Spread Across Networks

ModSim 23-24 Project 2

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RESEARCH QUESTION:

How does class size influence disease spread within a student population?

RESEARCH

Background Information + References

- Post-COVID-19, schools have aimed to comprehend **disease transmission within classrooms** *(Hekmati)*.
- **Limited research** is done on infectious disease behavior and effective prevention strategies *(COVID-19 Working Group)*.
- Existing information is often based on **assumptions**, potentially leading to biased results *(COVID-19 Working Group)*.

OBJECTIVE:

Understand the impact of class sizes on disease spread and implement effective preventive measures to control outbreaks in school environments.

METHODOLOGY

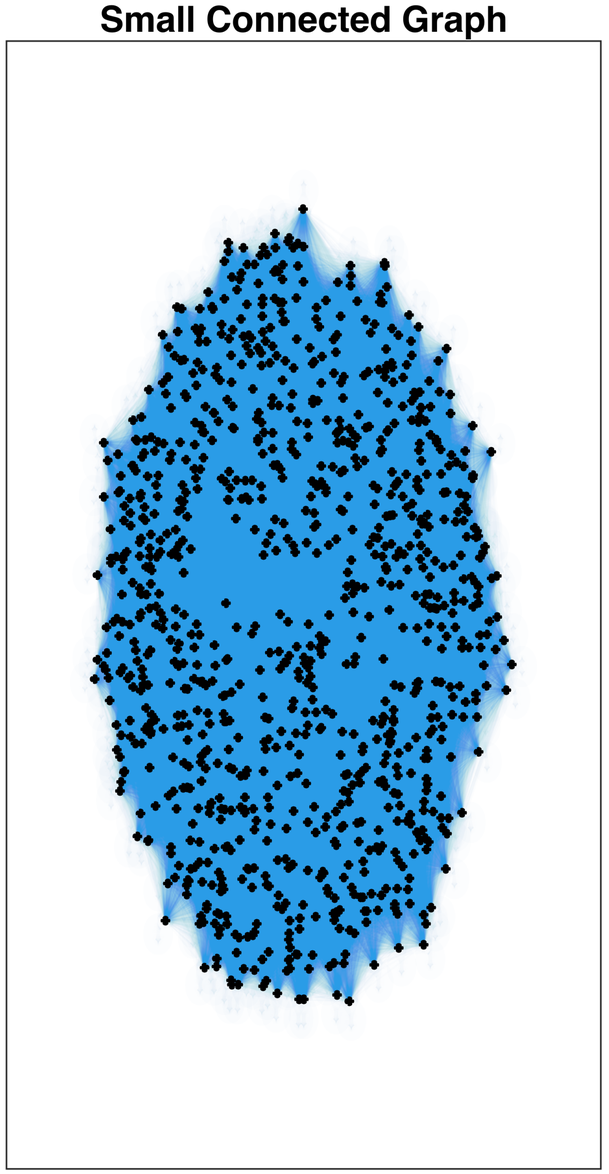
Modeling Classes and Population

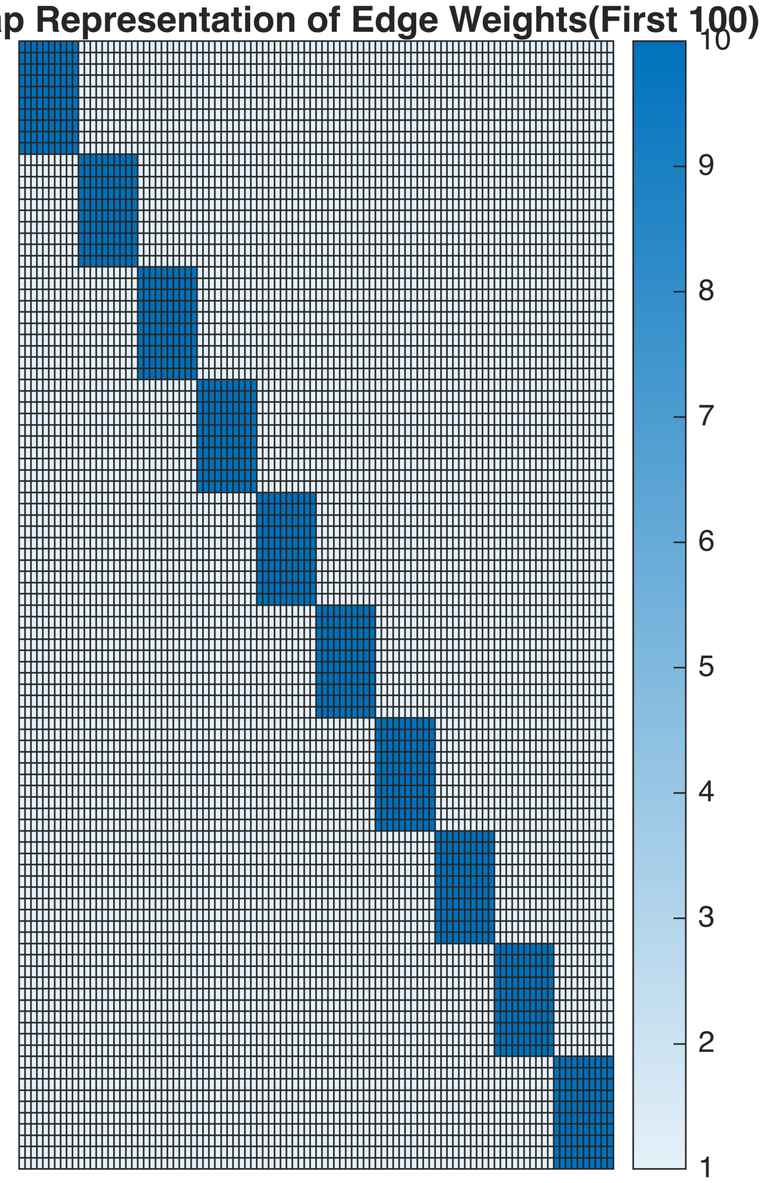
- Utilized the SIR agent-based model from worksheet four.
- Adopted a **"leaky pod"** agent-based model to represent classes as pods.
- The strength of connections within pods based on class size, represented as class size/total population ratio.
- Designed as a **complete graph** with relatively weak interconnections.

