**INFO6205**

**Program Structures & Algorithms**

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**Virus transmission simulation**

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1. **Introduction**

Coronaviruses are a wide group of viruses that typically causes mild to moderate upper respiratory tract infections. 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)
* MERS-CoV (MERS- Middle East respiratory syndrome)
* SARS-CoV-2 (COVID-19- coronavirus disease 2019)

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.

* **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, stages 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.

* **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.

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]

1. **Aim of the project**

The aim of the project is to simulate a SARS-CoV-2 virus and analyze the effectiveness of various preventive measures. The following parameters are taken into consideration for the simulation:

* The R-naught and k factor of the disease
* The usage and effectiveness of masks and social distancing
* The prevalence of testing and contact tracing
* The availability and efficacy of the vaccine
* Remote work and schools
* Quarantine
* Group event

1. **Implementation**
   1. **Algorithm Flow Chart**



Figure 1: Flow Chart

* 1. **Data Structure**

The data structures used for the project are:

1. Array - Population: We store the entire population as an array, we loop through each person and based on their position and interaction with other nearby population we update their health conditions accordingly.
2. Directed graph: In this project directed graph is implemented to check contact tracing. We can get information on the people infected by a person. The directional graph is represented using adjacency list. The adjacency list complexity is O(N+M) where N denoted the number of nodes and M the number of edges.

The unique id of people is represented as vertices and once they collide, in the direction of collision the edges are stored. A HashSet is used to store the vertices and the edges of each vertices are saved in the LinkedList.

1. Hash map: All the constraints and factors required for the run are stored and retrieved from HashMap.
   1. **Simulation**

The project is developed using Java and the simulation is implemented using Java swing graphical user interface (GUI) and Graphics 2D. The simulation is modeled for both SARS-CoV-2 and SARS-CoV. The screenshot of the dashboard is shown in Figure 2.

The simulation is based on various assumptions and recent study reports and does not reflect the real-world scenario of SARS-CoV-2 or SARS-CoV, as it would include several other factors. This simulation helps us in getting a better understanding of the importance of the factors that we have considered and the effect they have on the transmission of the disease.

In the simulation each person is represented as a ball, the user can choose the total number of populations from the slider from a range of 50 to 1000. The health conditions of the population are represented by various colors as shown in the legend. The parameters can be marked and the equivalent simulation incorporating the parameter will be generated.

The value of R-naught can be defined by the user, the simulation will take it into consideration and during simulation each person can only infect that many numbers of people. In case if the R-naught value is not specified the simulation transmits on a general scenario where a person can infect variable number of people.

The real time display of the number of healthy people, number of infections, number of severe, number of recovered and dead people is provided for both the viruses. A plot of the number of infections over time is displayed. Once the simulation is stopped, we get the contact tracing displayed on the console of the IDE. The result session displays the values obtained for multiple runs of the application.

