YOUR NAME HERE

Complex Systems 270

Fall 2023

Lab 5, Part I: Conceptual Questions, Networks by Hand

1. Leaving the Grid Behind, Part II (15 points)
   Review your answer to Lab 4, Problem 5. In this problem, you will continue to work on and refine the idea that you came up with there, for a **free-motion model** (a conceptual question about a network-based model is coming next week, in Lab 6). If you want to switch topics, that's also fine. Remember that you may come back to these ideas when it comes time to start your final project.

   Now that you've gone back and jogged your memory, do the following:
   - Briefly summarize your chosen topic and your answer from Lab 4, Problem 5. You just need two to three short sentences here, unless you've decided to switch topics.
   - How is your world initialized? In other words, what does your model look like before it starts running? How are relevant characteristics of agents and the environment represented?
   - In plain, precise language, write down the rules that your model would follow. How do the agents move about and update in each timestep?
   - Come up with some parameters in your model that you could change to conduct an experiment.
   - Describe the experiment you would conduct by altering these parameters. Your experiment can be similar or different to the one you conducted in Lab 4, Problem 4.
   - Do you expect your model to oscillate, settle to a fixed state, or would it depend on parameters?

YOUR ANSWER HERE

The chosen topic focused on the migration patterns of several different agents such as zebras, elephants, and gazelles. Energy levels, temperature or weather variations, and predator threats all have an impact on migration speed and directions.

The model is initialized with several herds of agents including zebras, elephants, and gazelles, each at a random geographic location. Every animal has a heading vector pointing in the direction of its common migratory destination and a starting energy level. Environmental elements such as weather, topography, and predatory zones are also included on the global map.

Here are some rules that my model would follow. Each agent will move in the direction of its breeding grounds with some random variations at each timestamp. Agent's energy levels will decrease as they move. If the energy level reaches zero, they will stop and rest. After this, the energy level returns to its starting point. Agents tend to avoid severe weather conditions such as thunderstorms, and blizzards. When they encounter snow or rain, they will slow down their moving speed. They might also change their path to stay clear of predator zones. We could give each predator agent a random likelihood of attacking animals. The animal being attacked will decrease its energy, and its population will decline as well. Besides, to better protect themselves from predators, we can add a group movement to make the same herd of agents stay close to their own herd. Upon reaching their migration destination, they will stop moving.

Some parameters in my model that I could change to conduct an experiment:

a. The migratory direction and speed at different timestamps

   By default. the migratory direction of each herd is pointing toward its breeding grounds. However, factors such as predatory threats and weather conditions can vary the direction of a group. Based on the rules, the moving velocity decreases when they encounter bad weather conditions such as rain or snow. Thus, we should also include the speed as a parameter to see how that affects the migration route.

b. Predatory zones of each agent

   We might include predator agents and assign each of them varying probabilities of attacking animals. The energy level of the animal being attacked will decrease. The number of that animal will also be reduced randomly.

c. The energy level of each animal

   We can set the default energy value of different agents to higher or lower levels and observe how that affects their ability to move toward their destination.

d. Weather conditions in different locations

   We may change the weather to rain, snow, thunderstorm, or blizzard on the map and observe how the patterns change.

Here is the description of a experiment I could conduct by altering these parameters.

I would set different default energy levels of different animal agents. Some animals may start with higher energy level than others. For example, elephant will have higher initial energy level (70%) than that of zebras (40%) and gazelles (30%). The moving speed of the gazelles (50 mph) will be higher than that of zebras (30 mph) and elephant (25 mph). By introducing predators with varying predation chance and adjusting the extent of the predatory zones, we can run our experiment to better explore how the presence of predators impacts the directions and migration patterns, including the number of animals able to complete the migration under certain scenarios. By modifying the initial energy levels of different animals, we can investigates the effect of initial energy levels on the ability of animals to reach the destination. After the herds arrive at their destination, they will stop moving and at this time, we should output the animal's name with the number of that animal remaining.

We would then run simulations with distinct circumstances including high predation threat probability with low default energy, high predation threat probability with normal default energy, and normal predation threat probability with low default energy, etc.

Similar to lab 4, problem 4, we can implement the code to runs our model many times for each parameter combination and it is important to repeat our experiments multiple times to be sure that our results hold.

