qcb

Quantum Quarantine

A proof of concept for college campus

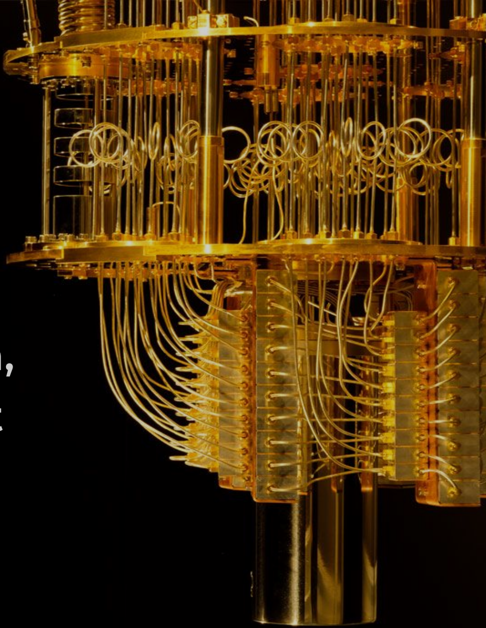
How can college students effectively quarantine on campus, so that Universities can reopen?

Motivation

Quarantine/shelter in place is an effective measure, yet the quarantine groups we choose may not be optimal

What if we can create a scheme that is based on physical interaction data?

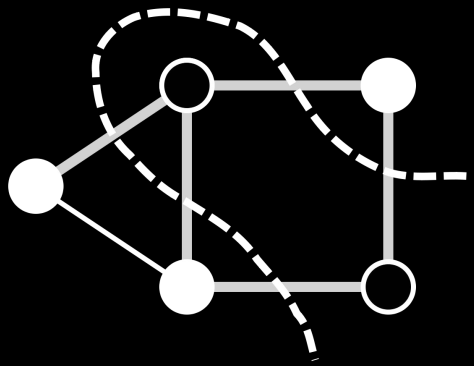
Goals & Assumptions



- Goal: **Given a social network (graph) of student population, develop a scalable, data-driven quarantine scheme to limit the spread of COVID-19**
- Assumptions:
  - Have a graph where nodes are students and edges are physical interactions between students
  - Approximate this graph if relevant data not found
  - Access to the interaction graph data
- Metrics to Minimize:
  - # of total infections
  - # of infected people at the peak of the disease

