An Agent-Based Model to study the spread and control of influenza

A project report submitted as a part of Major-II

In

Master of Technology in Computer Science and Engineering

By

Priya Gupta

2K15/CSE/15

Under the Guidance of:

Asst. Prof. Divyashikha Sethia

DEPARTMENT OF COMPUTER ENGINEERING

DELHI TECHNOLOGICAL UNIVERSITY

June 2017

CERTIFICATE

This is to certify that Project Report entitled "**An agent based model to study the spread and control of influenza**" submitted by **Priya Gupta** for partial fulfillment of the requirement for the award of degree Master Of Technology (Computer Science and Engineering) is a record of the candidate work carried out by her under my supervision.

Asst. Prof. Divyashikha Sethia
Project Guide
Department of Computer Science and Engineering
Delhi Technological University

DECLARATION

I hereby declare that the major Project-II work entitled "**An Agent-Based Model to study the spread and control of influenza**" is a bonafide report carried out by me. The material contained in this report has not been submitted to any university or institution for the award of any degree.

Priya Gupta

2K15/CSE/15

ACKNOWLEDGEMENT

First of all I would like to thank the Almighty, who has always guided me to work on the right path of the life. My greatest thanks are to my parents who bestowed ability and strength in me to complete this work.

I owe a profound gratitude to my project guide Ms.Divyashikha Sethia who has been a constant source of inspiration to me throughout the period of this project. It was her competent guidance, constant encouragement and critical evaluation that helped me to develop a new insight into my project. Her calm, collected and professionally impeccable style of handling situations not only steered me through every problem, but also helped me to grow as a matured person.

I am also thankful to her for trusting my capabilities to develop this project under her guidance.

Date :

PRIYA GUPTA

TABLE OF CONTENTS

LIST OF FIGURES

ABSTRACT

The world keeps on confronting flare-ups of illness because of normal causes and also the risk of biological warfare. Numerical modeling gives a road by which to foresee and eventually avert broad episodes. A wide assortment of modeling tools has been utilized as a part of the investigation into the illnesses dispersed, involving Partial Differential Equations, Ordinary Differential Equations, and Difference Equations.

Agent-based (AB) simulation is a useful tool for building highly granular disease spread models incorporating the epidemiological features of the virus as well as the demographic and social behavioral attributes of tens of millions of affected people. Such disease spread models provide excellent basis on which various mitigation strategies can be tested, before they are adopted and implemented by the policymakers. Mathematical modeling has provided an economical means to comprehend the transmission dynamics of diseases as well as the ability to choose the most effective and economical interventions aimed at preventing and treating disease.

An agent - based modeling is used to study the spread and control parameters of flu in this thesis. The NetLogo tool is utilized for the simulation purpose. The setup methods of such a model are completely discussed.

This simulation helps clients for comprehending new illness spread progression in connection with the adjustments in control measure, travel, and versatility and furthermore see the way R_0, i.e. reproduction number, speaks as far as possible for an epidemic and comprehend the connection to integrals and subordinates, and provide opportunities to extend or change the model to include some properties of a disease.

This model is used to study the effectiveness of isolation, immunization and quarantine as methods of epidemic control. It is determined that the most effective means of controlling an epidemic is to quarantine individuals. Thus, this work reduces the number of infected individuals and recovery rate due to control parameters. In addition to the control methods, travelling and social networking among individuals for spreading the influenza has been observed.

CHAPTER 1 - INTRODUCTION

1.1 Overview

From starting, illness and its emergence is a great concern. The Black Death ,the well known scourge which prompted passing the 33% of number of inhabitants in Europe, to latest scourges in the public eye , SARS and AIDS, former times is loaded with records of the appalling impacts of sickness. Keeping illness spread is winding up noticeably progressively essential as the world develops persistently "littler" effortlessly of travel. Propels in numerical demonstrating give approaches to anticipate, avert, and decide the patterns of since a long time ago dreaded scourges [1].

Displaying of sicknesses can be followed back similarly meanwhile John Graunt took an observational review on all sorts of illnesses which had been executing people in different areas all through Britain. Afterward, more deterministic methodologies were created as people attempted to make forecasts with respect to when, where, and to what extent an ailment would advance in a group[4]. David Bernoulli built up information as well as condition placed technique the point at which he took a gander on scourge i.e. smallpox which happened in country Europe [2]. As numerical demonstrating advanced, demonstrates turned out to be more complex and exact. Scientists are displaying each detail from HIV, flu, and normal cough dispersion, to a conceivable dispersion of organic firearms [3].

At that point, the capacity to anticipate contagion disperse is vital, maybe critical part of such investigation sort is having the ability to keep scourges by happening in any case when an contagious illness is brought in the community.

There are a few distinct sorts of models being utilized as a part of this area involves Partial Differential Equations (PDE's) [9, 10], Difference Equations [11, 12, 13], Ordinary Differential Equations (ODE's) [4, 5], and Operator-Based Models (ABM's) [31, 32, 33].

1.2 ODE Models

These demonstrate utilize varying conditions for demonstrating the momentary measure of progress of specific factor. They are having negative as well as positive features [4]. To begin with, ODE's consider the assurance of different sorts of arrangements including approximate and explicit when concentrate a plague framework. In any case, a disadvantage with such models is neglecting to provide a satisfactory depiction of varieties in conduct of people and impacts on area of a pestilence. They are additionally deficient as far as the blending examples of a populace [5].

SIR (Susceptible-Infectious-Recovered)-

The population is divided into three distinct classes:

- *Susceptible* (S): healthy individuals who can catch the disease;
- *Infectious* (I): those who have the disease and can transmit it; and
- *Recovered* (R): individuals who have had the disease and are now immune to the infection (or removed from further propagation of the disease by some other means).

The most popular ODE models is the Kermack-McKendrick SIR (Susceptible–Infectious–Recovered) demonstrated as follows.

$$\frac{dS}{dt} = -rSI \qquad \text{Eq-(1)}$$

$$\frac{dI}{dt} = rSI - aI \qquad \text{Eq-(2)}$$

$$\frac{dR}{dt} = aI \qquad \text{Eq-(3)}$$

Here S speaks to count of vulnerable people, R addresses count of recouped people, r represents disease measure, I is count of tainted people, and a represents the recuperation measure, which can be credited to either resistance or death.

In such specific demonstrate, this is expected that once an individual recoup from the sickness, regardless of whether by death or different means, individual acquire lasting insusceptibility [3]. Inductions of such essential demonstrate has been utilized for showing pathogenic diseases [6], and haematids B [7].

SEIR (Susceptible–Exposed–Infectious–Recovered) –

- *Susceptible*: Initially, individual/host is susceptible to infection: no pathogen is present; just a low-level nonspecific immunity within the host.

- *Exposed*: In early stages, the host may or may not exhibit obvious signs of infection and abundance of pathogen may be too low to allow further transmission.

- *Infectious*: Host encounters infectious individual and becomes infected with a micro parasite; abundance of the parasite grows with time.

- *Recovered*: The host is either no longer infectious or 'removed' (dead).

All the additional as of late, Chowell, et al. [8], utilized SEIR type demonstrate, displayed as follows, to show the flu emergence in the France, US, and Australia. Contrasted with SIR demonstrate, a SEIR display incorporates behavior for people who are presented to sickness, yet did not begin to show side effects.

$$\frac{dS}{dt} = - \frac{\beta SI}{N} \quad \text{Eq-(4)}$$

$$\frac{dE}{dT} = - \frac{\beta SI}{N} - \kappa E \quad \text{Eq-(5)}$$

$$\frac{dI}{dt} = \kappa E - (\gamma + \delta) I \quad \text{Eq-(6)}$$

$$\frac{dP}{dt} = \gamma I \quad \text{Eq-(7)}$$

$$\frac{dD}{dt} = \delta I \quad \text{Eq-(8)}$$

Here, the extra factors E, P, and D speak to count of uncovered, resistant or ensured people, and passed away people, separately. Also, β speaks to passing measure of illness, N speaks to aggregate populace, κ defines the measure by which people go from uncovered to tainted, and γ speak to recuperation measure and δ speak to death measure. Chowell, et al. [8] utilize such demonstrate for evaluating a proliferation number of flu as well as concentrate viability of present immunization methodology in such nations. By their information, they could presume that keeping in mind the end goal to decrease the flu dispersion considerably greater immunization measure of non-sick people will be important and in addition an arrangement to inoculate again as latest demands of the contagion create.

1.3 PDE Models

The ODE demonstrates in which aggregate count of individuals in every gathering is related serve to depict frameworks, an alternate kind of framework is important to incorporate extra components in demonstrates, for example, area or age. PDE displays fill such need.

A case of PDE display for scourge disperse is Murray's model [9] of fox rabies demonstrated as follows.

$$\frac{\partial S}{\partial T} = -rIS \qquad \text{Eq-(9)}$$

$$\frac{\partial I}{\partial t} = rIS - aI + \mathrm{D}\frac{\partial I}{\partial x} \qquad \text{Eq-(10)}$$

In this exceptionally oversimplified to demonstrate, foxes are arranged into two gatherings, to be specific tainted I, vulnerable S. Murray takes a gander at the scourge dispersed at location the foxes are permitted to go in any measurement. Here r speaks to passing measure, a represents death measure of foxes, and D the measure of fox diffusion.
The other case of PDE utilization in scourge demonstrating is Feng's, et al. [10] arrangement of PDE's to display a malady in shifting age bunches utilizing a SIS display.

$$\left(\frac{\partial}{\partial t} + \frac{\partial}{\partial a}\right) si(t,a) = -\mu i(a) si(t,a) - \Delta \mathrm{i}\big(\mathrm{a}, \mathrm{u}(\mathrm{t},.)\big) si(t,a) + \gamma \mathrm{i}(\mathrm{a})\mathrm{ui}(\mathrm{t},\mathrm{a}) \qquad \text{Eq-(11)}$$

$$\left(\frac{\partial}{\partial t} + \frac{\partial}{\partial t}\right) ui(t,a) = -\mu i(a) si(t,a) - \Delta \mathrm{i}\big(\mathrm{a}, \mathrm{u}(\mathrm{t},.)\big) si(t,a) - \gamma \mathrm{i}(\mathrm{a})\mathrm{ui}(\mathrm{t},\mathrm{a}) \qquad \text{Eq-(12)}$$

Here, every gathering i, $s_i(t,a)$ speaks to age particular volume of vulnerable people to time unit t and $u_i(t, a)$ speaks to the age particular volume of tainted people at time unit t. $u_i(a)$ speaks to fatality measure and γ_i speaks to recuperation measure. At last, K_i as well as $K_{i,j}$ speak to the passing measure of sickness inside gathering i as well as between gatherings i , j, separately. The advancement as well as investigation into such demonstrates, Feng, et al. could reach determinations in regards to facts important to worldwide endurance.

1.4 Discrete (Difference Equation) Models

The ODE as well as PDE demonstrates depict framework where factors have been recognized for progress on the persistent premise. The other way to deal with demonstrating a scourge happens in utilization of difference or distinction conditions. Such sort of demonstrating decides changing amounts at particular pace interims [11]. This upside to utilize difference demonstrates is that it regularly give superior portrayal for information getting considered, as information is ordinarily gathered in non-continuous time interims instead of persistently [12]. Beforehand, a case of a persistent SIR model was depicted, yet a similar idea may be connected to difference framework. A fundamental SIR show in difference shape is demonstrated as follows.

$$S(t+1) = St - \frac{B}{N}ItSt + b(It + Rt) \quad \text{Eq-(13)}$$

$$I(t+1) = It(1 - r - b) + \frac{B}{N}ItSt \quad \text{Eq-(14)}$$

$$R(t+1) = Rt(1 - b) + rIt \quad \text{Eq-(15)}$$

In this arrangement of conditions, S_t, I_t, and R_t speak to count of tainted, vulnerable, and recouped people, separately. B speaks to count of associations which outcome in the contagion, b is beginning and ending measure, r is proliferation measure from an ailment. This accepts that people have been conceived defenseless of some specific maladies which show that beginning and demise measure are equal. The arrangement of conditions, or comparable sub-ordinates of it, can be utilized to display different maladies, and other adolescence sicknesses [11].

Ramani, et al. [12] utilized difference pace demonstrates, particularly a SIRS display, to take a gander at the wavering conduct of plagues after some pace. They took a gander at the incidents, the consistent populace when no demise happens, as well as when the populace was having the capability to increase lasting resistance either with recuperation or fatality [14]. At this point when populace stayed consistent, the scourge moved toward a settled point, where in any event some portion of the populace stayed tainted. Be that as it may, when people were permitted to leave the populace by methods for death or lasting insusceptibility, this wavering impact was at first present, however in the end the scourge vanished totally.

The models examined most importantly drop to classification of academic displays. Every sort is having a few points of interest and detriments relying upon the motivation behind the model [14, 15]. This review now hopes to analyze and build up a later way to deal with displaying, operator-based demonstrating.

1.5 Problem Statement

The proposed model considers the effects of demographic attributes of population, behaviors, and social networks and active degree of incubation individual.

This research gives a novel look into the basic science of epidemics modeling as well as presents potential factors particularly travelling and social connections among people for spreading the influenza in susceptible population. It also considers the control methods such as average-segregation-propensity and average-clinic-moving-propensity for limiting the transmission of influenza and thus helpful in fast recovery. Basic transportation principles are additionally utilized to simulate individual travels, taking into consideration the infection spread at the time of journey.

An agent-based modeling is used to simulate the spread and control of influenza in a semi-closed population, but with additional features such as separation, immunization, quarantine, travel and connections among people. However, it is assumed that the virus does not mutate, and that upon recovery, an individual will have perfect immunity.