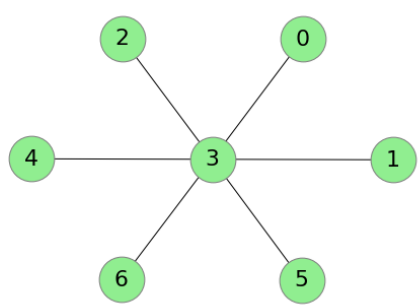
Given the circumstances, I expect that our model would also depend on some other conditions such as weather and temperature which likely oscillate seasonally in the map. But parameters of predation source and energy level are more likely to reduce populations of herds to lower levels that migration patterns completely collapse into a fixed failed state.

I expect my model to behave differently depending on different parameters.

Under normal cirsunstances (e.g. normal predation probability and normal energy level), we expect that the oscillatory behavior would be more common as animals population complete seasonal migration cycles every year. We believe that both the increased predation and the reduced energy would lower migration success, but the combination of both effects would have a stronger impact. With extreme parameter values such as extremely high predation probability or extremely low starting energy, the populations of animal agents might collapse to zero, causing the model to settle to a fixed state.

In addition, factors including likelihood of predation and energy levels may affect the amplitude and the offset of seasonal oscillation cycles. The model's behavior is thus expected to be dependent on the interactions and dynamics between these parameters.

2. You're a Shining Star, No Matter Who You Are (10 points)
   Given the network visualization, answer the following:



   a. (1 point) Look back at the "Major Network Types" discussed in Lecture 9. Does this network match one of the types? If so, which one?

Yes. This network matches the star network because there is one "hub" node 3 and all others are connected only to it.

b. (1 point) Is this network directed or undirected?

This network is undirected.

c. (1 point) How many nodes are in this network? How many edges?

There are 7 nodes and 6 edges in this network.

d. (1 point) Find the degree for each of the nodes: 0, 1, 2, 3, 4, 5 and 6. Fill out the table below.

Node	**Degree**
0	1
1	1
2	1
3	6
4	1
5	1
6	1

e. (2 points) Using the table below, construct an adjacency matrix for the network. The Node 0 column is completed for you.

	Node 0	**Node 1**	**Node 2**	**Node 3**	**Node 4**	**Node 5**	**Node 6**
Node 0	0	0	0	1	0	0	0
Node 1	0	0	0	1	0	0	0
Node 2	0	0	0	1	0	0	0
Node 3	1	1	1	0	1	1	1
Node 4	0	0	0	1	0	0	0
Node 5	0	0	0	1	0	0	0
Node 6	0	0	0	1	0	0	0

f. (1 point) What is the shortest path between nodes 0 and 4? Make sure to specify all of the steps along the way.

The shortest path between nodes 0 and 4 is node 0 -> node 3 -> node 4. Starting at node 0, we can move to node 3 as there is an edge connecting 0 and 3. From node 3, we can move to node 4 since there's also an edge connecting 3 and 4.

g. (1 point) How long is the longest shortest path in the network (Lecture 9, Slide 12)? Which node is on all of the shortest paths?

The longest shortest path in the network is 2. Node 3 is on all of the shortest paths.

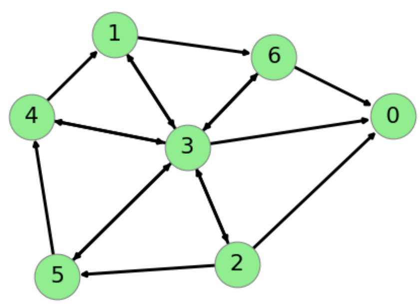
h. (1 point) Calculate the clustering coefficient (Lecture 9, Slide 13) of node 0. Then do the same for node 3.

The clustering coefficient of node 0 is 0. The clustering coefficient of node 3 is 0.

i. (1 point) How many connected components (Lecture 9, Slide 13) are in this network?

The number of connected components in this network is 1.

3. The game isn't over 'till the clock says zero (9 points)
Given the network visualization, answer the following:



a. (1 point) Is this network directed or undirected?

This network is directed.

b. (1 point) How many nodes are in this network? How many edges? If the network is directed, count every outgoing connection as an edge.

There are 7 nodes and 16 edges in this network.

c. (1 point) Find the out-degree and in-degree for each of the nodes: 0, 1, 2, 3, 4, 5 and 6. Fill out the table below.