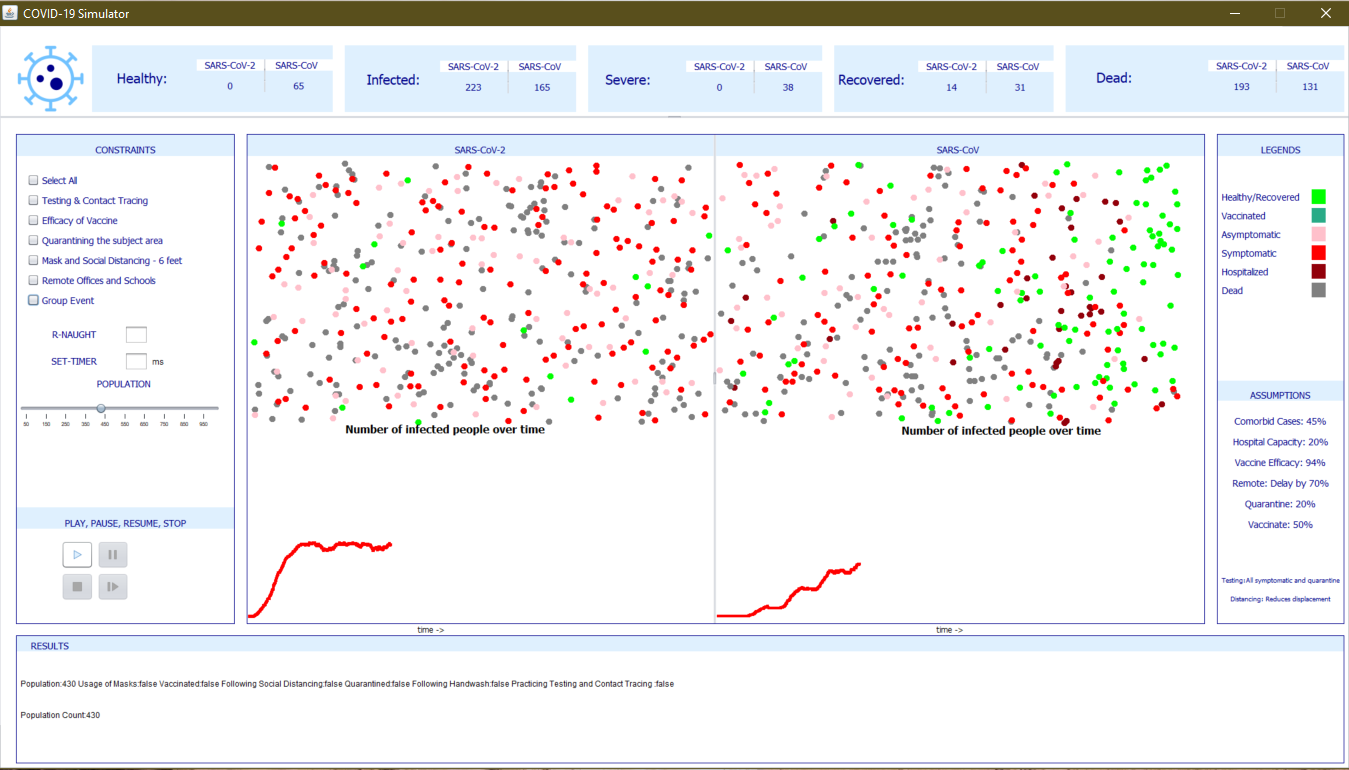


Figure 2: Dashboard

1. **Project Details**
   1. **Assumptions** 
      1. **Population types**
2. Healthy (Light Green): Susceptible to the virus. They include people with comorbid condition. This also includes recovered individuals.
3. Vaccinated (Dark Green): 94% of the population are protected from the virus.
4. Infected – Symptomatic (Bright Red): Primary transmitter of the virus until tested and quarantined.
5. Infected – Asymptomatic (Light Red): Undetected transmitter until tested and quarantined.
6. Hospitalized/Severe (Dark Red): If hospitalized they are immobile, and comorbid condition is checked.
7. Dead: Immobile and will not further transmit the virus.
   * 1. **Factors considered for simulation**
8. R-naught value:
   1. The R-naught parameter is user defined, the transmission changes depending on the R-naught parameter.
9. Vaccine:
10. 50 percent of the population is vaccinated.
11. The vaccine efficiency is considered to be 94%[11].
12. Individuals with comorbid condition will be vaccinated first.
13. There is no vaccine currently available for SARS-CoV, hence it is not considered for the comparison.
14. Testing and Contact Tracing:
15. Testing will detect all the infected population including symptomatic and asymptomatic population. So once testing is considered, the entire simulation will reveal all infected individuals.
16. Quarantine constraint is also considered if infected.
17. For contact tracing, the part of the population that comes in contact with the infected person is traced using directed graph.
18. Quarantining the subject area:
19. 20% of the population will be quarantined.
20. This will include healthy people who have recently travelled, people with health issues, people practicing self-isolation and infected people.
21. The quarantined healthy population will not be infected by the virus.
22. Infected people who quarantine will not be transmitting the virus to nearby healthy people.
23. Mask and Social Distancing – 6ft:
24. Population displacement will reduce when social distancing is practiced.
25. In this case the collision(interaction) becomes lesser resulting in less transmission of the virus.
26. Remote Offices and Schools:
27. Population movement is delayed by 70%.
28. Due to the delay the spreading reduces, as the recovery time elapses.
29. Group Events:
30. A closed confined massive gathering event is attended by a part of the population.
31. A single infected person can infect the entire attending population.
    * 1. **General**
32. The recovery time:
    1. Considering the number of population relative to the size of the panel, we have factored the recovery time of 15 days to 5ms.
    2. After recovery, they are considered as a healthy population and become susceptible to the virus.
33. Death Rate:
34. Both infected people with and without comorbidities get hospitalized based on hospital bed availability.
35. Asymptomatic Population:
36. We have considered one out of every 3 persons infected to be asymptomatic.
37. Hospitalizing severe population:
38. Severe patients would be hospitalized up to the hospital bed capacity.
39. The hospital capacity is considered to accommodate 20% of the population.
40. SARS-CoV incubation period:
41. We have factored the incubation period of 5 to 7 days to 3ms.
42. After the incubation period it gets transmitted to others.
    1. **Config.ini**