1.6 Scope of Work

In this thesis, we have considered the spreading factors of influenza and additionally control parameters. The influenza can spread through social networking and travelling from one region to the other.

Control parameters are average-isolation-tendency which slows down the transmission of disease and average-isolation-tendency which helps in faster recovery.

The proposed work reduces the number of infected individuals and recovery rate due to control parameters. Graphs are plotted for different strategies and the results are accounted for.

1.7 Thesis Organization

The rest of the sections of the proposal are sorted out as follows:

Chapter 2 presents the evolution of influenza and its transmission and control factors and also presents the detailed insight over the techniques used in the proposed work, i.e., agent-based modeling for simulation of influenza virus.
Chapter 3 discusses the related work of the various techniques for influenza spread and control. Brief overview is provided for the past techniques.
Chapter 4 gives the design and implementation details of the proposed work.
Chapter 5 gives the implementation details.
Chapter 6 presents the result analysis.
Chapter 7 concludes the thesis and presents the future work that could be done.

CHAPTER 2 - BACKGROUND

2.1 Evolution of Influenza and factors affecting Influenza

Influenza, ordinarily called as "**flu**", is a contagious illness created by flu bacteria [3]. Signs may be gentle to extreme [5].The usual signs are: a high fever, runny nose, sore throat, muscle torments, migraine, hacking, and feeling tired. These signs commonly start 2 days following the presentation to the contagion and must end fewer not as much as seven days. The cough, in any case, may keep going for over two weeks [3].
In kids, there might be sickness and vomiting, however these are not basic in youths. Vomiting and sickness happen all the more normally in the unrelated contagion gastroenteritis, which is now and again incorrectly know as "abdominal influenza". Difficulties of flu can incorporate bacterial pneumonia, auxiliary viral pneumonia, sinus contagions, and intensifying of past medical issues, for example, asthma or heart disappointment [4][5].

Three sorts of flu contagions influence individuals, called Type A, Type B, and Type C [4]. As a rule, the contagion is dispersed by wind from sneezes or coughs [3]. That is accepted to happen generally in moderately low separations.

In the Northern region and Southern region of the world, scourge happen mostly in cold season whereas in zones around the equator scourge can happen at any time of the year.

The most prevalent theories regarding why the influenza strikes in winter-

- During the winter, individuals spend more time inside with the windows fixed, so they will probably inhale an indistinguishable air from somebody who has the flu virus and subsequently get the virus [3].
- Days are shorter during the winter, and absence of sunlight prompts low levels of vitamin D and melatonin, both of which require sunlight for their evolution. This compromises our immune frameworks, which then diminishes ability to fight the contagion.

- The flu virus may survive better in colder, drier atmospheres, and hence the ability to infect more individuals.

2.1.1 Transmission

Seasonal flu spreads at ease, with fast carrying in swarmed regions including schools and nursing homes [21]. At the point when the tainted individual sneezes or coughs, droplets containing contagions are scattered into the air and are spread to people in closeness who inhale these droplets in. The contagion can likewise be spread by hands polluted with flu contagions [22].

At the point when a tainted people coughs or sneezes the greater part a thousand contagion pieces can disperse to those nearby. In generally not sick grown-ups, flu contagion exfoliating increments forcefully one-half to one day following disease, tops on second day and holds on for a normal aggregate term of 5 days—however can endure the length of 9 days. In the individuals who create symptoms from trial contagion, indications and viral shedding demonstrate comparative example, yet with viral shedding going before sickness by one day [12]. Kids are considerably more contagious than grown-ups.

Influenza may rise in 3 essential strategies i.e. by coordinate conveying (when a tainted individual sniffles bodily fluid straightforwardly into the eyes, nose or mouth of someone else); the flying course (when some individual takes in the mist concentrates conveyed by a polluted individual sniffling, hacking or spitting) and through hand-to-eye, hand-to-nose, or hand-to-mouth carrying, either from sullied areas or from straight individual link, for example, an agreement. The comparative significance of such methods of carrying is hazy, and all might add to the dispersion of the contagion. In the flying course, the droplets i.e. sufficiently little for individuals to breathe in are 0.5 to 5 μm in measurement and breathing in only one globule may be sufficient to bring about a disease. Despite the fact that a solitary sneeze discharges up to 40k globules, the greater part of these drops are very expansive, would rapidly put out of wind [23]. To what extent flu gets by in airborne droplets is by all accounts affected by the states of moistness as well as UV rays, having less moisture and an absence of sunrays in cold season supporting its endurance.

As this flu contagion can endure exterior of the body, it can likewise be transmitted by infected spaces, for example, banknotes, doorknobs, light switches and other family unit things. The time allotment the contagion will endure on the space changes, with the contagion making due for 1-2 days on hard, non-permeable spaces, for example, plastic or metal, for around 15 minutes from moisture less disposable fabrics, and just 5 minutes on film. Be that as it may, if the contagion is available in bodily fluid, this can secure it to huge time. Avian flu contagions can survive inconclusively during solidification [24]. They are suspended by warming to 56 °C for at least one hour, and additionally by acids (at pH <2).

2.1.2 Contagion control

Sensibly successful approaches to diminish the carrying of flu incorporate great individual wellbeing and cleanliness propensities, for example, not making physical contact with your eyes, nose or mouth; repeated hand cleaning; covering sneezes and coughs; dodging near link to debilitated individuals; remaining house yourself on the off chance that you are wiped out [25]. Abstaining from spitting is likewise suggested. Despite the fact that face covers may help anticipate carrying when looking after the wiped out, there is blended proof on advantageous impacts in the group. Smoking raises the danger of contracting flu, and creating more serious illness side effects.

Since flu emerges by droplets as well as association with tainted spaces, space disinfecting might assist keep a few contaminations [26]. Liquor is a viable sanitizer against flu contagions, while quaternary ammonium mixes can be utilized with liquor so that the disinfecting impact goes on for more. In clinics, quaternary ammonium mixes and dye are utilized to purify surfaces or tools that are being possessed by ill people with flu side effects. At their rest place, this should be possible successfully with a weakened chlorine blanch.

Social separating techniques utilized amid past scourges, for example, shutting schools, places of worship and theaters, hindered the contagion dispersion yet had not been big impact on the general fatality measure [10]. It is indeterminate while diminishing social groups, by for instance shutting schools and work environments, will lessen carrying since individuals with flu may simply be moved starting with one territory then onto the next; such measures would likewise be hard to uphold and may be disagreeable. At the point when little number of individuals are tainted, disconnecting the ill people may lessen the danger of carrying.

Hand washing frequently decreases the danger of disease in light of the fact that the contagion gets suspended with cleanser. Using a clinical face cover is likewise valuable. Annual inoculations contrary to flu have been prescribed by the WHO for those who are having great hazard. The antibody is normally powerful contrary to 3-4 sorts of flu. It is generally very much endured. An immunization which is created for a year might not be helpful in the next year, because contagion develops quickly. Antibacterial medications, for

example, the neuraminidase inhibitoroseltamivir, in mid of others, have been utilized to medicate flu. Their advantages in the individuals who are generally solid don't seem, by all accounts, to be more prominent than their dangers. No advantage has been found in those with other medical issues [27, 28].

Individuals with the influenza bacteria are instructed to receive lot of leisure, drink bounty regarding liquids, stop from using tobacco and liquor and, if fundamental, receive solutions, as an instance, acetaminophen (paracetamol) to diminish the muscle pains and fever regarding to flu [29]. Kids as well as youngsters having flu indications must avoid eating ibuprofen amid an influenza contagion, on the grounds that doing as such can respond Reye's disorder, an unusual yet possibly deadly liver illness.

Since flu is brought on by an contagion, anti-contagion operators have no impact on the disease; unless endorsed for auxiliary contaminations, for example, viral pneumonia. Antibacterial solution might be powerful, if provided quickly, however a few exertion of flu may demonstrate control of the normal antibacterial medications and there is worry regarding the nature of the exploration [30].

The 2 states of antibacterial medications utilized contrary to flu are M2 protein avoidance (adamantane subsidiaries) and neuraminidase avoidance (oseltamivir and zanamivir).

2.2 Agent-based Modeling

Individual based, or operator based demonstrating, is a generally recent range of learning when contrasted with traditional displays. Agent based modeling were available preceding PCs, their notoriety expanded through coming of PCs which assists by velocity and intricacy of reproduction study. To specific demonstrates have been verifiably perceived to their commitment for the area of learning. They are Botkin's JABOWA timberland demonstrate in the mid 1970's and De Angelis, Cox, and Coutant's display on fish accomplice development in 1980 [14].

So as to build up an operator based demonstrating, it is essential to unmistakably characterize the reason or objectives of such display. What data has been picked up by utilizing this display? What information will be gathered? When this is built up, the general demonstrate framework is thus characterized. That is the place an operator based demonstrating begins to segregate against traditional displays [31]. There are two essential segments, operators and environment in this demonstration.

The environment is made out of a network of fixes, or tissues, where people live. These fixes are the place the operators interface with atmosphere and different operators [32, 33]. As an instance, fixes may be having assets that operators expend. The fixes also possess qualities or traits that are characterized inside demonstrate [34]. Likewise, the operators are having their very own considerable lot properties. Every operator is given specific qualities, for example, an age, area upon matrix, the capability to roam, and some additional attributes regarded fundamental by the reason for the display. There might be a wide range of operators inside a model, each with its own particular arrangement of qualities; be that as it may, the additional operators there are , the extra prominent their disparities, the additional unpredictable the display moves toward becoming. When characterized, these operators continue to a progression of guidelines that enable them to communicate with different operators in the atmosphere and demonstrate [34].

The scope of collaborations amongst operators and additionally fixes is needy over the sort of demonstrate. As an instance, in a sociology display concentrated on isolation, contrasts among operators may make them move; in killer-victim demonstrates, one sort of operator can encourage off to other; in rivalry demonstrates, distinctive sorts of operators can go after the similar assets situated in a fix; in contagion displays, people can approach in association with others bringing about disease. In view of such associations, the qualities of every operator are changed amid imitations [35].

Keeping in mind the end goal to concentrate such demonstrates, a PC code of any sort is fundamental. With no successful innovation, such demonstrates rapidly wind up plainly unwieldy and lose their handiness. Gilbert [35] suggests a few pre-designed projects for ABM's and positions them as indicated by usability and a few extra conditions. The following projects he assesses are Repast [37], Swarm [36], Mason [38], and NetLogo [42]. At that time every one of the four projects has focal points, demonstrate in such review is created utilizing NetLogo for its convenience, satisfactory velocity, basic coding dialect.

The utilization of operator based demonstrating is being developed lately, and their esteem is rapidly getting to be noticeably clear in numerous zones. In scourge displaying ABM's is right now being utilized to create anticipation arrangements to keep both normally happening pestilences, for example, avian-influenza [39] from spreading and additionally to give reaction arrangements to natural fighting [40].

The fundamental cases of the utilization of genuine information in operator based demonstrating originated with longing for having readiness get ready for scourge flu. Germann, et al. [41] utilizes an operator based demonstrating and U.S. Registration information on populace circulations and additionally Department of Transportation information to build up a display to learn approaches to resistant the flu dispersion in the U.S.. With this demonstrates they may create expectations in regard to the spread of flu and how to suitably immunize the populace in view of how frequently people are in link with each other and the supply of immunizations i.e. accessible. That demonstrates likewise to

give proposals with respect to how to best moderate the scourge spread if immunization accessibility dips into a specific sum.

A moment case of the utilization of ABM's takes a gander at the dispersion of an ailment through Tokyo. Ohkusa and Sugawara [43] utilized genuine "Individual Trip" information for the Tokyo city to imitate the way a scourge will be able to disperse in this city. Utilizing the operator-based strategy and genuine information, they could mimic links at native place with the folk, amid conveyance, by cordial link to decide the way scourge would disperse.

Operator based demonstrating gives a technique for displaying by which to mimic typical circumstances or record for the distinctions between people. With expanding upgrades in innovation and PC coding, they keep on growing in prevalence as an approach to analyze difficult associations.

2.2.1 Features of Agent-Based Models

2.2.1.1 Operators

Operators are self-sufficient elements, i.e. their conduct is not dictated by a worldwide resistor; rather, they perform what these are customized to perform in their present circumstance. Every operator is having specific predefined qualities or characteristics. An operator collaborates with the environment and with themselves [44]. As an instance, sick people with particular illness qualities may taint different operators in their link. Operators may demise or bring forth recent operators. Operators additionally have recall and can take in new practices from different operators or with an atmosphere. Operators take after predefined tenets and heuristics that decide their conduct in predefined circumstance on the premise of their attributes and past time. Communications between operators can deliver chain impacts. Consequently, operator-based strategy can expressly catch informal communities, which once in a while are basic to imitating contagious ailment dispersion.

2.2.1.2 Environment

It gives a medium to cooperation among operators. Every operator demonstration inside their condition and may likewise cooperate by atmosphere. Cases of environment incorporate healing centers, schools and urban areas [45]. Nature may likewise incorporate detached articles, for example, streets or air fly out for operators to go inside their condition or to give operators assets, for example, access to medicinal services.

2.2.1.3 Emergence

A standout amongst the most essential and extraordinary qualities of operator based demonstrating is that it catches emanating marvels that outcome through communications of people elements. With knowledge, a developing wonder advances in an unusual path as the procedure advances. The key question about development is the thing that progression of the framework or what demonstrate results rise up out of what practices of the operators and what qualities of their condition [46]—for instance, the way people-rank choice to inoculate or to remain at house once wiped out amid the flu weather influences the pinnacle of a flu plague [47]. Reenacting singular level practices and their collaborations

and watching the frameworks level results can catch such 'base up' wonders. Different cases of rising impacts are the manners by which sexual practices, for example, inclination to utilize condoms or standards for liberality in polygamous practices, affect the HIV disperse pestilence in a specific culture; and the way a person's sticky to suggest isolate could influence a plague of Ebola contagion ailment in a group [45]. A rise marvel along these lines can be characterized utilizing the accompanying qualities: it is not just the total of features of the demonstrate people; it is an alternate sort of outcome from people features, and it can't be anticipated from people attributes [48].