Node	**Out-Degree**	**In-Degree**
0	0	3
1	2	2
2	3	1
3	6	5

4	2	2
5	2	2
6	2	2

d. (2 points) Using the table below, construct an adjacency matrix for the network. The Node 0 column is completed for you. Recall that columns represent incoming connections and rows represent outgoing connections.

	Node 0	**Node 1**	**Node 2**	**Node 3**	**Node 4**	**Node 5**	**Node 6**
Node 0	0	0	0	0	0	0	0
Node 1	0	0	0	1	0	0	1
Node 2	1	0	0	1	0	1	0
Node 3	1	1	1	0	1	1	1
Node 4	0	1	0	1	0	0	0
Node 5	0	0	0	1	1	0	0
Node 6	1	0	0	1	0	0	0

e. (2 points) What is the shortest path between nodes 4 and 5? How about between 5 and 4? 4 and 0? 0 and 4? Make sure to specify all of the steps along the way.

The shortest path between nodes 4 and 5 is node 4 -> node 3 -> node 5. Starting at node 4, we can move to node 3 as there is a direct edge from 4 to 3. From node 3, we can move to node 5 since there's also a direct edge from 3 to 5.

The shortest path between nodes 5 and 4 is node 5 -> node 4. Starting at node 4, we can move to node 5 as there is a direct edge from 4 to 5.

The shortest path between nodes 4 and 0 is node 4 -> node 3 -> node 0. Starting at node 4, we can move to node 3 as there is a direct edge from 4 to 3. From node 3, we can move to node 0 since there's also a direct edge from 3 to 0.

There is no shortest path between nodes 0 and 4 since the outdegree of node 0 is 0.

f. (2 points) How long is the longest shortest path in the network (Lecture 9, Slide 12)?

The longest shortest path in the network is not defined since there is no directed path between every pair of nodes. For example, there is no shortest path between 0 and 4. Thus, the diameter in this graph is not defined.

4. Centrality (4 points)
   Using the real-world scenarios below, explain the difference between degree centrality, closeness centrality, and betweenness centrality (Lecture 9, Slide 14). Rather than just telling me how to calculate these metrics, I want you to consider the intuitive concepts that they're designed to measure.

   Use these scenarios to help guide your answer:

   - You're trying to spread an embarrassing rumor about your arch-nemesis through a social network. You can choose one person to start the rumor. What type of centrality should your person of choice have to ensure that the rumor spreads to everyone in the network as quickly as possible?
   - In international shipping networks, the Panama and Suez canals are present on many critical trade routes. What type of centrality do these canals have?
   - For the last type of centrality, come up with a scenario on your own in which you think this measure would be of significant import.

YOUR ANSWER HERE

Degree centrality of a node is simply the number of edges it has in a network. Nodes with higher degree centrality are connected to more nodes directly. In the first scenario of a social network, if we want to use the social network to spread rumors about our arch-nemesis as quickly as possible, we can consider choosing the person with the highest degree centrality since this person has the most direct connections to others. A higher degree centrality indicates a greater immediate influence of a node. In this context, picking the person with the highest degree centrality can be useful at first.

Closeness centrality measures how close and reachable a node is to all other nodes in a network. It is a good metric for detecting nodes that are able to spread information efficiently through a graph. In the first scenario, we can consider choosing the person with the highest closeness centrality because this person can connect to other individuals in this network with the fewest steps on average. As a result, this person can propagate the rumors to all parts of the network quickly. The closeness centrality tells us how effectively a node connects to other nodes and would be a better choice compared to degree centrality for the first scenario.

Betweenness centrality describes how often a node functions as a link between other nodes. It is a great method to detect the amount of influence a node has over the flow of information in a network. Considering the second scenario that Panama and Suez canals are present on many critical trade routes in international shipping networks, we observe that these two canals have high betweenness centrality due to their locations, which also guarantees that a large part of trading routes pass through them.

In the first scenario, we should choose the person with the highest closeness centrality to ensure that the rumor spreads to everyone in the network as quickly as possible. In the second scenario, these canals have higher betweenness centrality. For the last type of centrality (degree centrality), we can think about the case when we need to predict the spread of a disease. In this context, degree centrality represents the number of direct connections each individual has. A person with more direct connections would be more likely to spread a contagious disease. By finding nodes with a high degree centrality, public health authorities can better prioritize disease controls and epidemic monitoring measures.