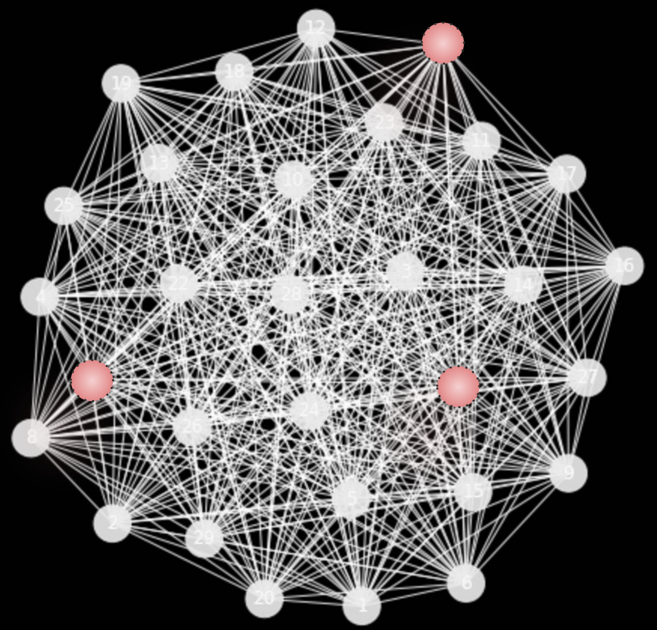
Design Choice & Explanations

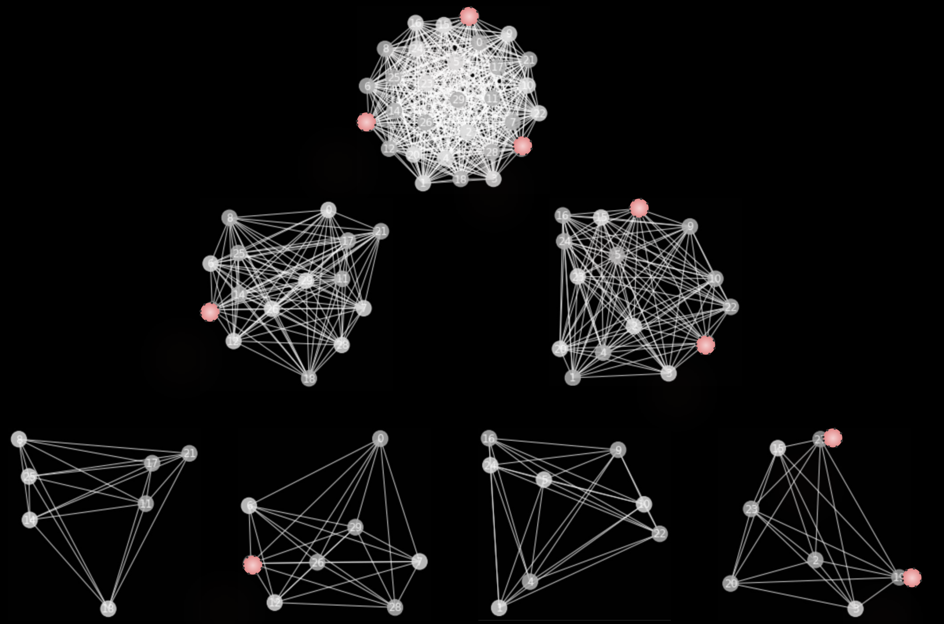
- Max-Cut using Adiabatic Quantum Computing
    - Finds a cut in that severs the most edges
    - Run on a D-Wave hybrid quantum computer
- Explanation
    - We would like to eliminate as many potential contacts as possible
    - Runtime does not increase with the size of the graph.



Design Process & Iteration-I

- Graph structure:
  - complete graph
  - Everybody can be contacted by anybody
- Algorithm method:
  - recursive max-cut
  - Split the initial population
  - Repeat the process for the resulting two subgroups
  - Repeat until we hit a head count target for each group