The parameters that can be changed in the Config.ini file is given below:

1. Infection Parameters:
2. infectionRate: This is the percentage of population initially infected. We have taken it as 0.1, which means 10% of population would be infected at the start of simulation.
3. asymptoticFraction: Fraction of infected people that are asymptomatic. We have taken 3, i.e, 1 out of 3 infected people is asymptomatic.
4. comorbidPercentage: Percentage of population that are comorbid. Currently considered as 45%.
5. infectedQuarantinePercentage: When quarantine constraint is selected, this is the percentage of infected population that actually quarantine. Taken as 20%.
6. Vaccine Parameters:
7. vaccinatedPercentage: This is the percentage of population that are vaccinated when we consider efficacy of vaccine constraint. Currently considered as 50%.
8. vaccineEffectiveness: Percentage of vaccinate population that do not get infected. Effectiveness is considered as 94%.
9. Population Ball Parameters:
10. populationBallHeight: Height of the 2D Graphics ball shape components that we have considered for displaying population.
11. populationBallWidth: Width of the 2D Graphics ball shape components that we have considered for displaying population.
12. Other Conditions:
13. hospitalCapacity: Capacity of hospital is considered based on percentage of population taken. i.e, if hospitalCapacity is 0.2 then the hospital capacity is 20% of the population.
14. **Outputs**

**Plots graphs and compare.**

* + 1. **Comparison Plot for Quarantine condition**

Chart, line chart

Description automatically generated

We observed that when quarantine is not considered the mean infected count is 208 and when quarantine is considered it is 55. There is 73% reduction of infection if we follow quarantine.

* + 1. **Comparison Plot for Social Distancing and Mask condition**

Chart, line chart

Description automatically generated

We observed that when social distancing is not followed the mean infected count is 169 and when social distancing is considered the mean infection count is 128. There is 24% reduction of infection if we follow social distancing and use masks.

* + 1. **Comparison Plot for Vaccine condition**

Chart, line chart

Description automatically generated

We observed that when in group without any vaccination the mean infected count is 244 and when group with vaccination is considered, the mean infection count is 75. There is 69% reduction of infection.

* + 1. **Comparison Plot for Remote Work/School condition**

Chart, line chart

Description automatically generated

We observed that when all Offices and schools are open the mean infected count is 240 whereas the mean count is 24 when offices and schools go remote. There is 90% reduction of infection.

1. **Unit tests result:**
2. **Mathematical Analysis/Evidence**
   * **Big O**
   * **Entropy –**
   * **Invariant –**
3. **Conclusion**
4. **Reference:**
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