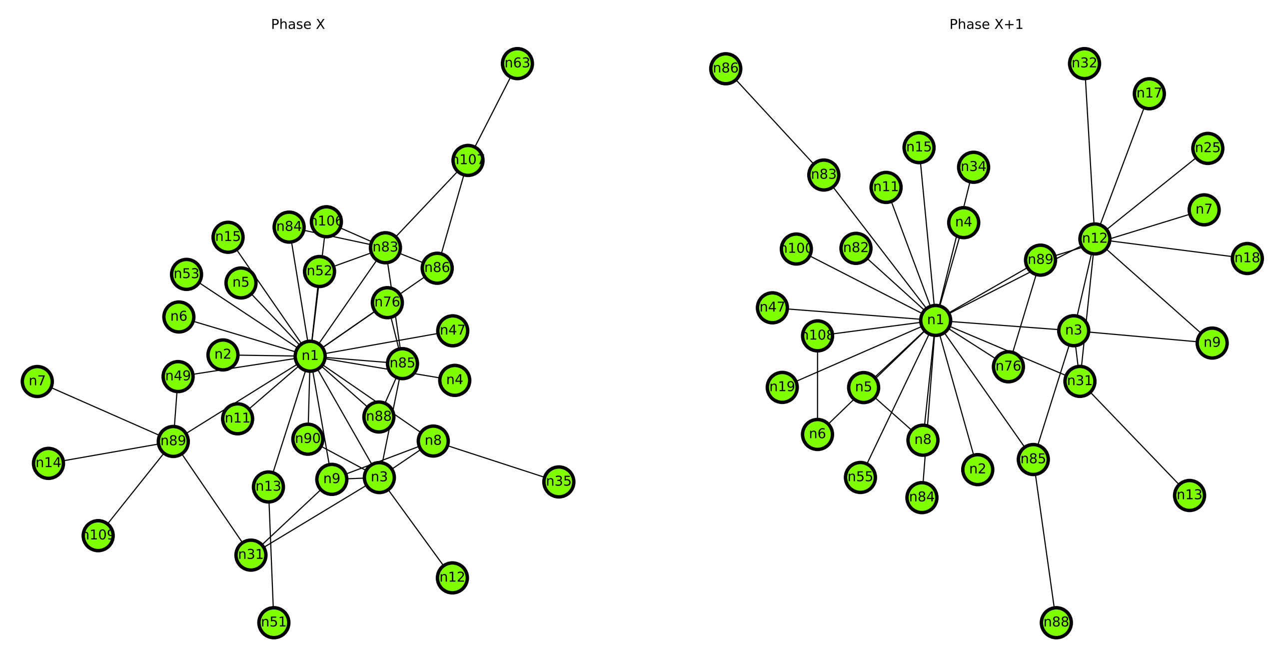
Additional observation: Later police records show that n85 is not a trafficker; however, the high degree of centrality would likely lead the police to investigate this actor regardless.

Part (f) Question 1

2.0/2.0 points (graded)

Now, we will attempt to analyze the overall evolution of the network and correlate the patterns we observe to events that happened during the investigation.

The plots below visualizes the criminal network for 2 consecutive phases Phase x and x+1. Identify x using your visualization in Part (a) Question 2.



$X =$ 4 ✔ **Answer:** 4

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Answers are displayed within the problem

Part (f) Question 2: (3 points) Include your answer to this question in your written report. (∼200 words, 300 word limit.)

The change in the network from Phase X to X+1 coincides with a major event that took place during the actual investigation. Identify the event and explain how the change in centrality rankings and visual patterns, observed in the network plots above, relates to said event.

Grading rubric:

Award each of the following according to whether the requirement is met:

- **(1 point)**: Identifies that the major event is the first police seizure.
- **(1 point)**: Uses the graph structure to infer a change in business operations: eg, diversification to cocaine.
- **(1 point)**: Uses the graph structure to infer a change in leadership operations: eg, organization becomes less heirarchical.

Example solution:

During phase 4, the first police seizure occured. We can assume that this is the first time that the criminal enterprise learned that they might be under police investigation. As such, we can expect that large changes would occur in the organization.