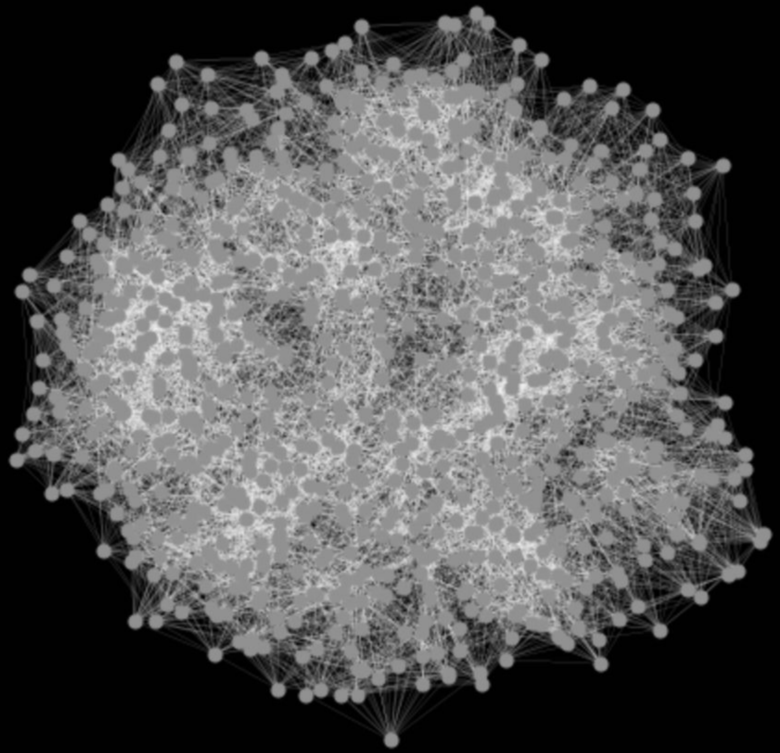
Group 1 Group 2 Group 3 Group 4

Design Process & Iteration-II

- Idea:
  - Make graph look more like small college campuses
  - Nodes are students, edges are shared courses
  - Implement cut by spatially separating students in a classroom
- Graph structure:
  - small-world graph
  - Sparsely connected local neighborhoods
  - This may better simulate a college major clusters
- Compare to random quarantine
  - Shelter in place doesn't take into account previous social interactions, is relatively random

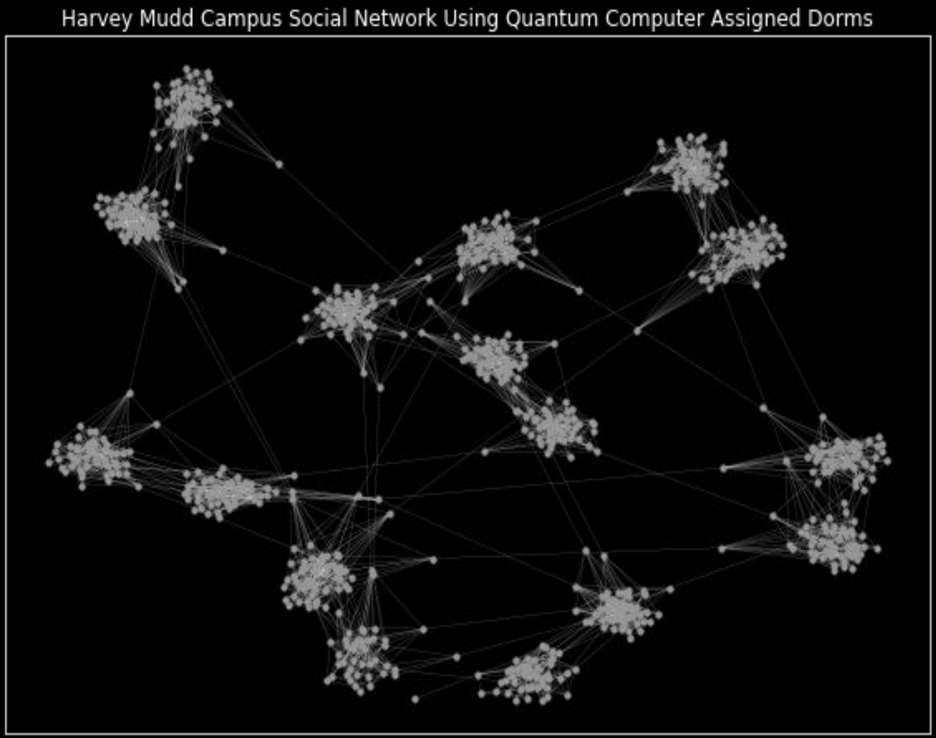
Design Process & Iteration-II

- Graph structure: Cornell Course Graph
  - Simulate Cornell campus using network properties of the school's liberal arts college (2)
- Epidemic Modelling:
  - Used an existing package that computes infections using the SIR epidemic model,
  - Infection and recovery rates deduced from CDC data