2.2.1.4 Network Structure

The fundamental favorable circumstances of operator based demonstrating is their capacity to catch linking systems between people [49]. The system framework figures out which people can collaborate with which different people and conceivably carry illness [34]. The topology of the system of connections characterizes such co-operations. A few standard system structures can be utilized to characterize collaborations among specialists, for example, completely associated systems, arbitrary systems, little world systems and without scale systems [34]. These system structures have diverse properties, for example, the speed of the spread of malady and network between operators. For instance, a person with a greater system of connections assumes a vital part in the spread of malady, or an irresistible individual in an exceedingly bunched system is profoundly prone to contaminate others in the system.

2.2.1.5 Randomness

Operator based demonstrating regularly are random in nature. Randomness alludes to the way that people confronting similar probabilities and results will encounter the impacts of a sickness or mediation distinctively [49, 50]. For instance, assumption is ten percent of ill people in a hospital experiments pass on inside a year. In an affair that this occasion is displayed in a gathering of hundred partners, roughly 10 individuals would bite the dust and the rest would survive. The random way of operator based demonstrating gives the benefit of catching arbitrariness, all things considered, situations. This irregularity is otherwise called first-arrange instability and is caught by the utilization of pseudo-arbitrary

numbers. Conversely, deterministic models dependably create similar outcomes each time they are run. While first-arrange vulnerability identifies with haphazardness in results, second-arrange instability identifies with parameter instability, which emerges through the way that genuine estimation of factor can't be recognized from hospital review and just an assessment may be defined [49, 50]. Auxiliary-arrange instability is ordinarily assessed with affectability examination. The rank of first-request instability may be greater in operator based demonstrating than in STMs or DES. This is on the grounds that ABMs catch co-operations among operators, and in addition movement toward illness (or different occasions) inside every operator. To start with request vulnerability may be decreased by executing the display a few pace, utilizing distinctive arbitrary integers [52]. This repetition of pace is additionally normally called the first-request Monte Carlo reenactments or experiments count. The adequate count of needed Monte Carlo simulations relies on upon the framework, quantity of factors and the pace skyline of demonstrates, and it may be surveyed either subjectively or by assessment of the difference in display results [50, 51].

2.2.1.6 Time Increments

Time may progress either in non-continuous time units, called the loops, or in a constant way in which a one of a kind occasion decides the following augmentation. Inside every non-continuous time unit, particular occasions may happen (e.g. carrying of illness, movement of ailment or development of specialists); in this way, the arrangement of occasions for every loop is vital. Inside every cycle, each operator is made a request to refresh their attributes in a specific request. As an instance, numbering participation in the start of the cycle in STM brings about overestimation of the future, and tallying enrollment toward the finish of the cycle in STMs brings about underestimation of the future. In this way, half-loop rectification can likewise be required in operator based demonstrating. The next choice of time increases from operator based demonstrating is to utilize planned occasions rather than settled interims. In such strategy, just operators that require for making a move are conjured and time forwards to the following occasion. That strategy is like time additions. Rather than propelling the time by settled loops, the display forwards to the following occasion happening to whatever time later on. That needs planning of every forward occasion. Nonetheless, planning of occasions for the most part turns out to be

more confounded with the non-continuous occasion strategy in correlation with the settled loop strategy in operator based demonstrating. What's more, utilization of occasions to propel time can define execution of connections extra entangled than in the settled loop strategy [53].

2.2.1.7 Open Versus Closed Populations

Open populace alludes to the way that recent individuals are included to demonstrates like beginning, settlements, measure, and so on. Operator based demonstrating also permit the adaptability of displaying open as well as shut populaces. Conversely, Markov models for the most part begin with a shut companion and don't permit beginnings in display. Leverage of open populaces is that they can successfully catch true marvels, for example, upright carrying of illness (or different attributes) from mother to kid, or migration to a nation. Furthermore, open-associate demonstrates additionally intently speak to this present reality than shut partner models by catching populace progression, for example, expanding life span after some time. Open displays can reproduce numerous birth companions after some time [52, 53]. Rather than shut companion displays, open-associate demonstrates may give profits reliant on the planning of execution of intercession [53]. Numerous AB recreation models utilize human-helped alignment [15, 29, 32, 35, 47, 53], while some perform calculation driven adjustment [34, 48]. Despite the fact that calculation driven adjustment is programmed, the speed of the alignment procedure relies on upon the multifaceted nature of the calculation.

CHAPTER 3 – RELATED WORK

In this section, related work is presented on existing techniques of spread and control of influenza virus. Overview is provided for each technique, with the tools used.

3.1 Operator-Based Modeling for Influenza H1N1 in an Artificial Classroom [16]

Tool- Bio War

An artificial classroom with operator understudy and specialist instructor has been simulated [16]. Relational associations in classroom are portrayed as get-together based social association sets. The crisis is instantiated as the over spreading procedure of flu in classroom from 8:00 AM to 12:00 AM. Operator in simulated classroom is made in two segments. One area is standard operator exhibit including major measurement attributes, hones, and casual groups that change an extensive variety of experts in simulated community. The other part is influenza H1N1referred estimation properties, practices, and association systems. Condition display gives geology, atmosphere and air, and building information underpins by API interface.

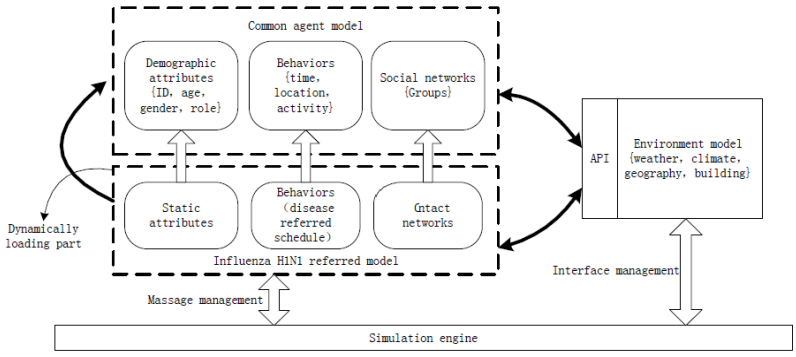


Figure 1: Conceptual framework of an artificial classroom

An artificial classroom is introduced with 160 seats. Classroom topography condition gives surface trademark objects data like work area, situate, stage, space and way, and furthermore denote the characteristics of specialists that enable different operators to get data of neighborhood or area data of their social connections.

Influenza H1N1 prepare in state of 144 understudies and 3 brooding people for 5 tests has been delineated. The outcomes demonstrate that:

- The total tainted count of people differed in analyses.
- The trials show that tainted measure in early morning span is greater than the measure after 10:00 AM, and tainted measure has a tendency to be smoothness, and the count of tainted persons develops gradually.
- The outcomes of most of the trials with same parameters are agreeing, and has not indicated amazing marvel.

The explanations behind moderate developing tainted measure is that person has tendency to converse with the one have social connections, and people have social connections are before sit together [16]. In the mid 2 hrs, brooding people quickly taint their associate by chatting close-by, amid following 2 hrs, brooding people scarcely to taint different individuals having no social connections. Thus, the tainted measure backs off.

Computational investigations are taken in the simulated classroom, and outcomes show that the dispersion of flu H1N1 among high thickness of populace is identified with statistic properties, practices, and informal organizations and dynamic level of brooding person.

The correlation of infected rate with various initial incubation people has been appeared. Clearly when size of tainted people climbed, the tainted measure develops all the more quickly.

The research gaps here are travelling, immunization, isolation, and medication rest.

3.2 An Operator-Based Modeling for Scourge Influenza in Egypt [17]

The suggested multi-operator display depends upon the demonstrating of people's connections in a space time setting [17]. An imaginary multi-operator display is proposed to imitate day by day individual-to-individual contact of individuals in an expansive scale group influenced by the scourge flu in Egypt. This suggested demonstrate includes distinctive sorts of parameters, for example, social operator properties, dispersion of Egypt populace, and examples of operators' communications.

This suggested augmentation to SIR model includes recent states; displaying the genuine scourge conduct and resistant states, for example, (associated, isolated, not isolated, passed away, and vaccinated).

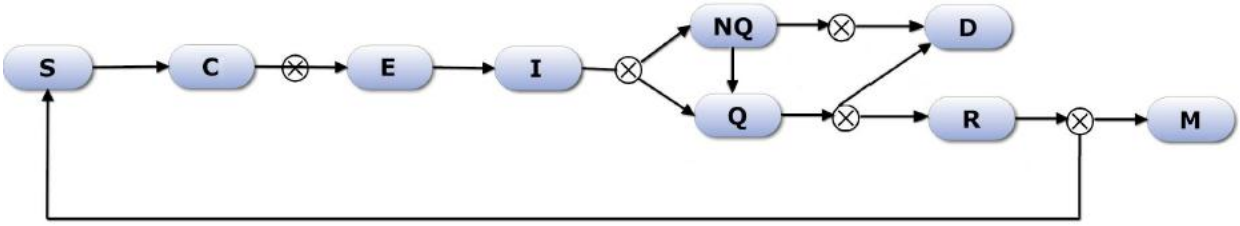


Figure 2: State chart of proposed extension to SIR model.

X-probability

(S) Vulnerable, (C) Associated, (E) Uncovered,(I) Tainted, (Q) Segregation, (NQ) Not segregation, (D) Passed away, (R) Recouped, and (M) Inoculation.

The **first state** defines the (S) Vulnerable operators, who are not linked with other tainted operators therefore liable to get tainted. Toward beginning of this demonstrating, all operators come under (S) Vulnerable state. The **second state** is the (C) Associated operators, who are directly linked with different contagious operators. The **third state** is the (E) Uncovered operators, who are tainted operators amid the brooding time of the sickness. The **fourth state** is the (I) Contagious operators, who are tainted. The **fifth state** is the (Q) Segregated operators, who are tainted operators separated by the social insurance experts. The **sixth state** is the (NQ) Not Segregated operators, who are tainted operator yet not separated. The **seventh state** is the (D) Passed away operators. The **eighth state** is the (R) Recouped operators. The **ninth state** is the (M) Inoculation operators, who are vaccinated against the ailment contagion.

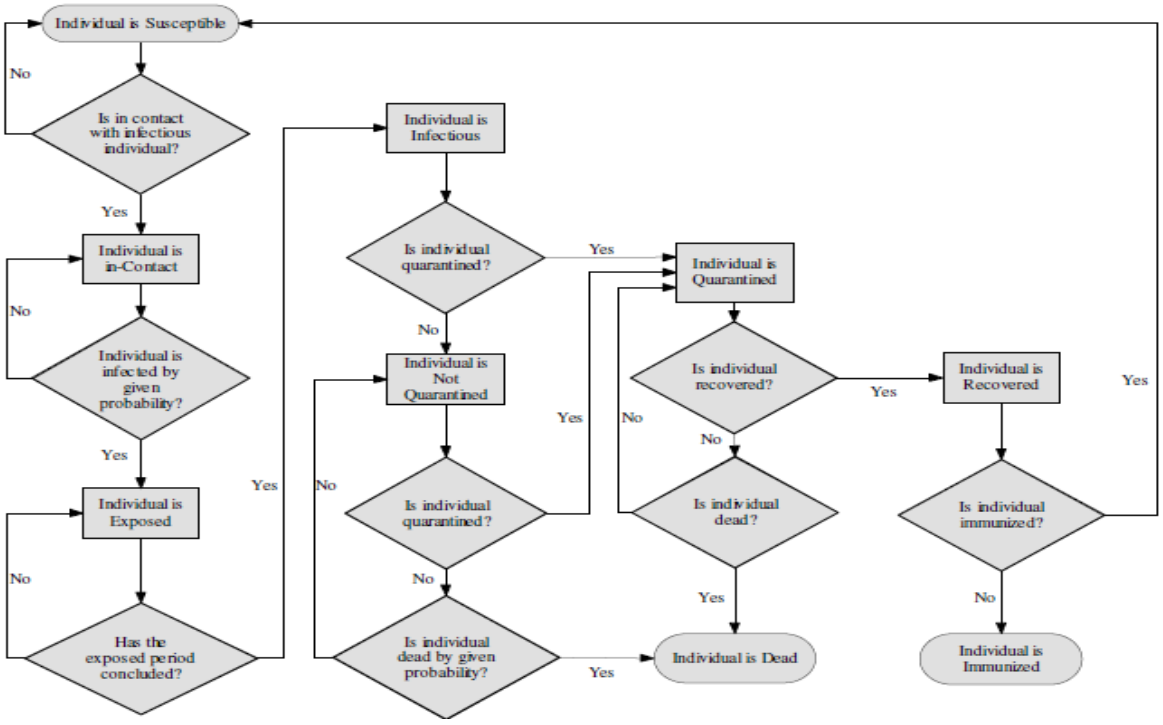


Figure 3: Flow chart of the proposed extension to SIR model.

Operator wellbeing behavior and ailment watch are affected by the suggested expansion to SIR demonstrate. Tainted operator would influence every operator in his informal communities to get uncovered. Subsequently, likelihood of operator to get tainted increments as per count of tainted operators in his informal organizations.

