SISMID Module 9
Lab 5: Intervention strategies

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July 2015

Implementing intervention strategies

In this course, we have talked about a number of different intervention strategies. We can model some of these strategies using the percolation simulation that we developed in the last lab. In this case, we will use the Vancouver urban network that we used previously in Lab 1 (`urban_net.csv`). Let's look at the effects of three intervention strategies in particular: two vaccination strategies and one "social distancing" strategy.

Since vaccination makes it impossible for an individual to get infected (assuming a 100% effective vaccine), we can model vaccination by removing nodes from the network, or more generally by making it impossible for those nodes to participate in the epidemic.

Since "social distancing" reduces an individual's disease-causing contacts, we can model this strategy by removing edges from the network.

I've given you a head start with a fairly fast implementation of the percolation simulation. You can download the program from the link "Lab 4: Intervention percolation code." (This code is also reproduced in the appendix to this lab.) Run the program as-is, and record the mean epidemic size when no intervention measures are in place. Call it S.

Now implement the following strategies:

1. Locate the commented block with the words "Implement intervention strategy here" (Line 40). Write a block of code that vaccinates 17.8% of the population **randomly**. Hint: the easiest way to do this is to loop through all nodes, and with 17.8% probability delete all of that node's edges. Now run the program and record the mean epidemic size. Call it S1.

2. For each individual vaccinated, how many people did the random vaccination strategy prevent from becoming sick? That is, to what extent did we achieve herd immunity?

3. Write intervention code that vaccinates the 17.8% of the population with the highest degrees. Hint: 17.8% of the urban network is 480 nodes. If you vaccinate all individuals with degree greater than or equal to 23, you will vaccinate the top 17.8%. Run the simulation again, and call the resulting mean epidemic size S2.

4. Write intervention code that **randomly** reduces each individual's edges by 17.8%. Run the percolation simulation again, and record the resulting epidemic size. We'll call this S3.

5. Compare the four epidemic sizes (S, S1, S2, S3). How much of a reduction in epidemic size did each control strategy yield, relative to S? Which strategy is best?

6. Which of these strategies do you think would be easiest to implement practically/logistically/ethically? How does one implement the second strategy in practice? (i.e. How do we know who in the population is "high degree"?)

Additional exercise: Age-based strategies

Download the urban network ages file, `urban_ages.csv`. Take a moment to look at the contents of the ages file: notice that it is structured much like an edge list file, but in this case only the first column contains node names (which are integers), while the second column contains age classes. These classes are as follows:

Age class	Description
1	Infants and toddlers (age < 3)
2	Preschoolers ($3 \leq$ age < 5)
3	Children ($5 \leq$ age < 18)
4	Adults ($18 \leq$ age < 50)
5	Elderly living at home ($50 \leq$ age)
6	Nursing home residents ($65 \leq$ age)

Figure 1: Age class definitions for Vancouver urban network

Ages are also strongly characterized by different mean degrees:

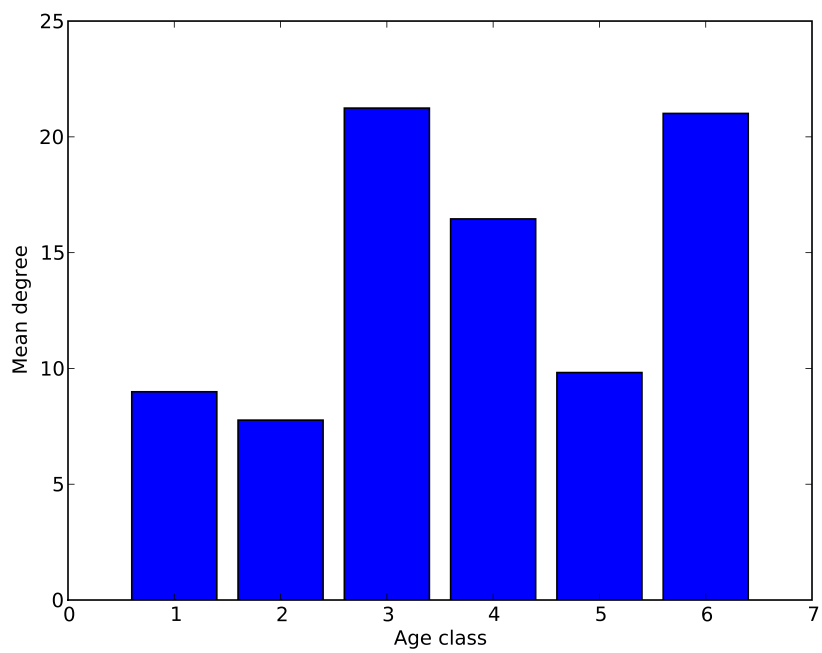

Figure 2: Age versus mean degree for Vancouver urban network

Try implementing the following vaccination strategies:

- As suggested in the previous exercise, identifying high-degree people directly may be difficult. If we know, however, that age can be an indicator of degree, how might we design and implement a vaccination strategy to target high-degree individuals? Does the effectiveness of this approach warrant its use?
- Now consider that for influenza, the very young and the very old are the most likely to die due to primary or secondary infection. How should we weight preventing death versus preventing illness? Do we prevent more death by vaccinating the vulnerable, or by vaccinating the high-degree individuals?

Appendix: intervention_perc.py

You may download this file, but sometimes seeing a printed copy makes reading code easier.

```
#!/usr/bin/python
from networkx import *
from random import *
from pylab import mean

### Define percolation simulation, using graph G and transmissibility T
def percolate(G, T):
    states = dict([(node, 's') for node in G.nodes()])

    p_zero = choice(G.nodes())
    states[p_zero] = 'i'
    infected = [p_zero]
    recovered = []

    while len(infected) > 0:
        v = infected.pop(0)
        for u in G.neighbors(v):
            if states[u] == 's' and random() < T:
                states[u] = 'i'
                infected.append(u)
        states[v] = 'r'
        recovered.append(v)
    ### return the epi size as a fraction of the ORIGINAL population
    return len(recovered)/float(net_size)

### Set transmissibility
### Corresponds to an R0 of about 2.5 for the urban network
T = 0.1357

### Build urban network
file = open("urban_edges.csv")
G = Graph()
for edge in file:
    node1, node2 = edge.strip().split(',')
    G.add_edge(node1, node2)
net_size = G.order()


############################################
### Implement intervention strategy here ###
############################################


### Run the simulation a bunch of times
results = []
for i in range(100):
    s =  percolate(G, T)
    results.append(s)

### Print the mean epidemic size
print mean(results)
```