Indeed, we can see that n12 makes their first appearance in phase 5, and maintains their own group that is seperate from the main enterprise. The police later identified n12 as the main point of contact for the cocaine operation, so it appears that after the marijuana seizure in phase 4, the enterprise decided to diversify into another market. Somewhat interestingly, the betweenness centrality goes down for most actors between these phases, while the eigenvector centrality goes up. This suggests that the organization became less heirarchical overall. We can see from the visualization that, with the exception of n12, this is largely true as more actors are now directly connected to n1 — it seems that n1 may have become less trusting, and decided to take direct control of most operations after this shake-up.

Part (g): (4 points) Include your answer to this question in your written report. (∼200 words, 300 word limit.)

While centrality helps explain the evolution of every player's role individually, we need to explore the *global* trends and incidents in the story in order to understand the behavior of the criminal enterprise.

Describe the coarse pattern(s) you observe as the network evolves through the phases. Does the network evolution reflect the background story?

Hint: Look at the set of actors involved at each phase, and describe how the composition of the graph is changing. Investigate when important actors seem to change roles by their movement within the hierarchy. Correlate your observations with the information that the police provided in the setup to this homework problem.

Grading rubric:

Award each of the following according to whether the requirement is met:

- **(1 point)**: Observes the disconnection of n12 from the main enterprise, and comments on a potential reason.
- **(1 point)**: Observes a change in how n1 is connected to the enterprise, and comments on a potential reason.
- **(2 points)**: Provides an observation that is not one of the two above. Eg: change in connectivity of n3, how n37 enters and leaves the operation, the axis of control.

Example solution:

As discussed previously, from phase 4 onward significant evolution of the criminal network occurred. At phase 5, actor n12 gains a significant group of actors. n12 is the only point of contact for these actors, so it is clear, at this point, that n1 began delegating operations to n12. We can see, also, that during phase 7 and phase 10, n12 disconnects themselves from n1, likely to keep themselves sheltered from the main enterprise. Correlating this with the police activity, we can see that large seizures occurred during phase 6 and phase 9, both times before n12 disconnects.

Starting in phase 6, we can see that n3 begins gaining authority within the enterprise, as multiple actors are now connected principally to n3. In phase 7, n76 gains authority over three other actors. In phase 8, n87 gains authority over four actors. In phase 10, n37 is given authority over six actors.

By phase 11, it is clear that the police activity has caused n1 to switch from a totalitarian management style to a compartmentalized operation. Whereas, in phase 3, n1 was connected to nearly every actor in the group, in phase 11, n1 is connected to just a handful of actors. A clear axis of control emerges around n79, n76, n87, n41, and n12. n37 appears to have left the enterprise.

Part (h): (2 points) Include your answer to this question in your written report. (∼50 words, 100 word limit.)

Are there other actors that play an important role but are not on the list of investigation **(i.e., actors who are not among the 23 listed above)** ? List them, and explain why they are important.

Grading rubric:

Award one of the following:

- **(1 point)**: Identifies n37 or n41 but provides no explanation.
- **(2 points)**: Identifies an actor that is not on the list of 23, and gives a convincing explanation for why they are important.

Example solution:

n37 and n41 both take central roles in the last two phases of the operation, as discussed above. Their late entrance into the operation is a likely reason for why they evaded the police. Indeed, n37 drops out of the structure entirely in the last phase.

The remaining two questions will concern the directed graphs derived from the CAVIAR data.

Part (i): (2 points) Include your answer to this question in your written report. (∼150 words, 250 word limit.)

What are the advantages of looking at the directed version vs. undirected version of the criminal network?

Hint: If we were to study the directed version of the graph, instead of the undirected, what would you learn from comparing the in-degree and out-degree centralities of each actor? Similarly, what would you learn from the left- and right-eigenvector centralities, respectively?

Grading rubric:

Award one of the following:

- **(1 point)**: States that the directed graph gives more information without interpretation in the context of a criminal network.
- **(2 points)**: Explains what information incoming edges provide about a node, and what information outgoing edges provide about a node.

Example solution:

The directed graph gives strictly more information. For example, when an actor gains authority over other actors in the undirected graph, it is unclear what the relationship is. They could be giving orders to rank-and-file criminals, or they might be an investor acting as a front to collect funds from other investors.