Examination of demonstrating results prompts comprehending the qualities of the displayed scourge, carried designs, the situations in which scourge may happen. Moreover, the suggested demonstrate is utilized to gauge viability of various resistant systems to mediate an scourge dispersion.

The proposed model is utilized to evaluate the viability of various scourge resistant techniques on the scourge disperse.

The research gaps here are travelling, immunization, and medication rest.

3.3 Influenza scourge spread simulation for Poland [18]

Basic transportation guidelines were utilized to copy people's travel in unique course evolving plans, taking into account the contagion spread during a trip [18].

The supposed states are as accompanied-

- ✓ Each operator, not yet tainted, is completely vulnerable.
- ✓ Every operator can get contagion just once, i.e. every recouped operator remains not sick until the last of the reproduction pace.
- ✓ Every contagion endures a week. It incorporates: a brooding phase for the initial two days, and after that a contagious phase, of consistent contagiousness, throughout the previous four days. The brooding time frame is a contagion stage, where an operator is tainted, but has not yet manifestations of illness, in this manner not contagious.

The assignment stream is accompanying:

- Scan in artificial community information.
- Scan in the estimation of imitation factors.
- Accomplish the primary spiral, i.e. at every time unit:
    - For every operator: give tour rank
    - For every operator: ascertain likelihood of contagion

  For a solitary operator, at time step t_k this likelihood is ascertained in view of the generally utilized equation, $P(t_k) = 1 - \exp(-\alpha n_F (t_k))$

  where α is the contagion carrying likelihood, i.e. likelihood of contagion being exchanged during association to a contagious people, n_F is force for every association of provided operator to tainted operators.

    - Result present scourge insights (aggregate count of sick people, recently sick, recouped, and so forth.).

Here proliferation ratio was controlled via doing the preparatory 4 days in length proliferations for each arrangement of α(carrying likelihood) and f (part of operators not remaining at native place during tainted)parameters. For these specific imitations length of brooding time frame had been stretched out to be four days. That permitted gathering aggregate count of contagions called just by the essential presenters amid their four days lasting contagious course. In this manner, fundamental reproductive proportion was assessed utilizing the numerical investigation covering the underlying period of the scourge episode, and representing the impacts of the carrying joint, the system format, progression.

It had been observed that estimation of R0 does not decide the scourge course. In particular, for the same or comparative estimation of R0, however extraordinary carrying measure of the contagion, additionally link factors, distinctive scourge situations had been taken. Along these lines, the estimations of the information parameters for requesting and classification of the outcomes were utilized.

As contagion is just conceivable when linked to a contagious people, it is adequate to decide count of co-tourists, particularly these contagious, to every voyaging operator amid his tour. Thus, rather than assuming a correct tour way, just middle of the road exchange urban areas between endpoints were considered.

A 2D sweep of f, α factors was executed keeping in mind the end goal to decide practical situations of scourge development. It ought to be noticed, that the same R0 esteems might be acquired with various arrangements of α and f parameters.

The research gaps here are social networking, immunization, isolation, and medication rest.

3.4 Quantitatively Evaluating Interventions in the Influenza A (H1N1) Scourge on China Campus Grounded on Individual-based simulations [19, 20]

The scourge flu (H1N1) carrying through grounds contacts was demonstrated and after that predict the adequacy of mediations for simulating contagious illnesses [19, 20].

In this model, the grounds populace is demonstrated as an interpersonal organization with hubs speaking to people and edges speaking to contact between two individuals, and every person (hub) with heterogeneous contagion movement is additionally displayed like performing operator. In this manner, the likelihood of disease for the vulnerable people is dictated to availability of that person, the contagion condition of their accomplices (associating hubs) in such systems. Students are normally doled out to residences after enlistment. Amid semesters, every student moves day by day between the quarters, swarmed refectories and classrooms on grounds. The entire populace living inside the grounds makes an extensive bunch over the span of a grounds episode of airborne flu A (H1N1).

A few presumptions are as per the following-

- Every tainted people is similarly contagious.
- The harmfulness of the scourge flu (H1N1) contagion stays immutable over the span of spreading.
- The insusceptibility and vulnerability of every individual is indistinguishable paying little mind to their age. That implies a suspicion of uniform insusceptibility and vulnerability framework in populace, i.e. true for this review.
- The term of brooding takes after homogenous dispersion of two days, people during this time are thought to be non-contagious.
- The span of indicative phase takes after homogenous appropriation of one to seven days. The person would be able to receive analyzed instantly following indications show up lastly get recouped toward the finish of this indicative phase without fatality.

- The contagiousness of a tainted people stays constant over span of indicative phase.
- No demographical impact was considered, i.e., disregarding the impact of individual's outflow and inflow on the contagion dispersion.
- People are invulnerable to scourge flu (H1N1) contagion without special case either subsequent to getting recouped from past contagion or with a postponement of fourteen to twenty one days following inoculation.

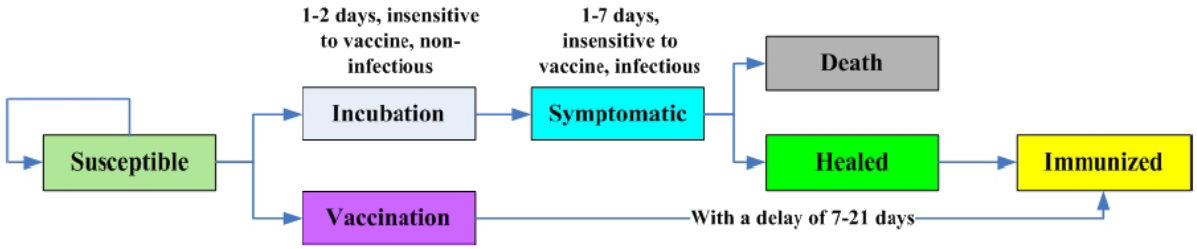


Figure 4: Contagion Progression of a Host Operator

The scourge flu A (H1N1) spreading simulations were performed in a populace of 10000 speaking to the grounds group. At first, an arbitrarily picked people are considered to be tainted, the time unit is fixed as one day. The carrying likelihood was signified inside a given time frame, i.e. 1 day, over the line which associates tainted people, a vulnerable people denoted as P.

All outcomes recommend that scourge flu (H1N1) on grounds would be able to cease to exist without mediation received; the best intercession is as yet isolating affirmed cases as ahead of schedule as would be prudent and, what's more, immunizing vulnerable individuals can additionally diminish the greatest day by day number of the tainted.

The research gaps here are travelling, immunization, isolation, and social networking.

CHAPTER 4-DESCRIPTION OF THE MODEL

4.1 Proposed model

This model mimics the infectious ailment dispersion in semi-closed populace, but with additional components, such as travel, segregation, hospitalize, immunization, and connections between people. In this case, presumption is that the contagion does not transform, and that upon recovery, an individual will have idealized resistance.

People roam the world over in irregular movement. There are two gatherings of people, spoken to as two different regions.

The nearness of contagion in the populace is spoken to by the shades of people. Four shades are utilized: white color denotes untainted people, red color denotes tainted people, green color denotes recouped people, and blue color denotes vaccinated people. The yellow individual symbolizes the well-being authority or emergency vehicle, who watches the world looking for tainted individuals.

After coming into contact with a tainted individual, an individual has a shot of getting the illness. Contingent upon their propensities (normal segregation propensity, normal clinic moving propensity), which are set by the client, tainted individual will either disengage from present area, and therefore remains there till complete recuperation or will go to doctor's facility (as demonstrated by the white color) and recover in one fifth of the recovery time, be compel quarantined into a doctor's facility by well-being authorities, or simply just roams. The tainted person is having the possibility of getting recuperation once the recuperation time gets slipped by. Once recouped, the individual is for all time resistant to the contagion.

Tainted people who are neither hospitalized nor isolated are having the shot of passing the contagion to other likely individuals in their vicinity. The likelihood of passing the contagion will be doubled, if the individual is in close proximity.

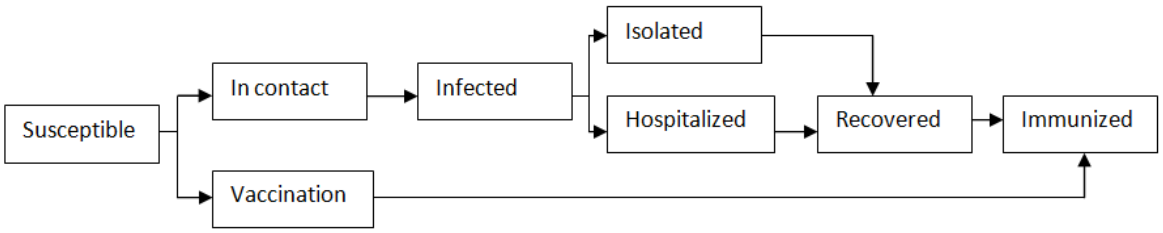


Figure 5: Proposed model diagram

Switches in the model are-

Links : There may be two options either on or off. Whenever on, there will be connections arbitrarily allocated to individuals, an illness gets to disperse double quickly than those of the tainted individual. Whenever switch is off, an ailment will disperse by equivalent opportunity for all tainted individuals.

Tour : There might be two choices either on or off. Whenever on, individuals from the two areas are permitted to move. Whenever off, the population remains in the area in which they stay.

Various sliders in the model are-

Initial-individual: The aggregate people count when the simulation starts.

Contagion-probability: The likelihood of passing contagion starting with one person then onto the next.

Recuperation-probability: The likelihood of a recuperating a person, once the normal-recuperation-time gets slipped by.

Average-recuperation-time: It is the time taken by a person for recuperation, by and large. The genuine person's recuperation time is taken from an ordinary circulation spun with its average as the normal-recuperation-time, and one-fourth of normal-recuperation-time as its standard deviation. This is to represent the variety of hereditary contrasts and the resistant framework elements of people.

Average-segregation-propensity: This defines the normal propensity for persons for segregation, therefore won't disperse ailments. Whenever any tainted individual gets recognized as the “segregator,” then that person will remain in the present area till complete recuperation by segregating.

Average -clinic-moving-propensity: This is the person normal propensity for moving to the healing facility during sickness. On the off chance that a tainted individual is distinguished from "clinic movers," at that point tainted person would move to doctor's facility, therefore gets to recuperate by a fraction of season in a normal recuperation time, because of proper pharmaceutical.

Emergency-vehicles: Number of well-being authorities or ambulances that move about at random, and compel-quarantine wiped out people. These well-being authorities get invulnerable to illness. They are not limited by geographic area.

Immunization-probability: The likelihood of an individual getting immunized, and thus invulnerable to the contagion.

Various graphs are as follows-

Cumulative infected and recovered: It shows the aggregate number of tainted or recouped people.

Populace: It shows the count of people whether sick or healthy.

Infected and recovery rates: It shows the assessed measures for dispersing the ailment. Disease and recuperation measures plot demonstrates the progress made by the combined tainted and recouped in populace. This marks the normal count of auxiliary diseases as well as recuperations.

Likewise with numerous epidemiological models, the number of individuals getting to be noticeably tainted after some time, in case of a scourge, is known as "s-bend."

R_0: Reproduction number.
In the study of disease carrying, the fundamental multiplication number (once in a while called essential regenerative proportion, or inaccurately essential conceptive measure, and meant R0) of a contamination can be thought of as the quantity of cases one case produces all things considered through the span of its irresistible period, in a generally untainted population.

This metric is valuable since it decides if an irresistible sickness can disperse through a populace.

At the point when

$R0 < 1$, the contagion will cease to exist over the long haul. In any case, if

$R0 > 1$, the contagion will have the capacity to disperse in a populace.

4.2 Simulation Model Set-up and Procedures

To achieve the outcomes, simulations were run utilizing the program NetLogo [2]. The SETUP button makes people as indicated by the parameter esteems picked by the client. After the necessary arrangements have been done, press button “go” for simulation. For stopping purpose again press the button “go”.

At first, all people are thought to be vulnerable. As the simulation advances, turtles experience certain techniques to emulate the spread of a scourge. The model goes through every methodology once each time step, which can be considered as any discrete unit the client picks identifying with the contagion. Turtles advance consistently, and in light of the average- recovery-time, these turtles are likewise ready to contract, spread, or recoup from the illness.

CHAPTER 5 – IMPLEMENTATION

This section gives the usage points of interest of the proposed model to concentrate the spread and control of flu contagion. The proposed model is actualized utilizing NetLogo.

NetLogo is an operator based coding dialect as well as coordinated displaying condition. It was outlined, in the soul of Logo coding dialect[54], to be "little limit or without upper limit". NetLogo is free and open source programming, under a GPL permit.
This shows programming ideas utilizing operators as turtles, patches, joins and the onlooker. NetLogo was intended for different groups of onlookers as a top priority, specifically: showing youngsters in the training group, and for space specialists without a programming foundation to display related marvels. Numerous logical articles have been distributed utilizing NetLogo.

The NetLogo condition empowers investigation of new marvels. It accompanies a broad models library incorporating models in an assortment of areas, for example, financial aspects, science, material science, science, brain science, framework flow. NetLogo permits investigation by changing switches, sliders, choosers, inputs, and other interface components. It is uninhibitedly accessible from the NetLogo site [55]. It is being utilized as a part of wide assortment of instructive settings from primary school to doctoral level school.

5.1 About NetLogo

5.1.1 Specialists

They are the part of NetLogo world. Specialists are creatures that would take be able to after directions. There are 4 sorts of operators in NetLogo: turtles, fixes, joins, and the onlooker. Turtles are operators that roam on planet[56]. The world is 2D as well as is secluded up into a framework of patches. Every fix is a square piece of "surface" where turtles can go. Connections are operators that associate 2 turtles. The onlooker is not having a range. The eyewitness doesn't watch inactively - it offers guidelines to alternate operators.