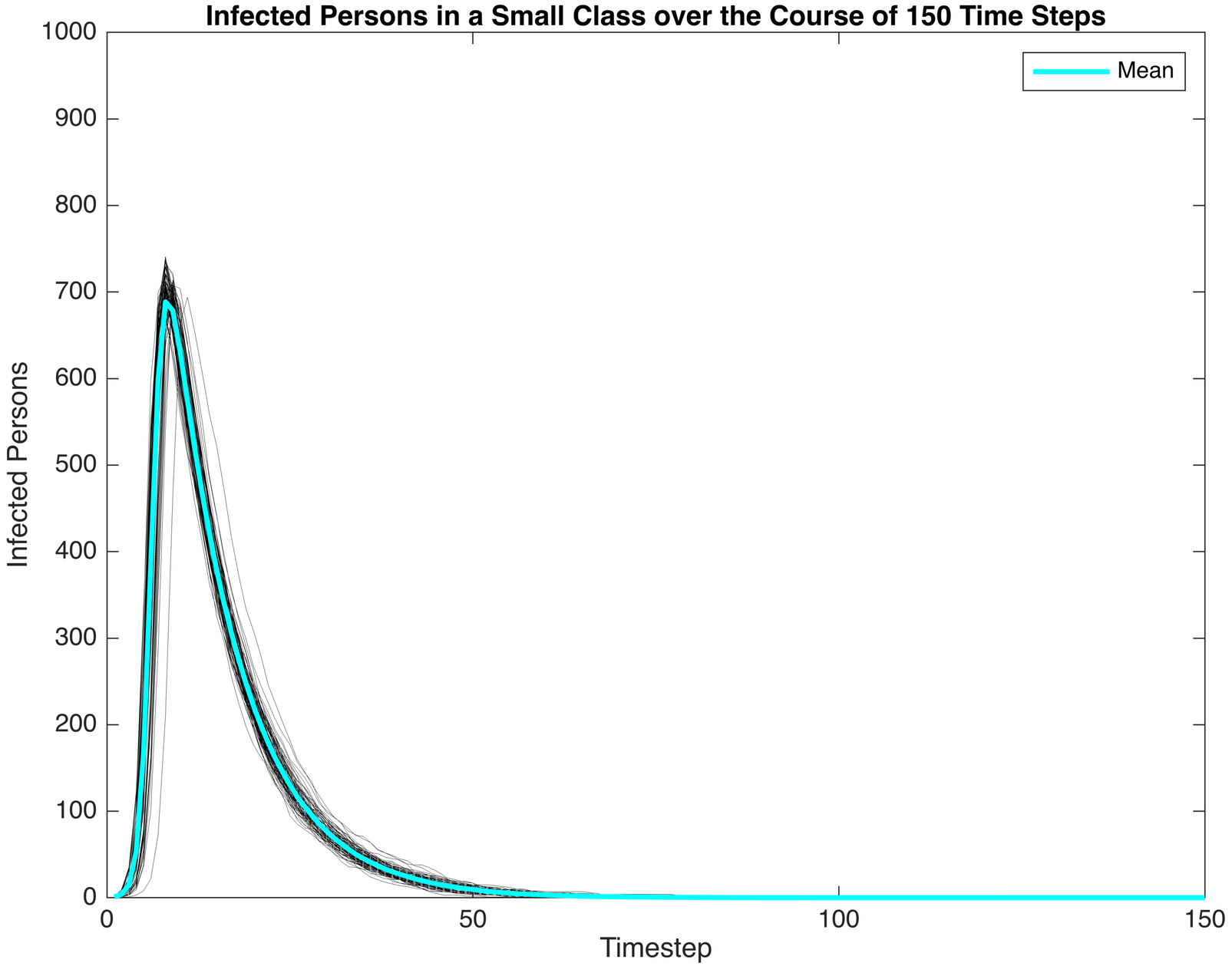
METHODOLOGY

Assumptions

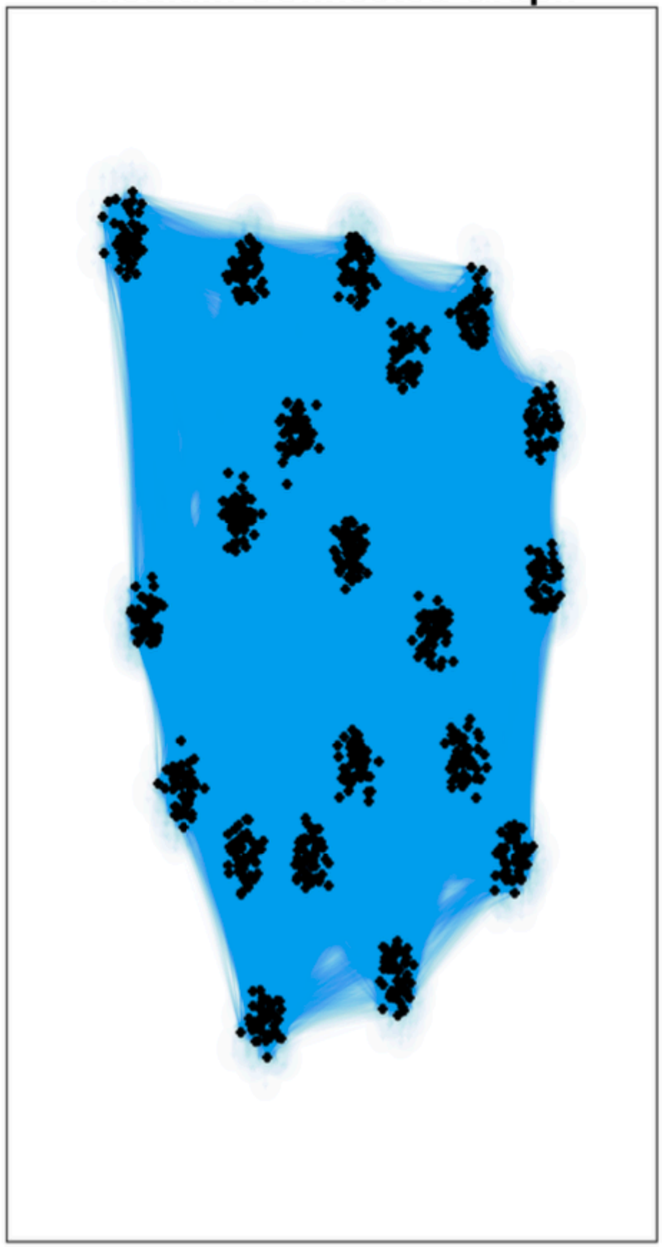
- Smaller class sizes promote stronger connections due to **interactive teaching styles**.
- **Complete interconnectedness** —> might not hold in larger colleges.
- **Equal connectivity** is assumed within each class.
- **Class sizes are assumed to be the same** for all classes —> real-life class sizes vary by student year.
- Small class = 10, Medium class = 50, Large class = 100.
- Total population = 1000.


