IE 206 - Term Project I

METU - New Corona Virus Modelling

As an Industrial Engineer, you are hired as a consultant by the government to study on recent Corona Outbreak. Your task is to create a computational framework for outbreak conditions and prevention by simulation. The government wants to understand the spread and develop some policies, and you are expected to simulate and perform computational analysis for these policies. You are required to present a report based on your findings.

Representation of the System and the Spread of the Pandemia

Given a TxT grid as in Figure 1, we have N people in the population that are distributed on the grid randomly. Initially, each cell must contain only one individual, and Δ_1 % of N people (denoted by N_S) are assumed to be infected.

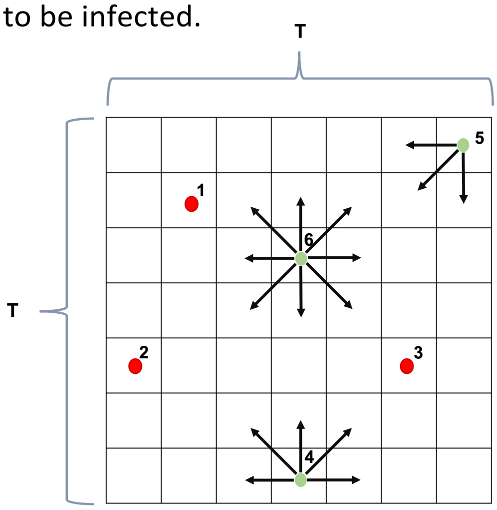

Figure 1: Representation of the problem. Green and red points represent healthy and infected people, respectively.

Each individual (for the rest of the text, **point** refers to an individual) can randomly move with equal chances as in Point 6 in Figure 1. In each direction, a point can move with a random amount of step(s) distributed with U[0,3]. While moving, if a point hits a boundary or a corner, it cannot move along all directions, but it can move to certain directions with equal chances in the next move. (In Figure 1, Points 4 and 5 have five and three available directions, respectively.

If an infected and a non-infected point coincide at a cell, the non-infected point will be infected with a probability of p, which is the *contagiousness* of the virus. Also, each infected point will be healed with a 0.95 probability after M iterations of *infectious period*. It is assumed that infected points can infect non-infected points during infectious period, M . The point that cannot be healed after M iterations will be dead.

Isolation Policy

Isolation means that an infected point can only move to neighbors of the cells where *it gets infected*. For example, as shown in Figure 2, a point infected at cell-A can only be found in cells A to I with equal probability in any iteration until it gets healed. In this policy, a newly infected point will be isolated with a probability of q_s and stays isolated for M iterations. Since not all people obey the rules, it may ignore the isolation rule with $(1 - q_s)$ probability and continue to move around as regular individuals. Initially, Δ_2 % of the infected people are accepted to be isolated until they are healed (for M iterations). Once a point is infected but not isolated, it will not be isolated in the following iterations.

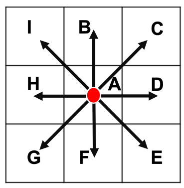

Figure 2: Representation of the isolation.

Vaccination Policy

In this policy, vaccination starts after the iteration t_s. At each iteration after t_s, Δ_3 of healthy individuals at that time, who have not been vaccinated yet, will be vaccinated. However, even though they get vaccinated, they can be infected with probability r_s in the following iterations.

Moreover, individuals that are vaccinated once, can have a second vaccination after t_{sec} period of their first vaccination with probability w. After the second vaccination, an individual's infection probability will reduce to 0, and s/he will be considered as fully protected. Individuals with only one vaccination can be infected with probability r_s until having the second vaccination. If an individual has not been vaccinated for the second time after the t_{sec} period, its infection probability will increase to p. Note that, if an individual is infected after the first vaccination, s/he will not be vaccinated for the second dose.

Model Parameters

Model parameter values are given in Table 1 below.

Table 1: Model Parameters

Parameter	Explanation	Parameter Values
T:	grid size	25 x 25
N:	population size	[120 - 500]
Δ_1:	percentage of infected people initially	[1% - 15%]
p:	infection probability in scenario of encounter	[0.1-0.7]
Δ_2:	percentage of isolated infected people at the initialization	[0% - 100%]
q_s:	isolation probability of a newly infected person	0.5
M:	infectious period duration (in number of iterations)	[10 - 50]
t_s:	iteration number where vaccination starts	20
r_s:	infection probability of vaccinated healthy people	0.05
t_{sec}:	number of iterations between two vaccinations	4
w:	second vaccination probability of healthy people	[0.4 - 0.8]
Δ_3:	rate of vaccination of healthy people	$\frac{1}{k*(t_v - 19)}$, for $t_v = t_s, t_s+1, t_s+2, \ldots$ $k = \{1.5, 2, 3, 4\}$

To observe how the system behaves, we consider the following performance criteria listed below. Note that not all criteria may be applicable to all situations.

- total number of infected people in the system in each iteration,
- total number of vaccinated people in the system in each iteration,
- total number of infected people who are vaccinated in the system in each iteration,
- total number of healed people in the system in each iteration,
- total number of dead people in the system in each iteration,

To consult the government on how the Covid outbreak spreads, different cases are studied (see below), and the results will be reported to the decision-makers. You are expected to make analyses using the computational environment you will generate and improve our understanding of the dynamics of the spread under different cases. Analyze the following cases and present your results by providing related graphs.

1. Consider there is no vaccination available, and the government implements an isolation policy. What is the impact of the initial number of infected people on the spread of the pandemic using different isolation policies?

2. Consider there is no vaccination available, what is the impact of the implementation of isolation on the spread of the pandemic?

3. Consider there is single vaccination available, and the government does not implement an isolation policy. What is the impact of the vaccination rate on the spread of the pandemic?

4. Consider there is no vaccination available, and the government only implements a certain isolation policy. What is the impact of contagiousness on the spread of the pandemic?
5. Considering there is no isolation policy, what is the impact of the prevention of vaccination on the spread of the pandemic under a double vaccination policy for different numbers of iterations between two vaccinations?
6. Consider the government implements a double vaccination policy. What is the impact of the willingness of people for the second vaccination on the spread of the pandemic?
7. Consider that the government aims to control the spread such that at most 30% of the population is infected. For such a case, what policy should be recommended to the government? Note that in this case $N = 150$, $p = 0.5$, $\Delta_2 = 5\%$, $M = 30$.