When this tool starts at that point no turtles are there. The onlooker would able to make recent turtles. Fixes would able to make recent turtles as well. Fixes are having facilitates. The fix with x-coordinate and y-coordinate as 0 is known as birthplace, directions of alternate fixes define level or upright separations. We call fix's directions as pxcor and pycor. An aggregate count of fixes is controlled by positions that are min-pxcor, max-pxcor, min-pycor, and max-pycor At that time when this tool begins, the value of max-pxcor and max-pycor are 16 and value of min-pxcor and min-pycor are -16. Turtles have arranges as well: xcor and ycor. The fix's directions depend upon numbers, yet a directions of turtle may be having points. That implies the turtle need not be in focal point of the fix , it can be situated anytime inside its fix[57].

Connections don't have facilitates. Each connection has two finishes, and each end is a turtle. In the event that either turtle passes on, the connection dies as well. A connection is spoken to outwardly as the bar associating 2 turtles.

5.1.2 Methods

Reporters as well as commands guide operators in this tool. A command is an activity for an operator to complete, bringing about some impact. A reporter is guidelines on registering the esteem, whenever asked by someone operator will provide it.

Commonly, title of command starts by gerund, for example, "make", "bite the dust", "bounce", "assess". The title of reporter is usually things or thing sentences.

Reporters as well as commands incorporated into this tool known as fundamentals. Reporters and commands we characterize ourselves are called systems. Every method is having title, gone before with catchphrase to, contingent upon in case it is the reporter system or a command strategy [58]. The watchword lastly denotes finish of laws in a strategy. Many reporters and commands use instructions - measures which a reporter or command takes while doing its activities or figuring its outcome.

5.1.3 Variables

Operator factors are spots to store esteems, (for example, integers) within operator. An operator inconstant may be worldwide inconstant, turtle inconstant, fix inconstant, and connection inconstant.

On the off chance that a variable is a worldwide variable, there is just a single an incentive for the variable, and each operator can get to it. Worldwide factors have a place with the observer.

Turtle, fix, and connection factors are distinctive. For each turtle inconstant, every turtle is having an incentive. Similarly for fixes and connections.

A few factors are incorporated with this tool. For instance, the turtles as well as connections are having shading inconstant, along the patches which are having pcolor inconstant.

Other implicit turtle factors incorporate ycor, xcor, heading. Another implicit fix factors incorporate pycor and pxcor.

5.1.4 Tick counter

Time goes in non-continuous strides in numerous demonstrates, known as "ticks". This tool incorporates an implicit tick counter to monitor what number of ticks that have been run by.

Tick reporter is utilized to recover the present estimation of tick counter in the program. The tick command propels tick counter by 1. An unmistakable every command undimmed the tick counter alongside every other thing [59].

When the tick counter is clear at that point, it's a mistake to attempt to peruse or alter it. Utilize the reset-ticks command to begin the tick counter.

5.1.5 Buttons

Buttons in the interface tab give a simple approach to restrict a model. Normally a display would be having no less than a "setup" button, for arranging the underlying condition of the universe, as well as a "go" button to create a demonstrate work constantly. A few demonstrates are having extra buttons which function different activities [53].

Ordinarily, the button is named associated by program which it has to execute. As an instance, a button that reveals "go" on it generally comprehend program "go", which signifies "execute go method".

5.1.6 Lists

In the most straightforward models, every variable holds just a single snippet of data, as a rule the string and an integer. Records allow us collect different snippets of data in solitary incentive with help of gathering the data in rundown. Every incentive in rundown may be the kind of significant worth: the string, or an integer, an operator or operator set, or considerably any other rundown.

Records take into account the helpful bundling of data in NetLogo [60]. On the off chance that operators complete a redundant computation on different factors, it may be less demanding to have a rundown variable, rather than numerous number factors. A few

primitives disentangle the way toward playing out a similar calculation on each incentive in a rundown.

5.1.7 Math

The digits in this tool are put away inside as twofold exactness decimal numbers, as characterized in an IEEE 754 approved.

In this tool, a "whole number" is essentially a digit that is having no partial portion. No qualification is made in the vicinity of 3 and 3.0; they are a similar number.

5.1.8 Random numbers

An irregular integers utilized by this are known as "pseudo-arbitrary"[61]. That implies they seem arbitrary, yet are in reality produced by a deterministic procedure. "Deterministic" implies that getting similar outcomes without fail, in the event that we begin with a similar arbitrary "seed".

With regards to logical demonstrating, pseudo-arbitrary numbers are really attractive. That is on account of this vital that logical examination be recreated - so anybody can attempt it themselves thus receive a similar outcome that you achieved. As this tool utilizes pseudo-irregular integers, the "tests" that we do with it can be repeated by others.

5.1.9 Strings

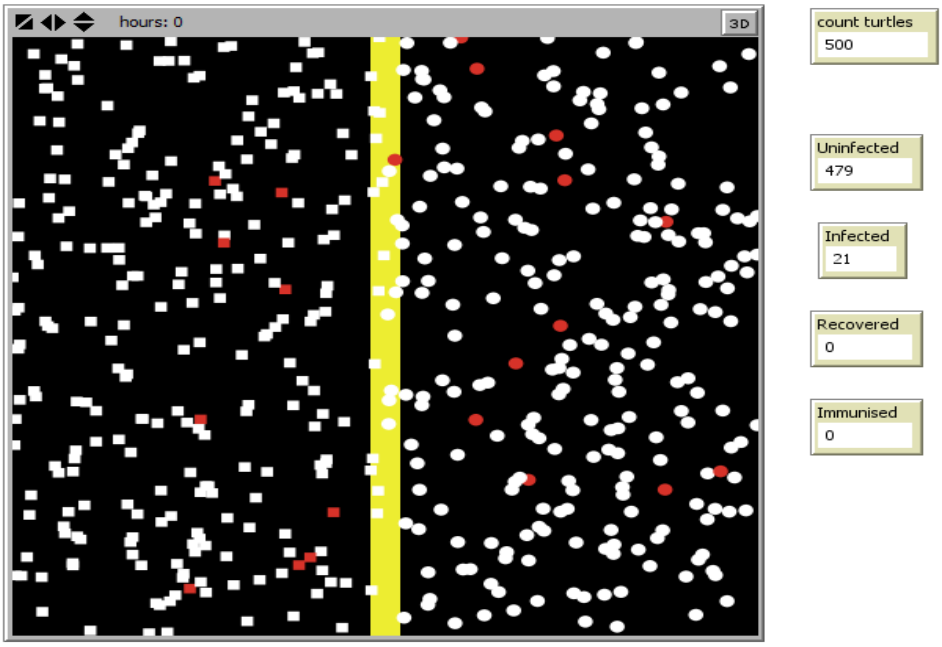
Strings can consist some Unicode set. To include a consistent string in this tool, encompass this by twofold citations [60]. A vacant string is composed by inserting emptiness along these lines: "".

CHAPTER 6 – RESULTS AND ANALYSIS

The results of the implementation of the proposed application are as follows-

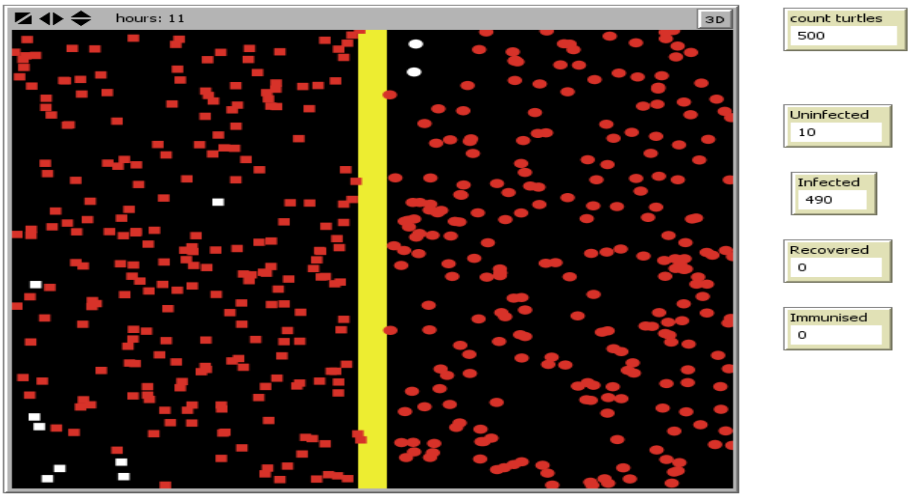
Test case no. 1-
To demonstrate the basic SIR Model.

Initial individual=500
Contagion-probability=25
Recuperation-probability=50
Average-recuperation-time=150



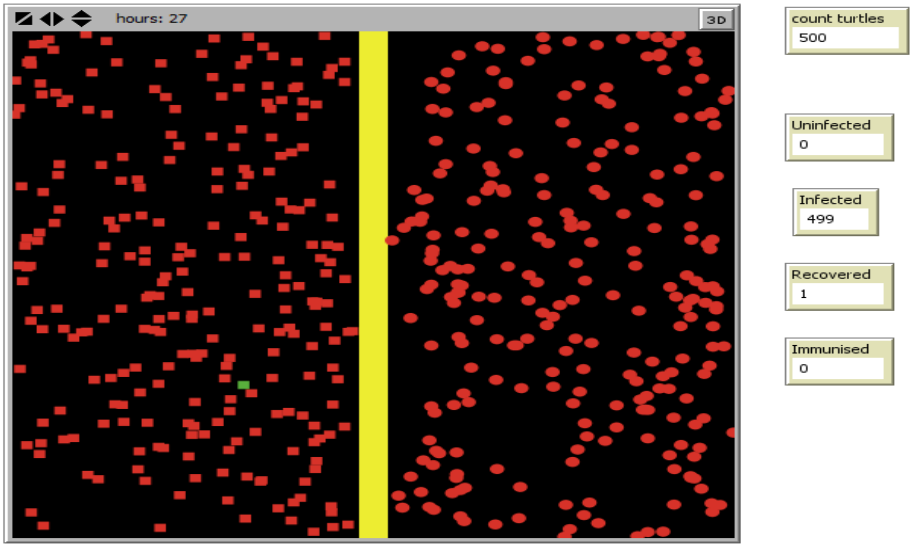
Screenshot 1

This screenshot shows that as the simulation begins, there are very few infected individuals.



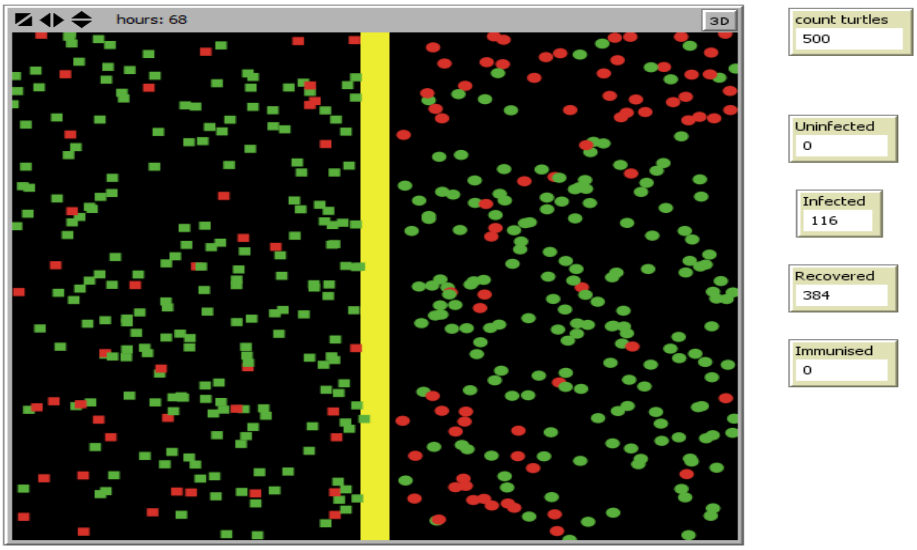
Screenshot 2

This screenshot shows that as the simulation progresses, infected individuals grow.



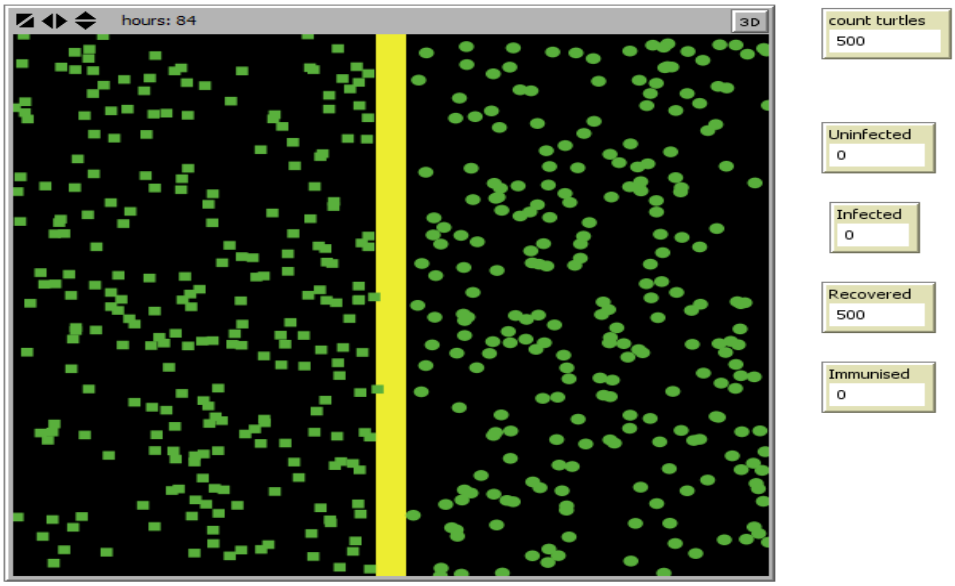
Screenshot 3

This screenshot shows that as the simulation advances, individuals start recovering.