Small Connected Graph

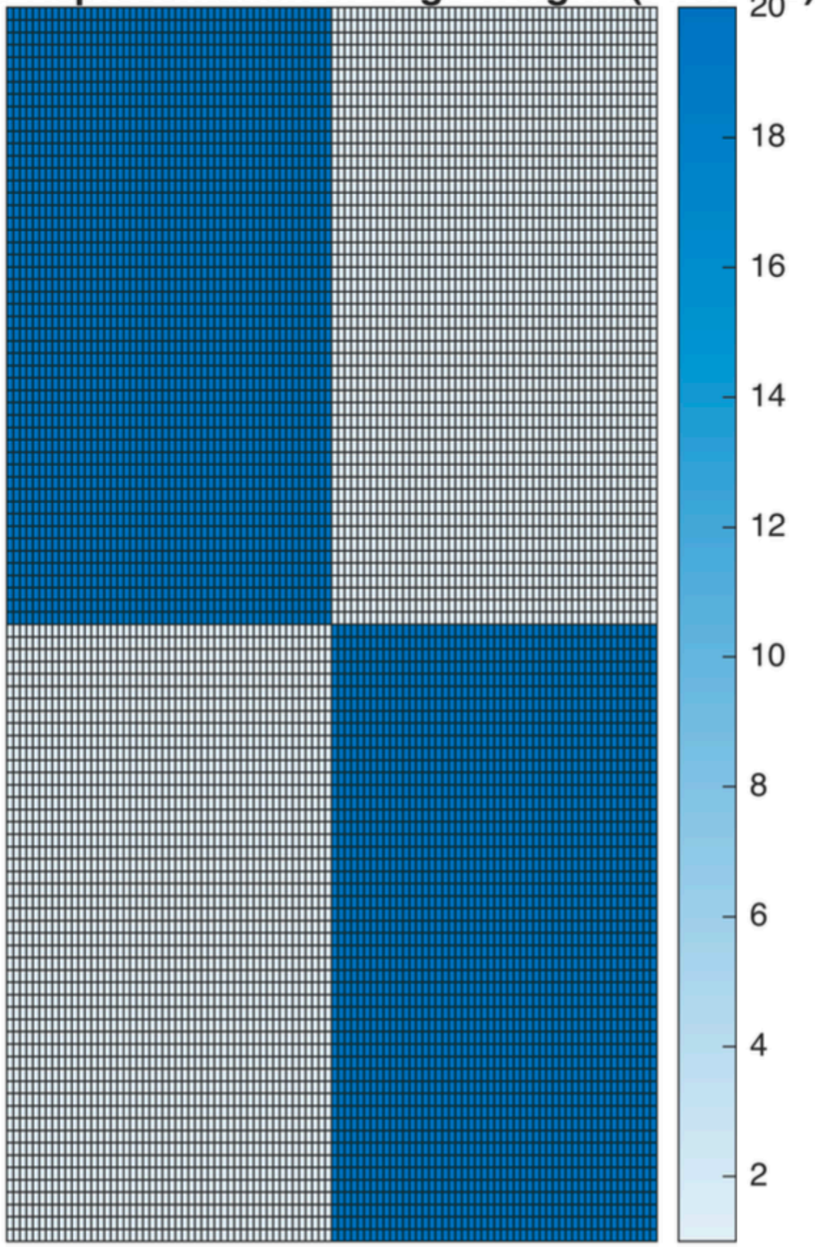

Heatmap Representation of Edge Weights(First 100)
10
9
8
7
6
5
4
3
2
1

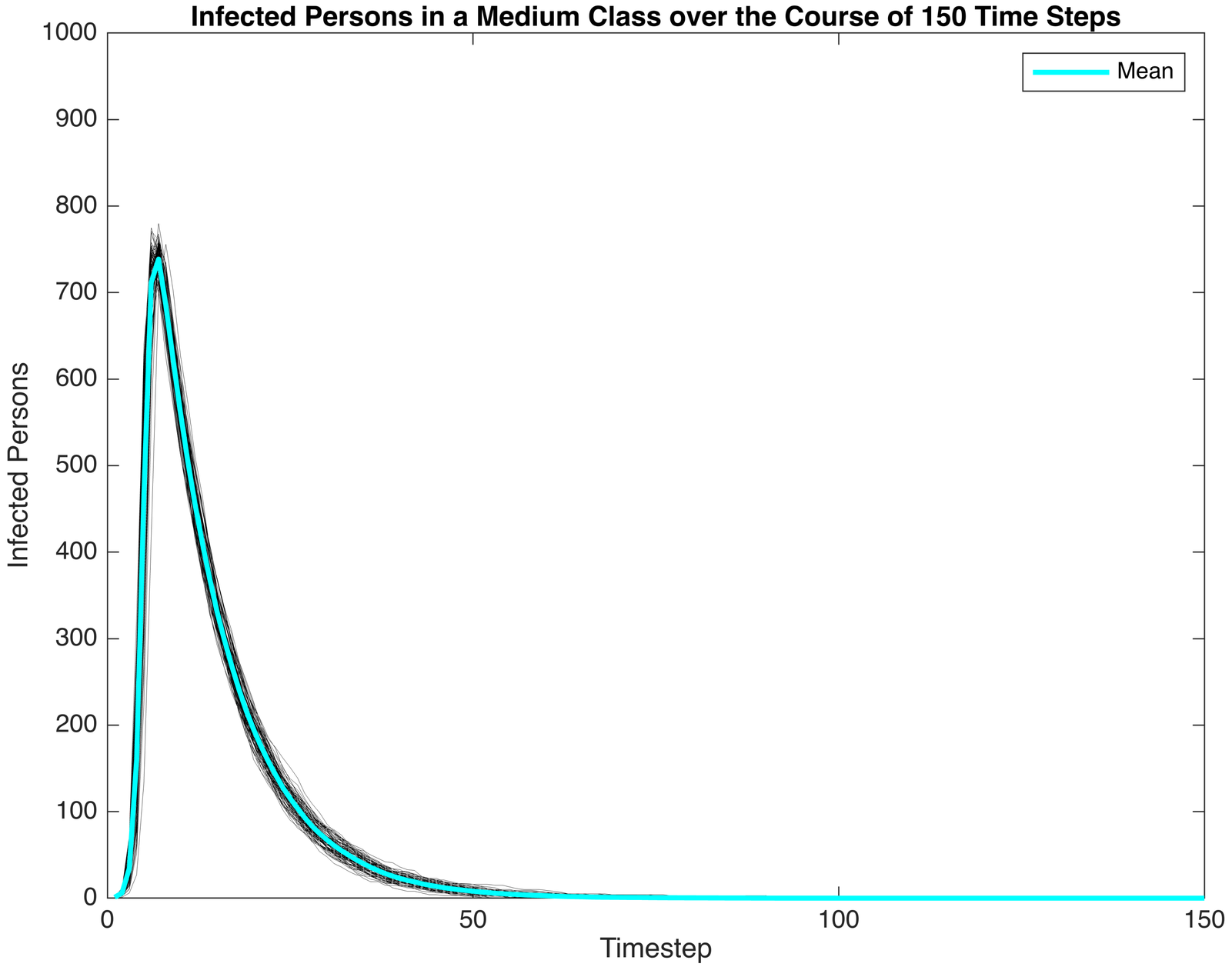

Infected Persons in a Small Class over the Course of 150 Time Steps