Examining the flow of information more closely can assist in identifying unimportant actors, who will mostly receive information (and thus have high in-degree and low out-degree), from those who are distributing information and controlling the enterprise (who will likely have more balanced in and out-degree). Similar information can be gleaned from the eigenvector centralities. Unlike the degree measures, these centralities will also measure the importance of the actors feeding information into a player (through the left eigenvector), or the importance of the actors that the player is giving information to (the right eigenvector).

Part (j): (4 points) Include your answer to this question in your written report. (∼300 words, 400 word limit)

Recall the definition of hubs and authorities. Compute the hub and authority score of each actor, and for each phase. (**Remember** to load the adjacency data again this time using `create_using = nx.DiGraph()`.)

With **networkx** you can use the `nx.algorithms.link_analysis.hits` function, set `max_iter=1000000` for best results.

Using this, what relevant observations can you make on how the relationship between **n1** and **n3** evolves over the phases. Can you make comparisons to your results in Part (g)?

Optional: Also comment on what the hub and authority score can tell you about the actors you identified in Part (e).

Grading rubric:

Award each of the following according to whether the requirement is met:

- **(1 point)**: Identifies that the hub score for n3 is breifly larger than that for n1 during phases 6 and 7.
- **(1 point)**: Provides an interpretation for the observed trend of the hub score in terms of the roles of n1 and n3 in the organization.
- **(1 point)**: Identifies that n3 initially has a higher authority score than n1, but there is a reversal during phases 6 and 7.
- **(1 point)**: Provides an interpretation for the observed trend of the authority score in terms of the roles of n1 and n3 in the organization.

Example solution:

In the earliest phases, n1 has a very high hub score, and so appears to have been the major commander of the enterprise during the early days. This changes with phase 6 and 7, where the hub score for n1 decreases by two orders of magnitude. During this period, the hub score for n3 gains significantly, suggesting that n1 offloaded command duties to n3 during this period.

n1 briefly regains command duties with a large hub score during phase 8 and 9, but this drops off by many orders of magnitude going into phase 10. This confirms the observation in part (f) that n1 withdrew from a central role and the enterprise became more compartmentalized during this period.

Recall that the authority score is based on the strength of incoming links. During phases 1-5, n3 has a higher authority score than n1, suggesting that n3 took the main coordination role during this period. This is an interesting observation, as it is not apparent from the network structure observed in the undirected graph.

In phases 6 and 7, n1 gained a higher authority score than n3. It appears that n1 and n3 traded roles during this period. Phase 7 concluded with the largest police seizure to date, and so n1 and n3 likely concluded this role reversal was sub-optimal and returned to the previous arrangement during phases 8 and 9. In phases 10 and 11, both n1 and n3 appear to take a back-role, again reflecting the compartmentalization of the enterprise.

Additional, optional, observations: Of the other primary actors. We can observe that:

- n85 generally has a higher authority score than hub score, suggesting that they mainly receive information from others and act in a coordination/advising role. Indeed, the police records list n85 as the accountant.

- n76 generally has a slightly higher authority score than hub score, suggesting that they are taking orders from another more important player. Thus, although n76 was observed to be highly connected in Part (f), they play the role of a middle-manager. The police records show them to be managing the transport of marijuana.

- n12 generally has a slightly higher hub score than authority score, but the hub score is still lower than n1 or n3. Therefore we can conclude that n12, despite enjoying a large degree of independence in Part (f), is also a middle-manager but with more independence than n76. Police records show them to be both managing the transport of cocaine, but also liaising with the Colombians.

Optional ungraded questions. You do not need to answer these questions; instead, consider them on your own time.

- Would you consider that the particular strategy adopted by the police had an impact on the criminal network throughout the different phases of the investigation? What kind of impact?

- What would have happened if the police had arrested players that they had already identified, and this at each phase? Do you think they would have managed to arrest as many players as they did in the end? If you were responsible for the criminal investigation, what would have been your strategy?

- Would you say your strategy is ethical? Does it only involve the local police or does it require the help from other agents? What are the implications of your strategy in terms of international policing cooperation?

- Some ethical considerations around the potential side effects of your strategy could include the following: displacement of traffic and sudden increase of criminal activity/chaos in another geographical area (locally, country-wide, or internationally), responsibility of a detective/investigator towards the unrest/chaos he/she can create in another community etc.

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left-eigenvector centrality?

question posted 2 months ago by anonymous

"You are as important as the ones point towards you", right?

and it is calculated A_t * A ?

Thanks!

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