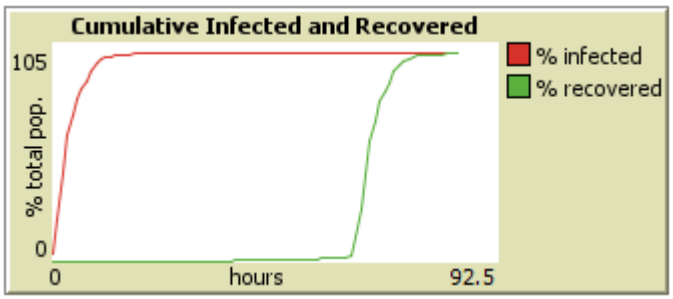
Screenshot 4

This screenshot shows that as the simulation progresses, there are very few infected individuals.



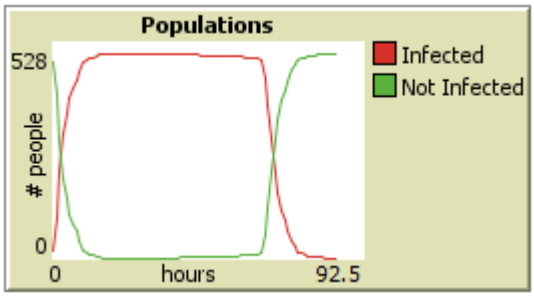
Screenshot 5

This screenshot shows that as the simulation ends, all individuals got recovery.



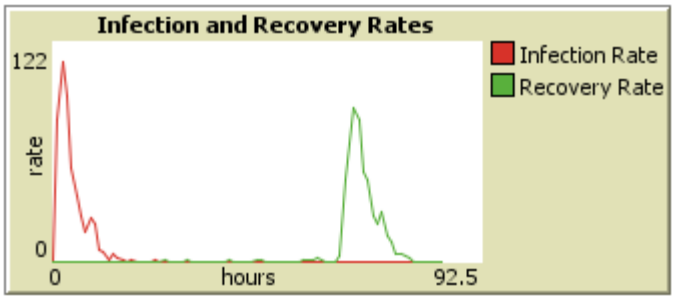
Graph 1

This graph plots the total percentage of individuals who have ever been infected or recovered.



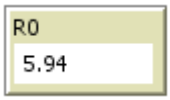
Graph 2

This graph plots the number of people with or without the disease.



Graph 3

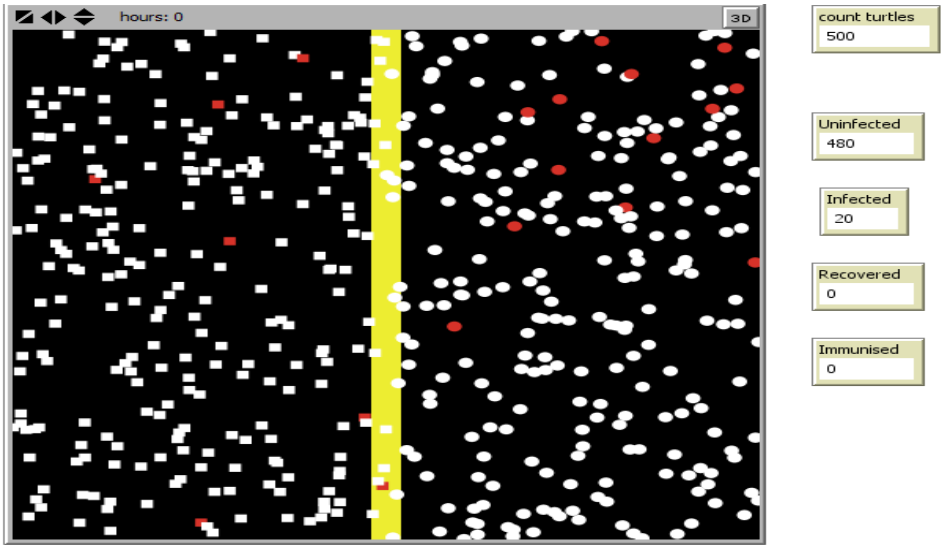
This graph plots the estimated rates at which the disease is spreading.



If the reproduction number is more than 1, it shows for the likeliness of an epidemic to happen. In the event that R0 < 1, it shows for the likeliness of holding back the infection transmission [11].

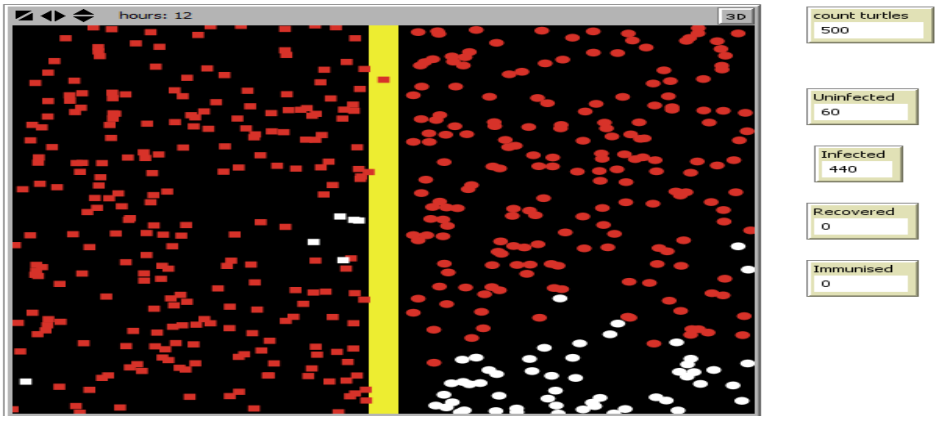
Test case no. 2-
To test the impact of increasing average-recuperation-time.

Initial individual =500
Contagion-probability=25
Recuperation-probability=50
Average-recuperation-time=200
When no links and no travel



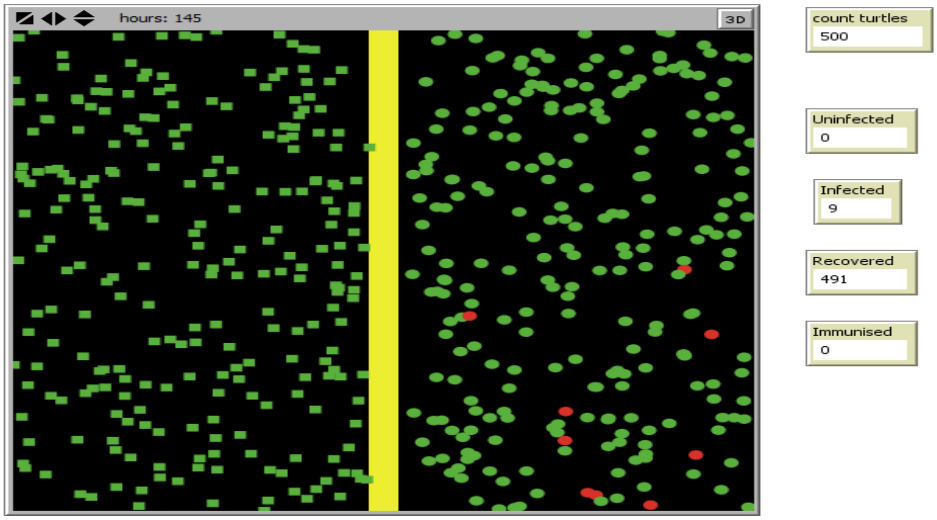
Screenshot 6

This screenshot shows that as the simulation begins, there are very few infected individuals.



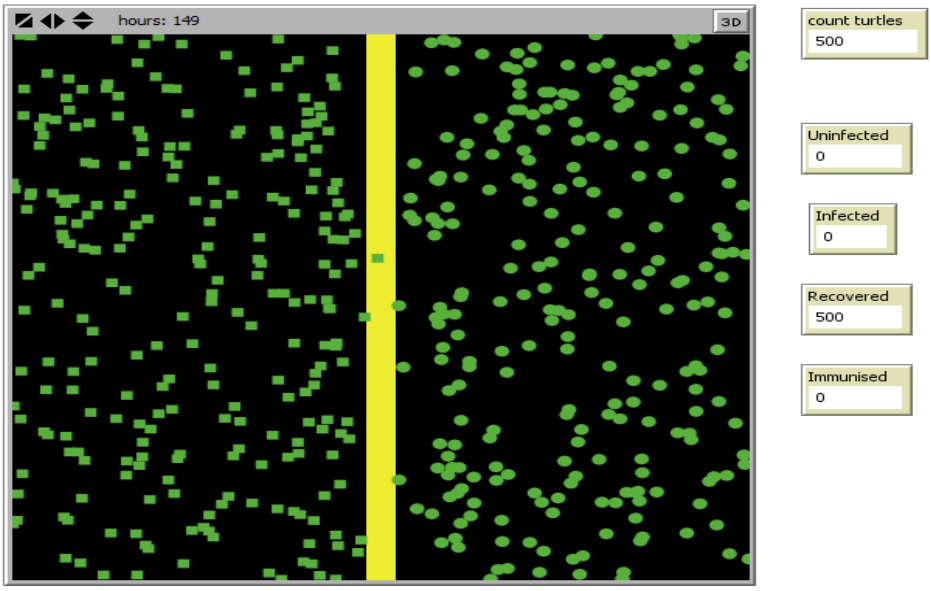
Screenshot 7

This screenshot shows that as the simulation progresses, infected individuals grow.



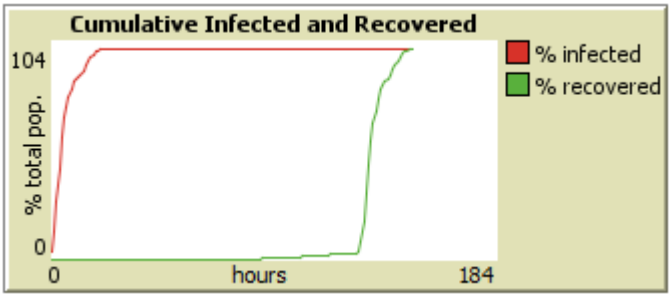
Screenshot 8

This screenshot shows that as the simulation advances, individuals start recovering.



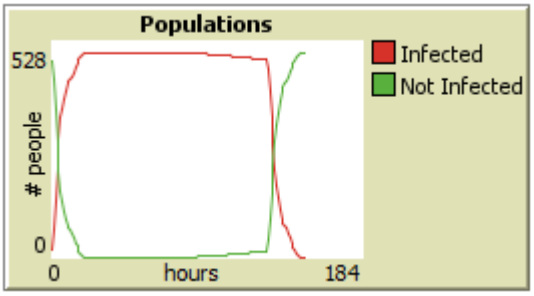
Screenshot 9

This screenshot shows that as the simulation ends, all individuals got recovery.



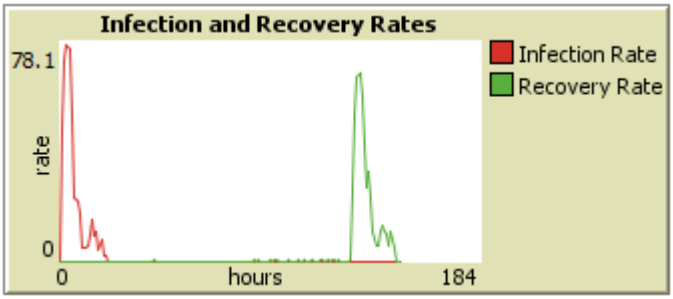
Graph 4

This graph plots the total percentage of individuals who have ever been infected or recovered.



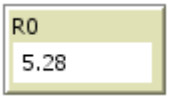
Graph 5

This graph plots the number of people with or without the disease.



Graph 6

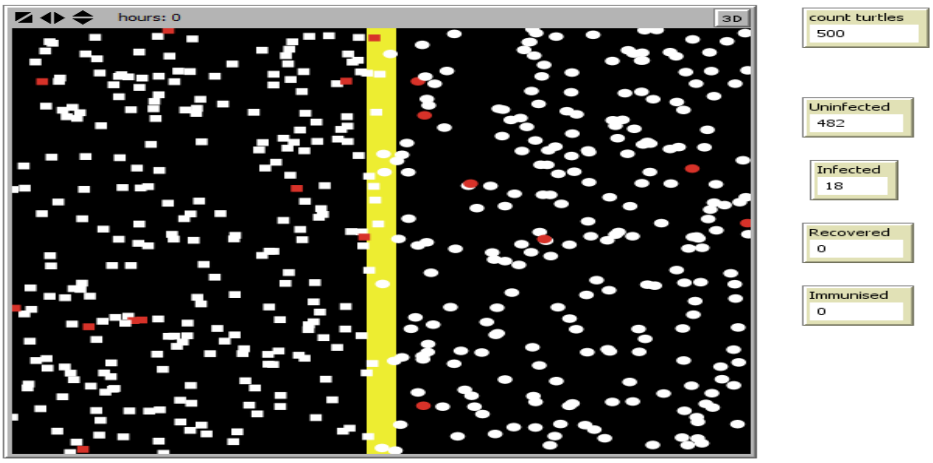
This graph plots the estimated rates at which the disease is spreading.



This demonstrates that when average-recovery-time is increased, the model takes more time to recover all individuals from contagion as the actual individual's recovery time gets increased.