Mean
Infected Persons
Timestep
0
100
200
300
400
500
600
700
800
900
1000
0
50
100
150

Medium Connected Graph

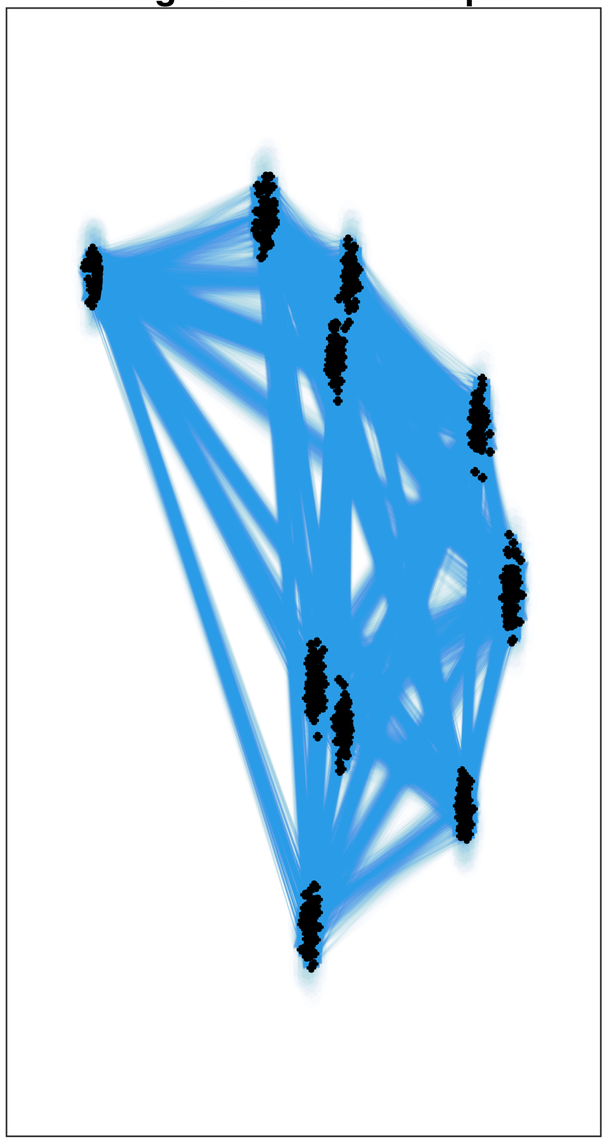


Heatmap Representation of Edge Weights(First 100)