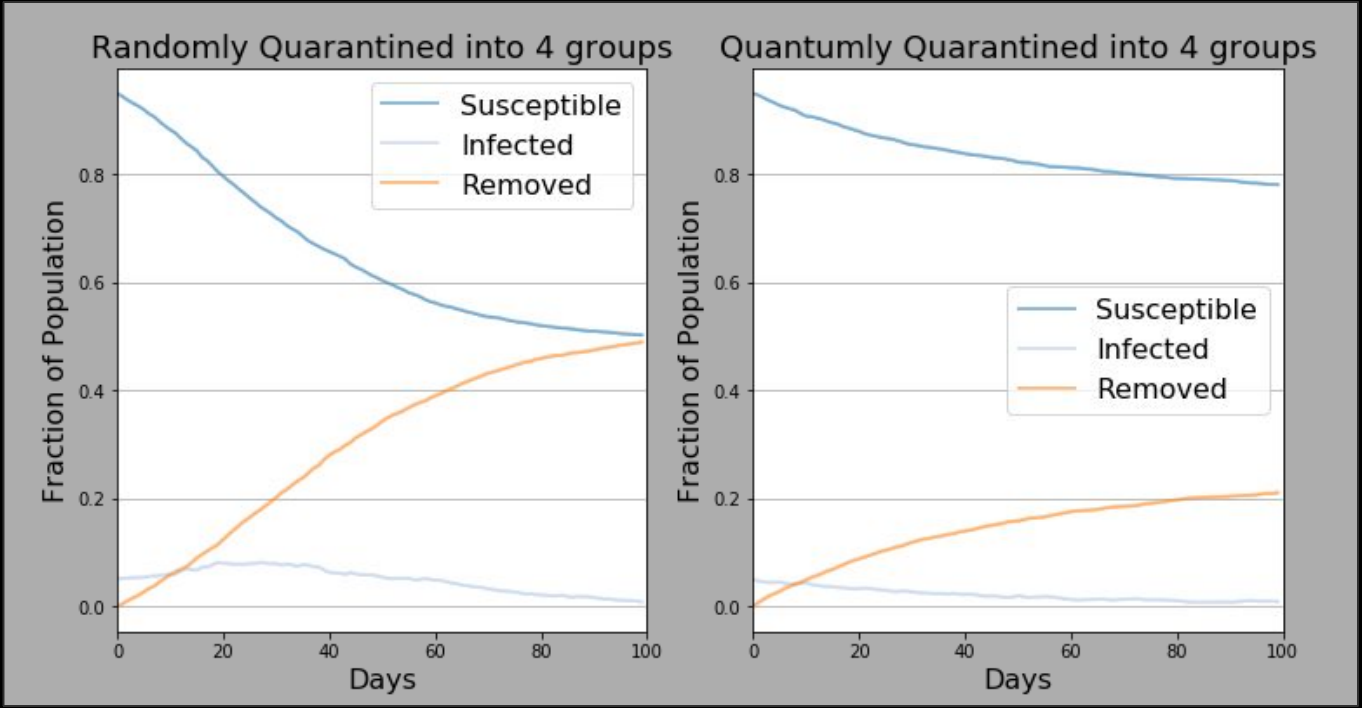
Design Process & Iteration-III

- Idea:
  - Use our algorithm to output dorm assignments
  - Implement on a campus where most students live in campus housing
- Adding Edges
  - Consider interactions from sharing floors, dorms, or randomly interacting
  - Add random edges for these interactions with tunable probabilities