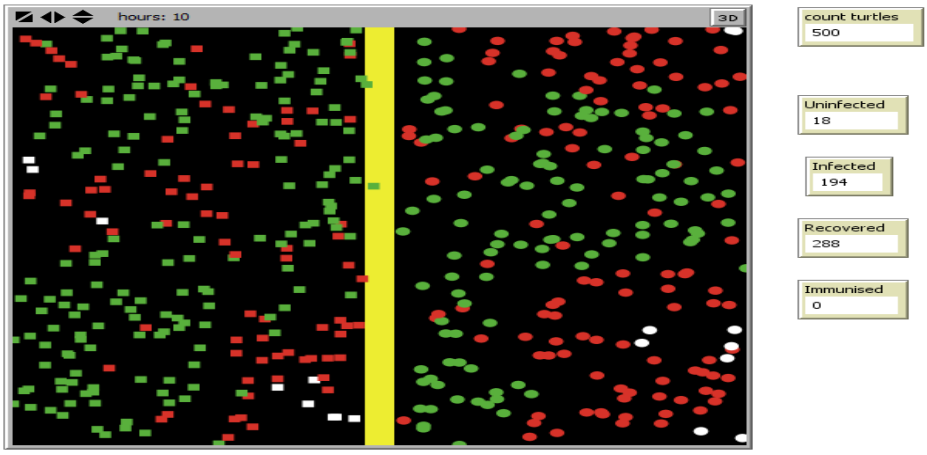
Test case no. – 3
To test the impact of increasing the recuperation-probability parameter.

Initial individual =500
Contagion- probability=25
Recuperation-probability=60
Average- recuperation-time=150
When no links and no travel



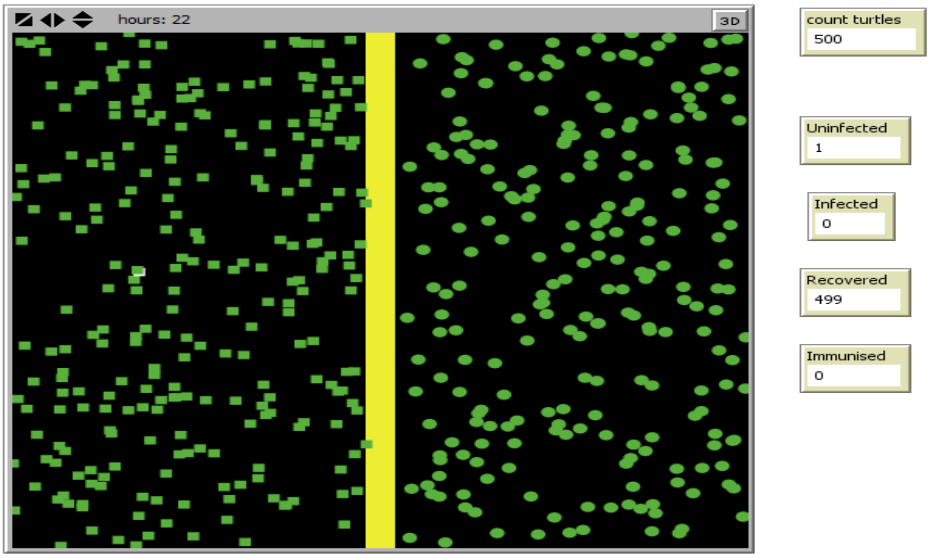
Screenshot 10

This screenshot shows that as the simulation begins, there are very few infected individuals.



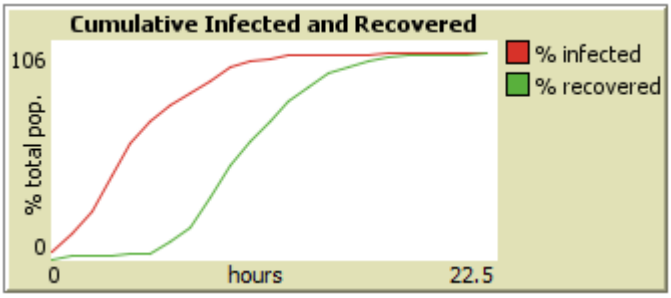
Screenshot 11

This screenshot shows that as the simulation advances, individuals start recovering.



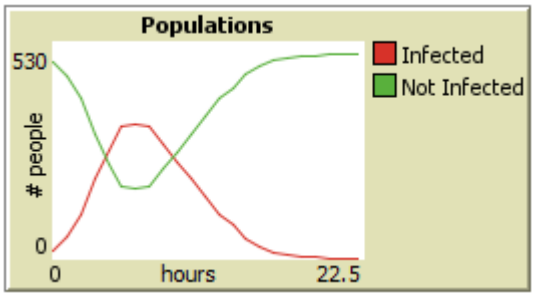
Screenshot 12

This screenshot shows that as the simulation ends, all individuals got recovery.



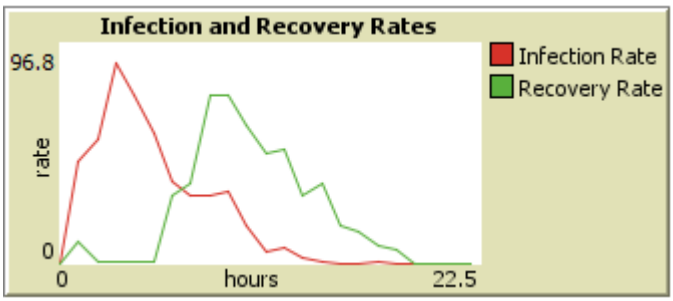
Graph 7

This graph plots the total percentage of individuals who have ever been infected or recovered.



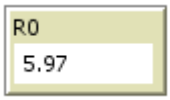
Graph 8

This graph plots the number of people with or without the disease.



Graph 9

This graph plots the estimated rates at which the disease is spreading.

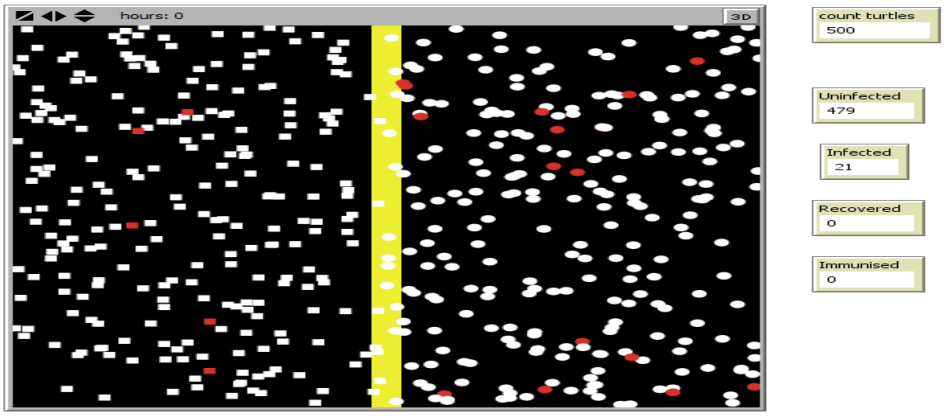


This demonstrates that by increasing the recuperation-probability parameter, the model takes less time to recover all individuals from contagion as the likelihood of individual's recovery gets increased.

Various additional parameters such as isolation, quarantine, and immunization are also added to help constrain the spread of influenza.

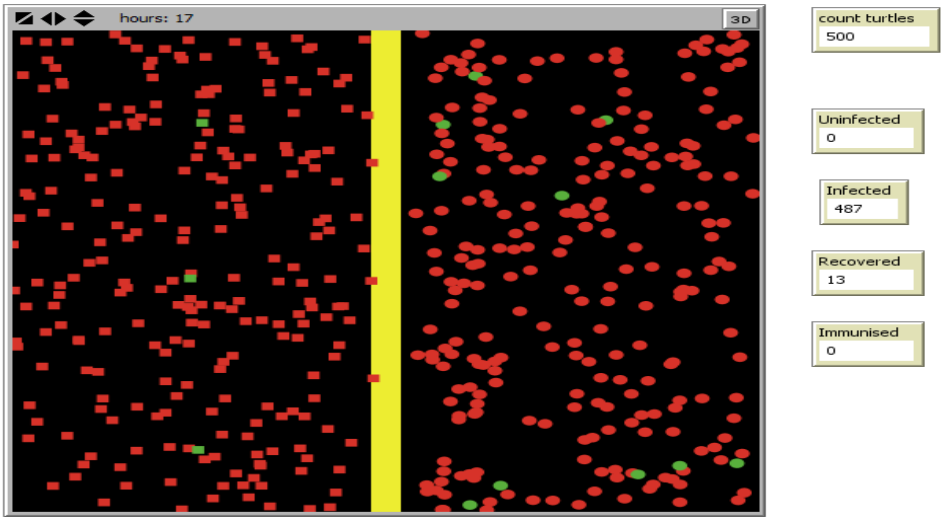
Test case no. - 4
To test the impact of segregation parameter on the influenza control.

Initial individual =500
Contagion-probability=25
Recuperation-probability=50
Average-recuperation-time=150
Average-segregation-propensity=20



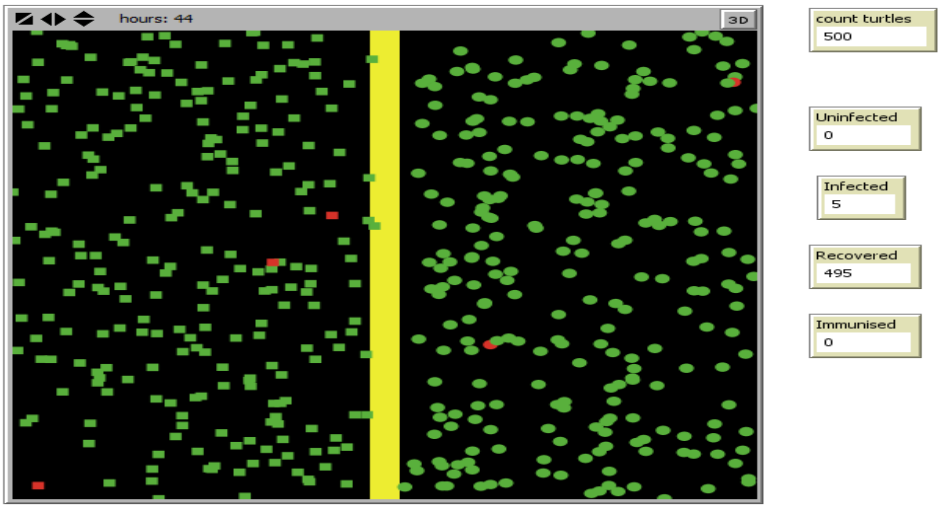
Screenshot 13

This screenshot shows that as the simulation begins, there are very few infected individuals.



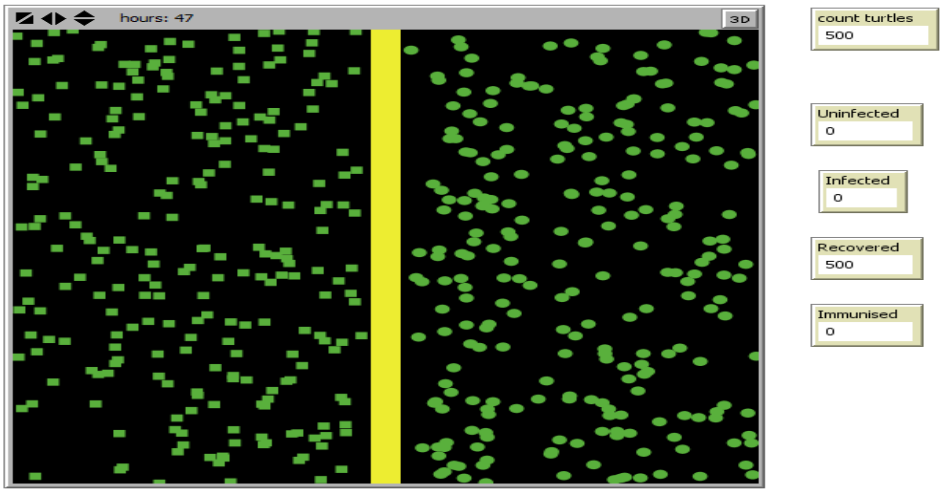
Screenshot 14

This screenshot shows that as the simulation progresses, infected individuals grow.



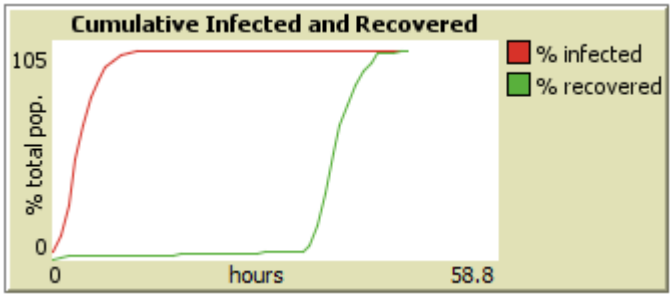
Screenshot 15

This screenshot shows that as the simulation advances, individuals start recovering.



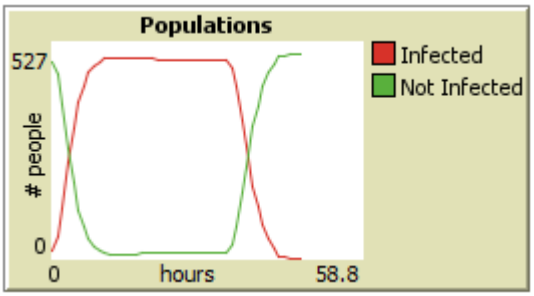
Screenshot 16

This screenshot shows that as the simulation ends, all individuals got recovery.