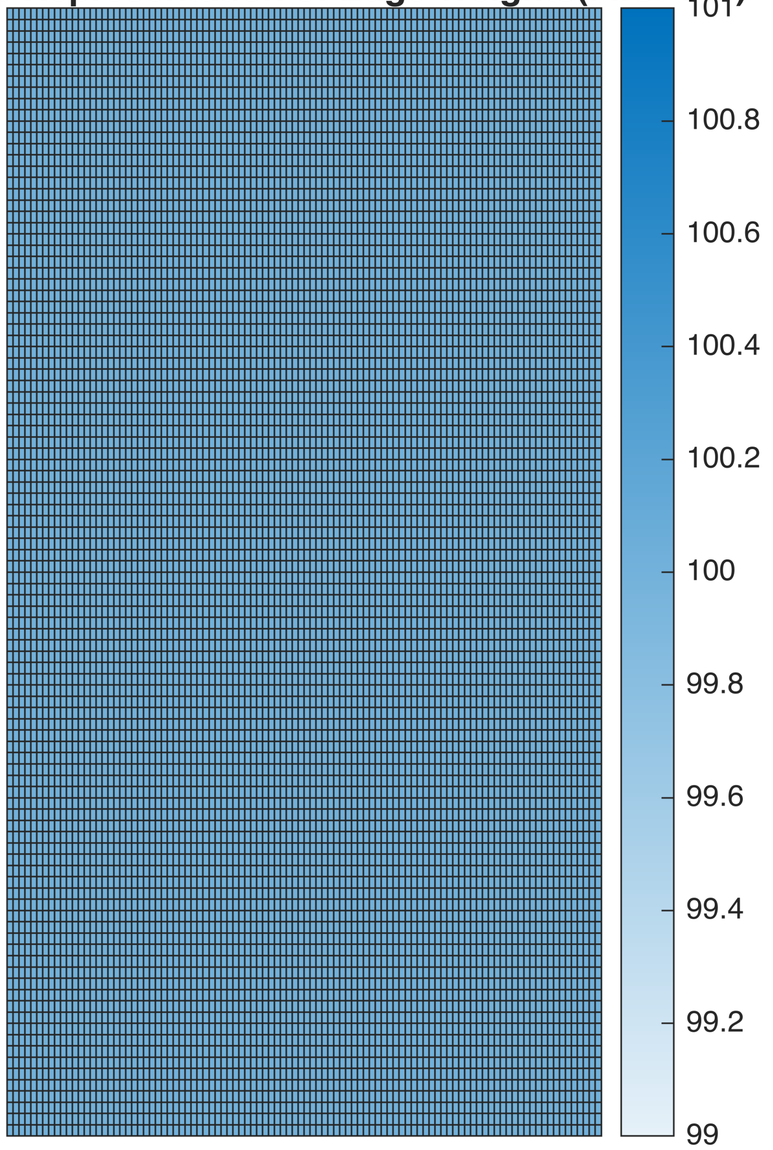


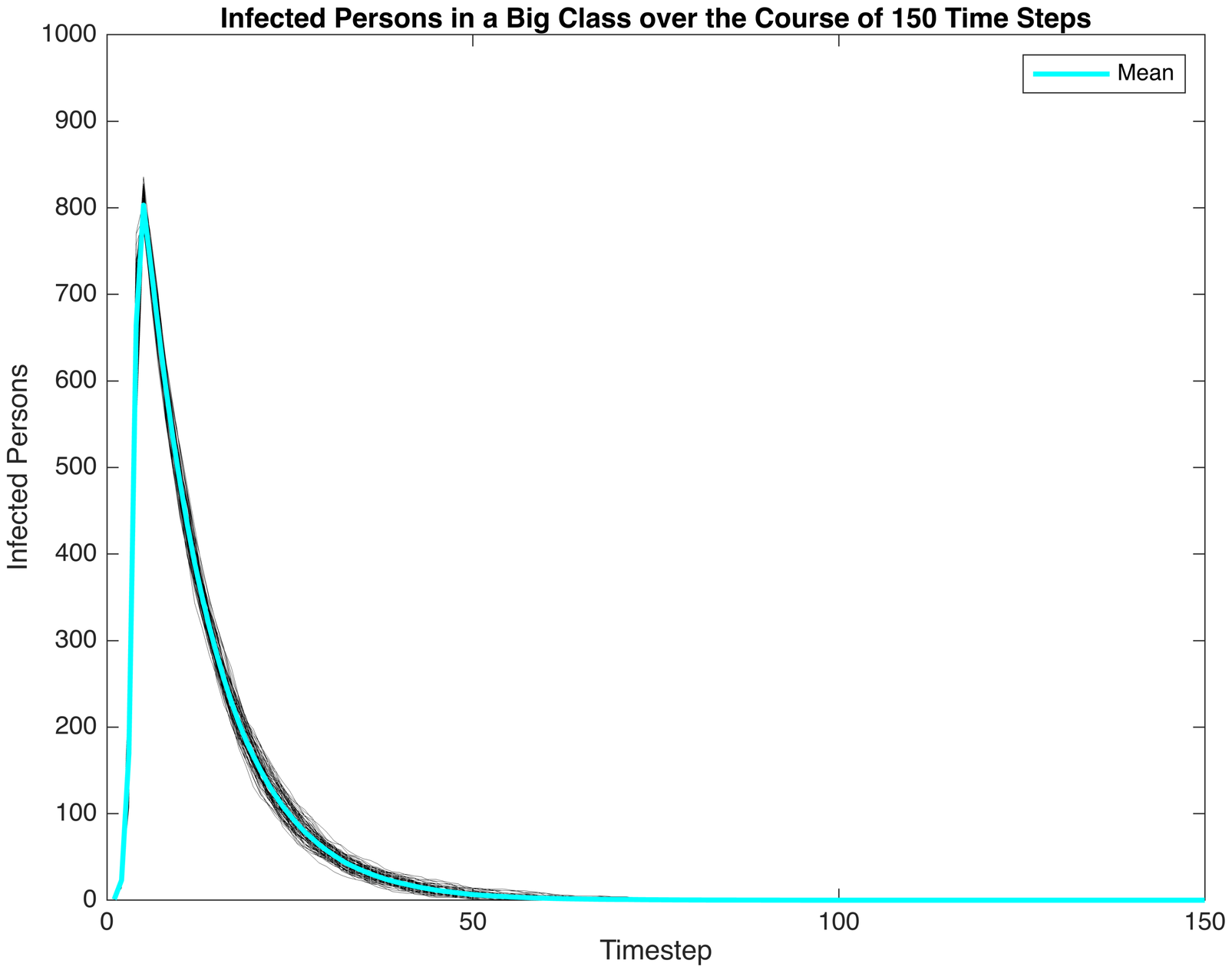

Infected Persons in a Medium Class over the Course of 150 Time Steps
Mean
Infected Persons
Timestep
0
100
200
300
400
500
600
700
800
900
1000
0
50
100
150

Large Connected Graph



Heatmap Representation of Edge Weights(First 100)




Infected Persons in a Big Class over the Course of 150 Time Steps
Mean
Infected Persons
Timestep
0
100
200
300
400
500
600
700
800
900
1000
0
50
100
150

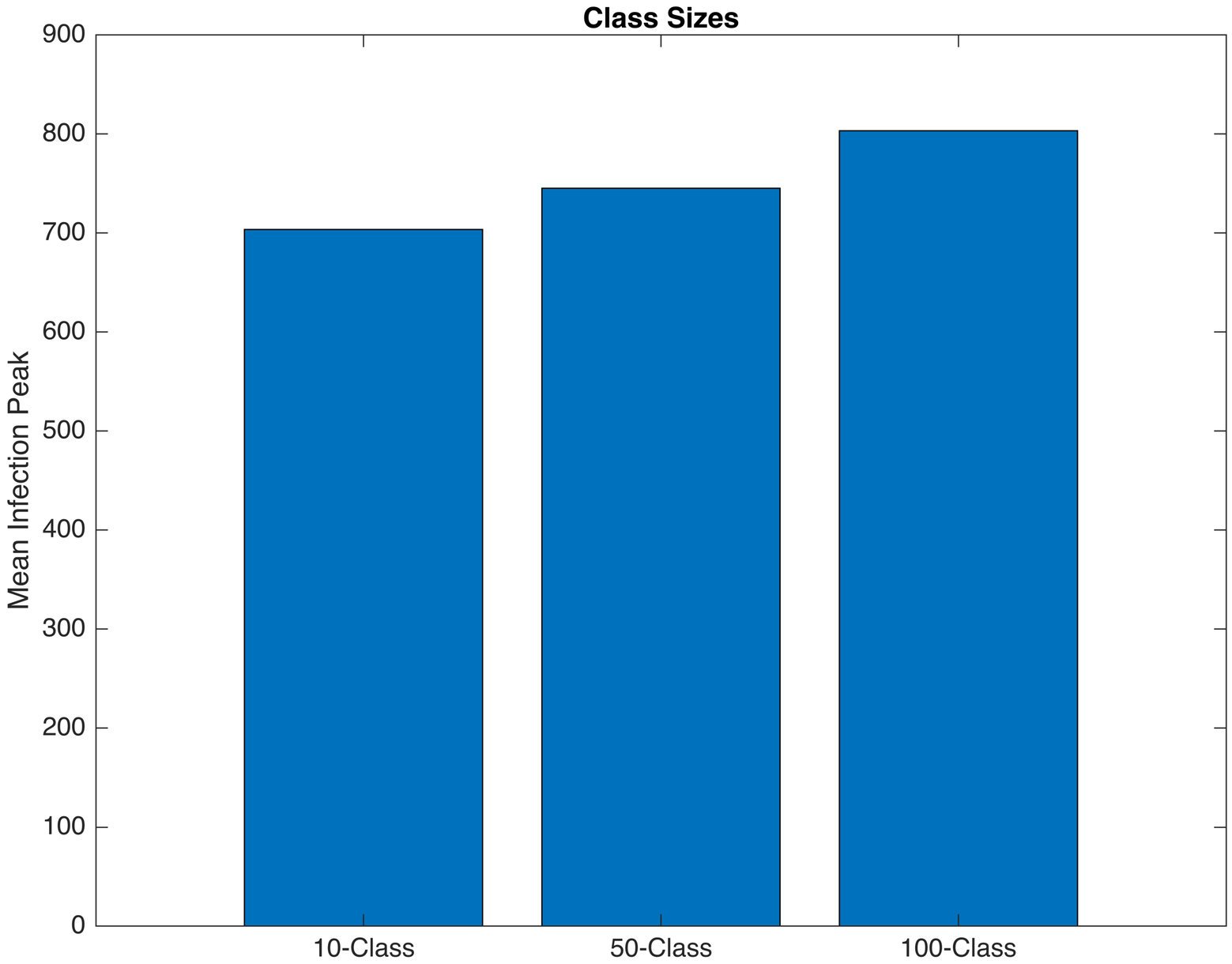
DEVELOPMENT

Verification Facts

- Checked for agents being in more than one state (value greater than one).
- Ensured agents weren't in multiple fractional states.
- Example:

```
%make sure agent is only in one state at a time
assert(sum(all(Ss+Is+Rs==1))==150)
%make sure an agent isn't in a fracitonal state(checking if rounding down
%in the matrix creates a matrix than is different from the original
assert(sum(all(floor(Ss) ~= Ss,'all')) == 0)
assert(sum(all(floor(Rs) ~= Rs,'all')) == 0)
assert(sum(all(floor(Is) ~= Is,'all')) == 0)
```

