**Program Structures & Algorithms**

**Spring 2021**

**Final Project - Virus transmission simulation**

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* **Task**

To simulate the spread of a virus such as SARS-CoV-2, the pathogen behind COVID-19 by taking into account the following parameters:

* The R and k factor of the disease.
* The usage and effectiveness of masks.
* The prevalence of testing and contact tracing.
* The availability and efficacy of the vaccine.
* Any barriers to entry (including quarantining) into the subject area.
* **Introduction**

Coronaviruses are a wide group of viruses that typically causes mild to moderate upper respiratory tract infections. But over the past two decades three new coronaviruses have emerged from the animal reservoirs causing serious widespread illness and death.

* SARS-CoV (SARS- severe acute respiratory syndrome) - November 2002 - 2004
* MERS-CoV (MERS- Middle East respiratory syndrome) - September 2012 -present
* SARS-CoV-2 (COVID-19- coronavirus disease 2019) - December 2019 -present

The COVID-19 is a communicable disease and was first reported in Wuhan, China in December 2019 and since then it has spread around the world. It has been declared a global pandemic by World Health Organization. As of today, a total of 2,891,018 death has been reported.

**R- naught**

For communicable diseases in a population with no immunity, the basic reproduction parameter (R-naught or ) is the estimated average number of infections produced by a single infectious person. values indicate how rapidly transmission will occur and if a disease will spread or decline within a community.

If the value of is >1 an outbreak will continue and will come to an end for <1. The values are established using mathematical models and are dependent on the parameters and model hence it varies hugely depending on country, culture, calculation, stage of the outbreak. Any mitigation or containment strategy will aid in reducing the reproduction number, either by decreasing the transmission rate or the time before infectious individuals are isolated.

**Rt**

The current reproduction number, Rt (R at time t).

**Effective reproduction number (R)**

R is similar to R0 but does not assume complete susceptibility of the population and therefore can be estimated with populations having immune members. Efforts aimed at reducing the number of susceptible persons within a population through vaccination would result in a reduction of the R value, rather than R0 value. In this scenario, vaccination could potentially end an epidemic if R can be reduced to a value <1.

The effective reproduction number can also be specified at a particular time *t*, presented as R(t) or *Rt*, which can be used to trace changes in R as the number of susceptible members in a population is reduced. When the goal is to measure the effectiveness of vaccination campaigns or other public health interventions, R0 is not necessarily the best metric (EID, 2019).

**Dispersion parameter(*k*)**

The dispersion parameter (*k*) plays an important role in explaining the overdispersion and super-spreading of the SARS-CoV-2 virus, it is the measure of the virus’s dispersion. As every infected person does not pass on the virus to the same number of people, this parameter helps in determining if the virus spreads by one person infecting many (big bursts) people or in a steady manner.

If the value of k is small, it means that one infected person can trigger many new cases in a very short time i.e., lower values of *k* corresponding to a broader distribution. Several studies suggest that the dispersion parameter *k* for SARS-CoV-2 is on the order of 0.1 [5], approximately 10% of infected people will result in 80% of new infections

* **Aim of the project**

The aim of the project is to understand how the various preventive measures helps with reducing the spread of Covid-19 and to compare it with the SARS-CoV.

* **Flow Chart**



* **Estimation**

SARS-CoV

* + - *k* for SARS-CoV is 0.16 with the negative binomial model (Singapore)[8]
    - is of the range 0.43–2.41 [9]

SARS-CoV-2

* + - *k* for SARS-CoV-2 is on the order of 0.1 [5]
    - is of the range 2-3 [6-7], A meta-analysis estimated that the initial median R0 for COVID-19 is 2.79 [10]

**Population Type:**

1. Healthy: Susceptible to the virus. They include people with comorbid condition. They include recovered individuals.
2. Vaccinated: 94% protected from virus.
3. Symptomatic Infected: Source of virus transmission if not controlled.
4. Asymptomatic Infected: These will also transmit the virus. These will be found and quarantined only by testing.
5. Hospitalized/Severe: Most of this population dies. Hospitalized will not transmit but servere people moving can transmit.
6. Dead: Immobile and will not further transmit the virus.

**Factors considered for simulation:**

1. Efficacy of Vaccine: 94% of vaccinated individuals will not get infected throughout the simulation. Individuals with comorbid condition will be vaccinated first. There is no vaccine for comparison virus – SARS so they will not be vaccinated.
2. Testing and Contact Tracing: Testing will fetch all the infected population including asymptomatic individuals. So the entire simulation will show all as symptomatic infected individuals. Quarantine constraint will apply. For contact tracing, we log all the individuals that come in contact with the infected person using directed graph.
3. Quarantining the subject area: 20% of population will quarantine. This will include healthy people for example people who have recently travelled, feel sick, practice self isolation, etc and infected people. Virus will not transmit to healthy people who quarantine. Infected people who quarantine will not be transmitting virus to nearby healthy people.
4. Hospitalizing Severe population: When virus infected comorbid population (45% of total population) they are considered severely affected. Severe patients would be hospitalized upto hospital capacity. Hospitalized patients will not transmit to others.
5. Social Distancing – 6ft and Mask : Population displacement will reduce randomly when social distancing is practiced. In this case the collision becomes lesser.
6. Remote Offices and Schools: Population movement delays by 70%. Since we also consider the infection recovery time the spreading reduces with delay.
7. Virus Recovery Time: Taking into account population relative to the panel for simulation, we have taken 5ms as the recovery time. After recovery, they are considered similar to healthy population and again become susceptible to the virus.
8. SARS-Comparison Virus incubation period : Taken as 3ms. After 3ms it gets transmitted to others.
9. Death Rate: Both infected people with or without comorbidities get hospitalized based on hospital availability. People in hospital will die especially with comorbid condition. With death, the person becomes immobile and will not transmit to other people.
10. Asymptomatic Population: We have considered one out of 3 infected to be asymptomatic. The asymptomatic fraction could be updated in the config file.
11. Group Events: In case of any events where there is massive gathering, the spreading is rapid if even one person is infected in that place. The people around the area can also get infected.
12. R-naught value: When R-naught is passed, the infected person will further transmit only to certain number of people based on this value.

**Assumptions for the simulation:**

Below are the assumptions for the user defined constraints that are taken into account for simulation:

1. Testing and Contact Tracing : All the population get tested– hence there would not be any asymptomatic infected population. Since they are tested the quarantine constraint will also apply here.
2. Efficacy of Vaccine: 50% of population will be vaccinated. The efficacy of vaccine would be 94%. Comorbid cases will be vaccinated first.
3. Quarantining the subject area: 20% population will quarantine.
4. Remote Work/Schools: Movement will be delayed by 70%.
5. Hospital capacity will be 20% of population.
6. Population will have 45% of Comorbid cases.
7. Recovery time is 5ms.
8. SARS Virus(Comparison Virus) incubation period is 3ms. It will transmit only after incubation period.

* **Solution**
* **Implementation**
* **Output**
* **Unit tests result:**
* **Mathematical Analysis/Evidence**
* **Conclusion**
* **Reference:**

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