Findings

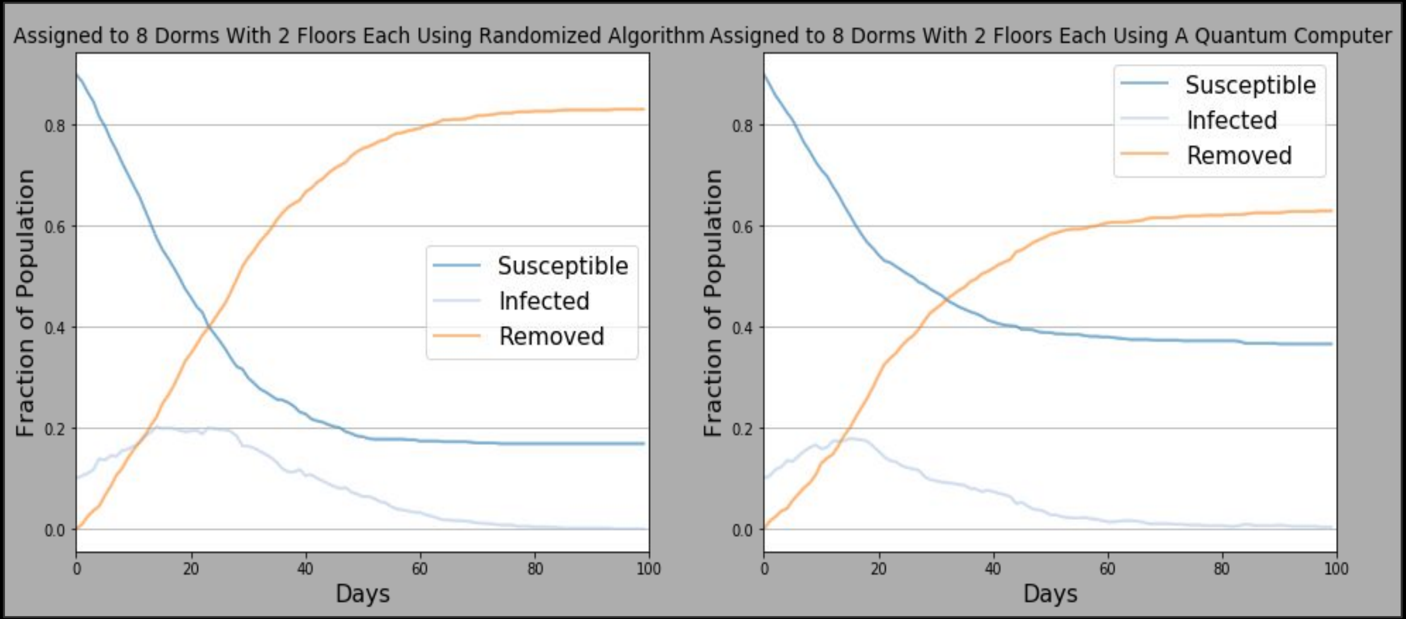
Note: The orange curve represents total fraction of population infected by a given dat



Results for a 3800 student course network mimicking Cornell's Liberal Arts college, with no extra edges added after quarantining. Reduced total infections by over 50%

- Assumes 5% of students are initially infected, an unquarantined R0 value of 6, and a recovery time frame of 10 days.

Findings



Results for a 1000 student course network mimicking Cornell's Liberal Arts college, with available housing similar to Harvey-Mudd campus (4), and with extra edges added after quarantining. Reduced total infections by around 20%

- Assumes 1% of students are initially infected, an quarantined R0 value of 2, a recovery time frame of 10 days, and floor, dorm, and campus edges with probability of .2, .005, and .0001, respectively

Social Implementation and Limitations

- Our model only presents advantages over random assignment of dorm if post-quarantine interactions are extremely limited. Otherwise all students will be quickly infected in either case
- We are not public health/campus officials, and understand that there may be many limitations to assigning students to housing based on an algorithm, and making sure there are as little connections as we need
- We are also not epidemiologist, and thus either the SIR model, the parameters for the model, or the input graphs we used may not be valid for modelling COVID-19

Social Implementation and Limitations

- D-wave's quantum annealer has a limit to the number of qubits (students) it can simulate
- There needs to be more well-researched field data in order to construct an accurate social interaction graph
- In most colleges, many students live off campus, this algorithm may not apply to these. There are many schools, however, where most students do live on campus

Sources

1. COVID-19 stats: https://wwwnc.cdc.gov/eid/article/26/7/20-0282_article
2. Cornell Enrollment Network Stats: https://osf.io/t7n9f/
3. U Michigan Course Enrollment Network Stats: https://link.springer.com/article/10.1007/s10755-019-09497-3
4. Colleges where most students live on campus: https://www.onlinecollegeplan.com/colleges-students-live-on-campus/

We would like to thank D-Wave Systems for complimentary use of their quantum computers for fighting Covid-19 and for volunteering staff to counsel us in this project. We would also like to thank the Jacob's Institute for hosting and mentoring through this important challenge

All code is public at https://github.com/qcberkeley/optimization/tree/master/quarantine_maxcut