Parameter Sweeps

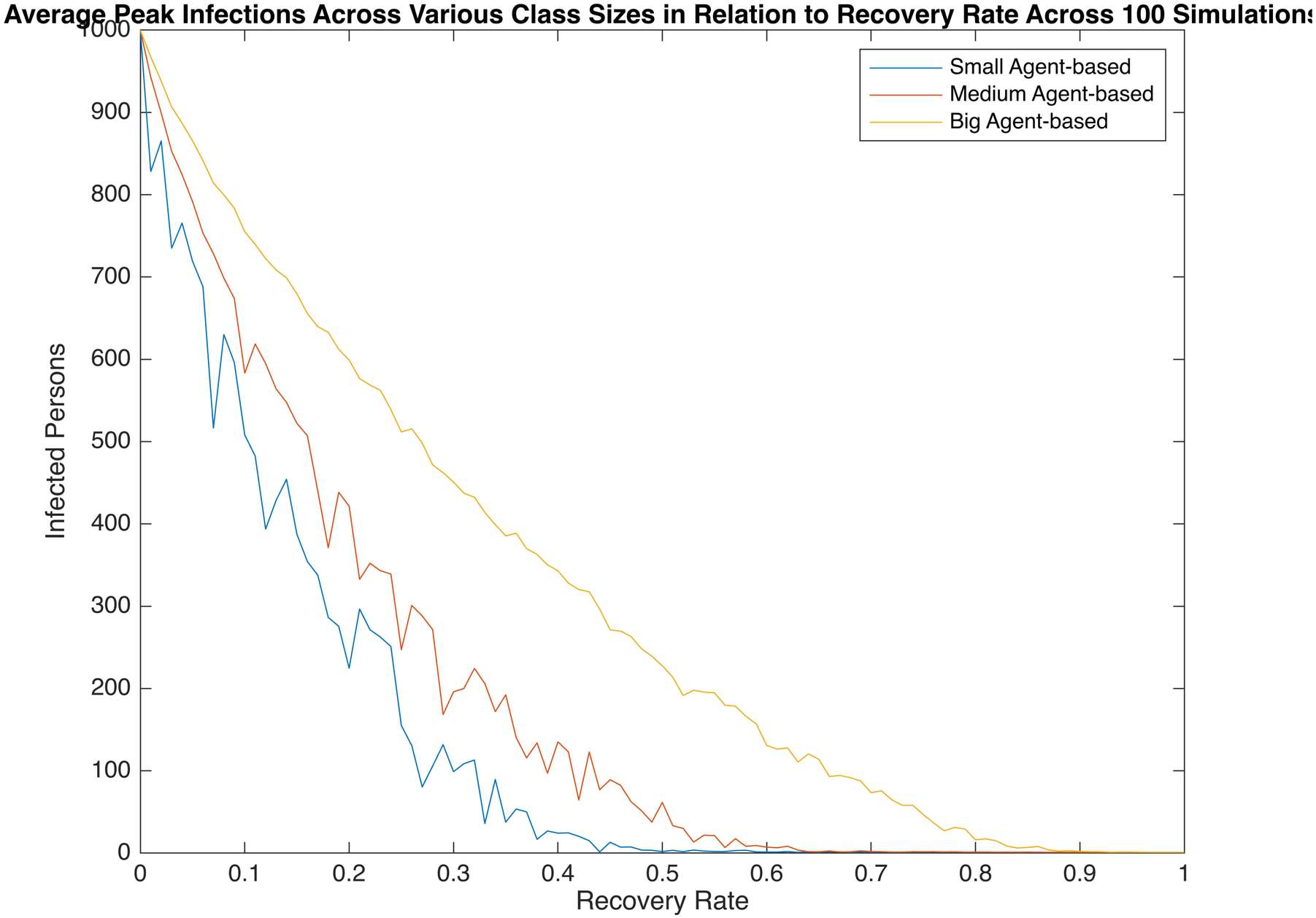

Class Sizes
Mean Infection Peak
900
800
700
600
500
400
300
200
100
0
10-Class
50-Class
100-Class

PARAMETER SWEEPS

Parameter Sweeps and Analysis

- Conducted parameter sweeps for **infection and recovery rates** across three class sizes (slides 17, 18).
- We used the metric of **mean peak infection** and calculated means based on 10 realizations due to computational limitations in MATLAB.

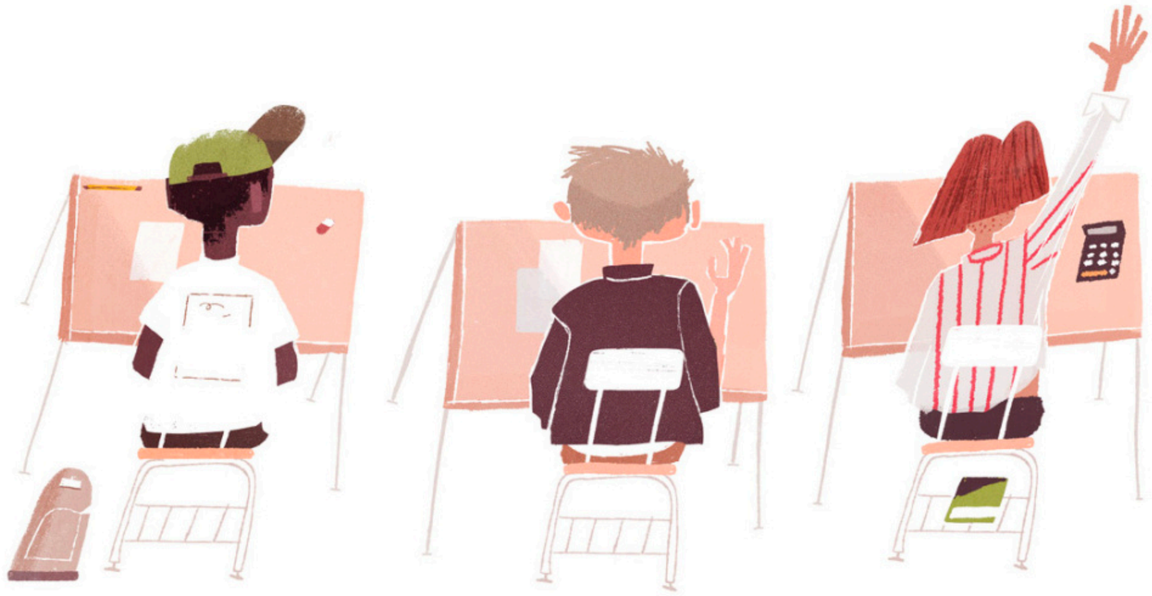

Average Peak Infections Across Various Class Sizes in Relation to Infection Rate Across 100 Simulations
Small Agent-based
Medium Agent-based
Big Agent-based
Infected Persons
Infection Rate
0
100
200
300
400
500
600
700
800
900
0
0.001
0.002
0.003
0.004
0.005
0.006
0.007
0.008
0.009
0.01


Average Peak Infections Across Various Class Sizes in Relation to Recovery Rate Across 100 Simulations
Small Agent-based
Medium Agent-based
Big Agent-based
Infected Persons
Recovery Rate
0
100
200
300
400
500
600
700
800
900
1000
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

ANALYSIS

Interpretations Based on Parameter Sweeps

- **Big classes exhibited the highest peak infections**, followed by medium and small classes.
- Trends held for realistic infection and recovery rates, avoiding exceptionally rapid trends.



ANALYSIS

Validation and Supporting Evidence:

- A study simulating COVID-19 in a university environment indicated that **moving large classes online effectively reduced COVID-19 infections**, aligning with our simulation data *(Simulating COVID-19 In a University Environment)*.

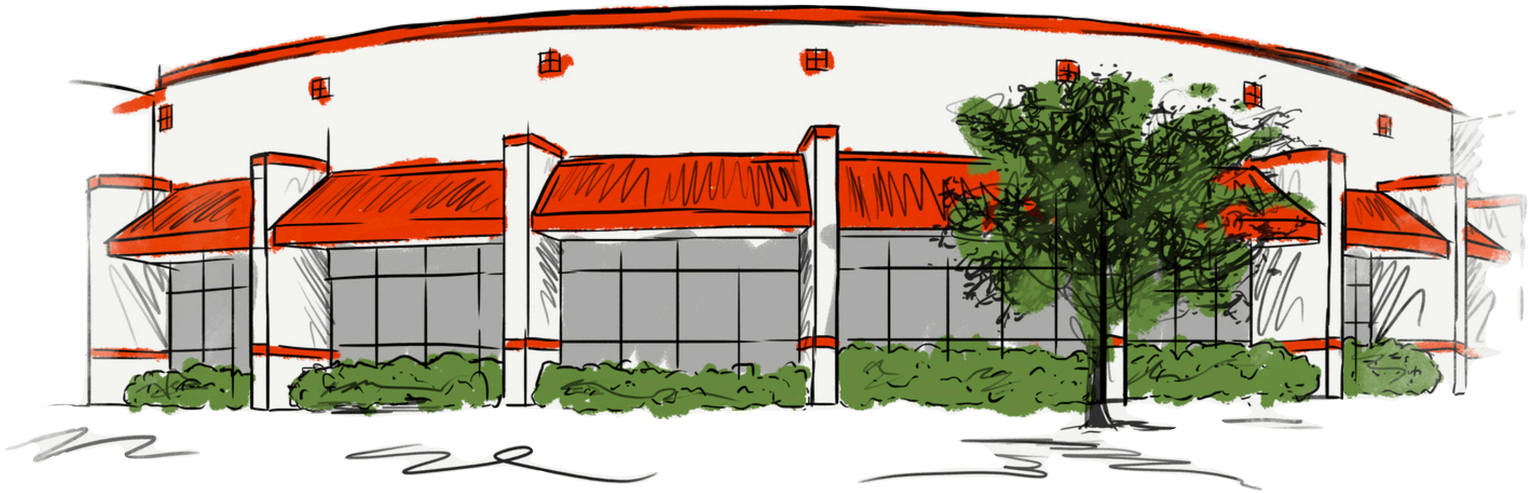
CONCLUSION:

Larger class sizes tend to result in the most disease spread as compared to medium or small classes.

INTERPRETATION

Limitations

- School **complexities** (varying class sizes, social circles, teachers, dormitories) were not incorporated, impacting model accuracy.
- Model designed for smaller to medium-sized schools; **assumptions may not hold for larger institutions**.



INTERPRETATION

Future Work

- Include **additional school intricacies** to represent larger educational settings better.
- **Increase realizations** for parameter sweeps to gather more robust data for meaningful conclusions.