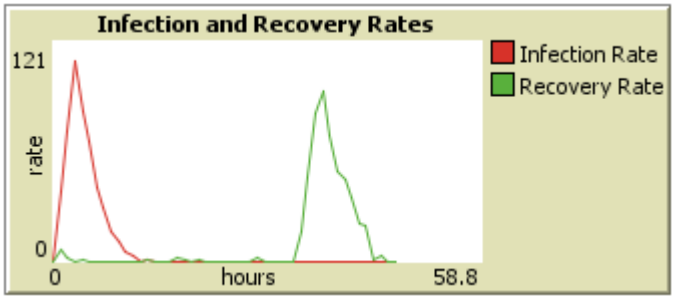
Graph 10

This graph plots the total percentage of individuals who have ever been infected or recovered.



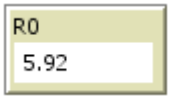
Graph 11

This graph plots the number of people with or without the disease.



Graph 12

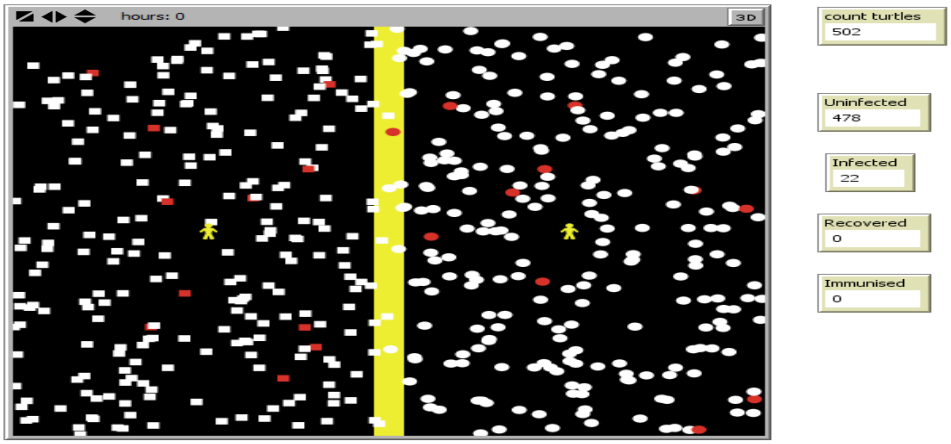
This graph plots the estimated rates at which the disease is spreading.



By including segregation parameter, the tainted people will separate themselves at home with the goal that contagion rate can be backed off [17]. As the tainted people won't come in direct contact with other vulnerable people therefore, spread of the flu can be controlled.

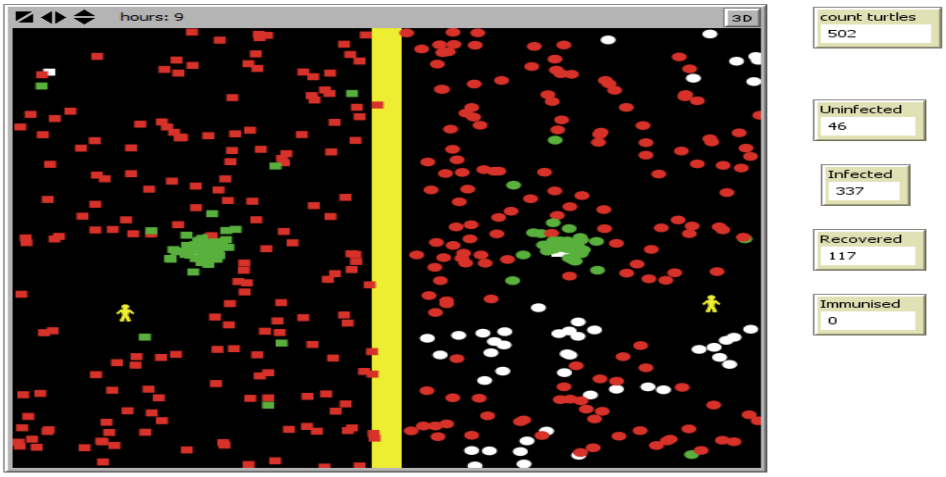
Test case no. - 5
To test the impact of quarantine parameter on the influenza control.

Initial individual =500
Contagion-probability=25
Recuperation-probability=50
Average-recuperation-time=150
Average-clinic-moving-propensity=10
Initial-emergency-vehicles=2



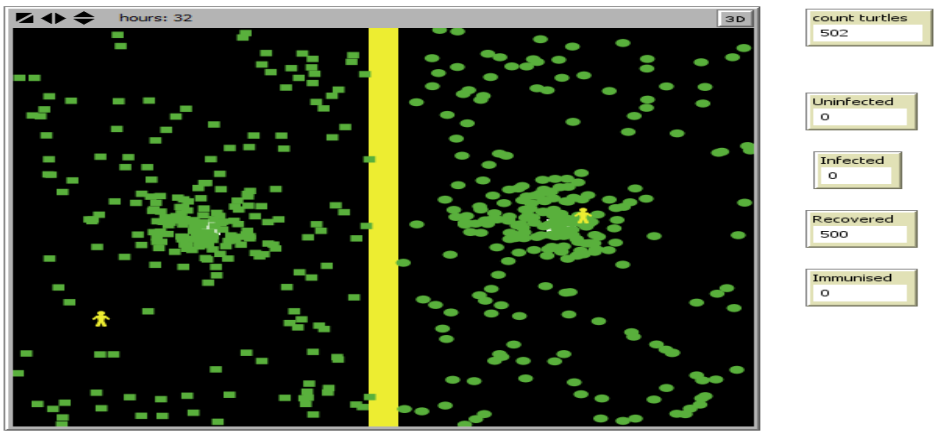
Screenshot 17

This screenshot shows that as the simulation begins, there are very few infected individuals and shows the ambulance.



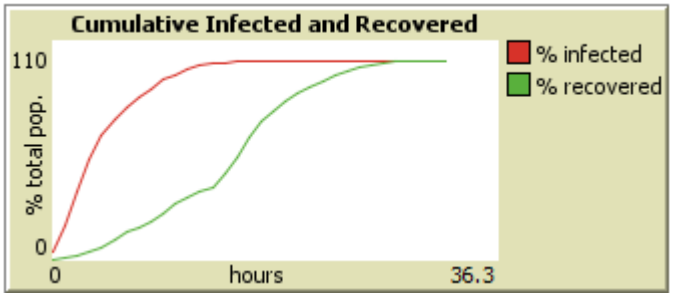
Screenshot 18

This screenshot shows that as the simulation advances, individuals start recovering due to clinical practices.



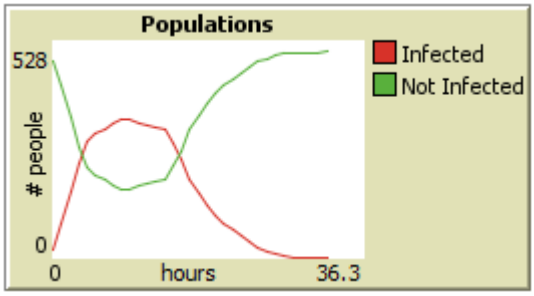
Screenshot 19

This screenshot shows that as the simulation ends, all individuals got recovery.



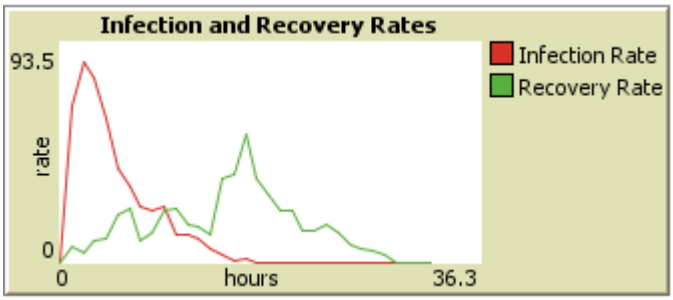
Graph 13

This graph plots the total percentage of individuals who have ever been infected or recovered.



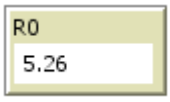
Graph 14

This graph plots the number of people with or without the disease.



Graph 15

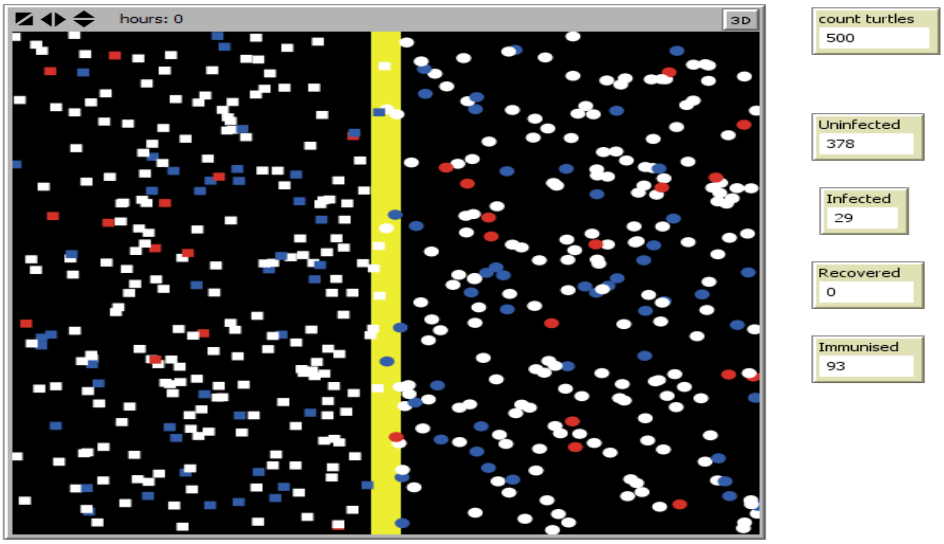
This graph plots the estimated rates at which the disease is spreading.



By including hospitalization parameter, the tainted people will either go to the healing center of their own or compelled to be hospitalized by the emergency vehicle so that the quick recovery rate can be accomplished because of better medication and rest [19].

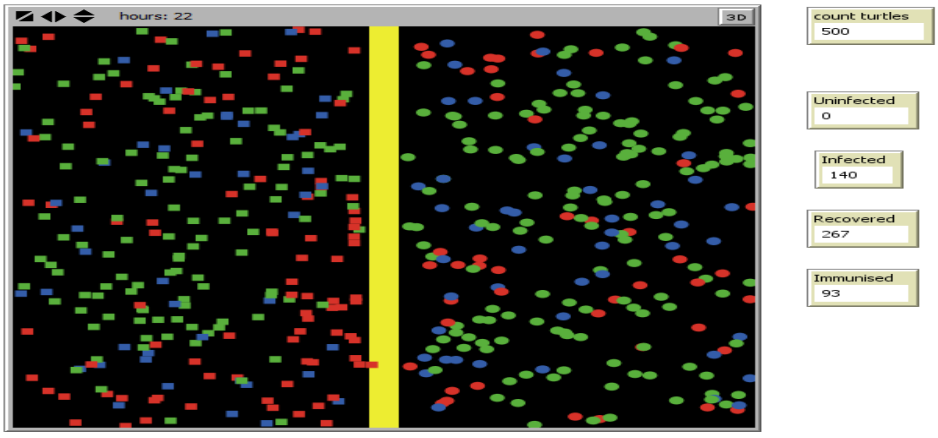
Test case no. – 6
To test the impact of immunization parameter on the influenza control.

Initial individual =500
Contagion- probability=25
Recuperation - probability=50
Average-recuperation-time=150
Immunization-probability=20



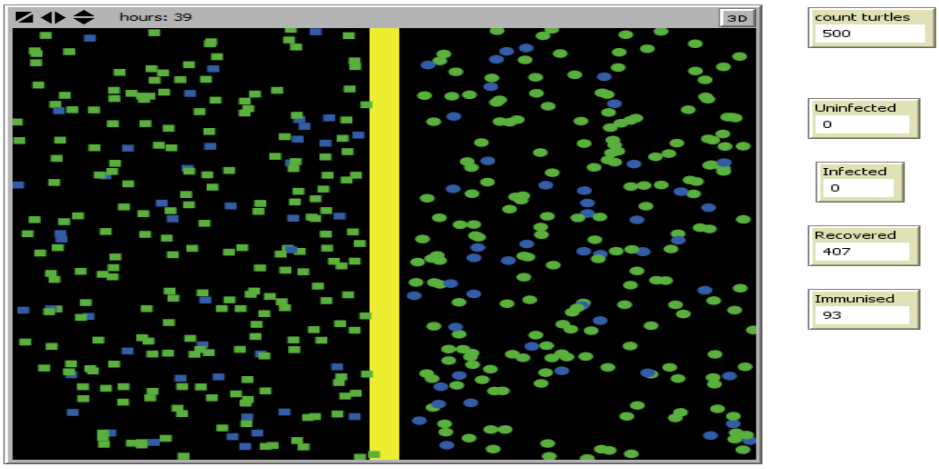
Screenshot 20

This screenshot shows that as the simulation begins, there are very few infected and immunized individuals.



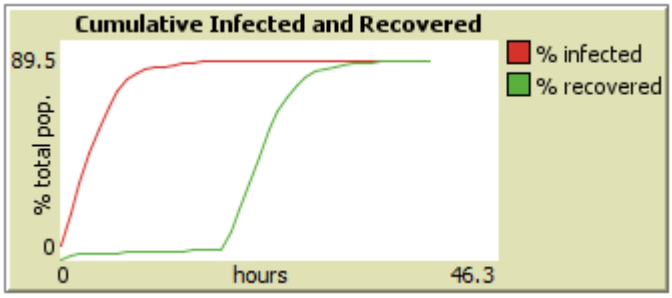
Screenshot 21

This screenshot shows that as the simulation progresses, infected individuals grow.



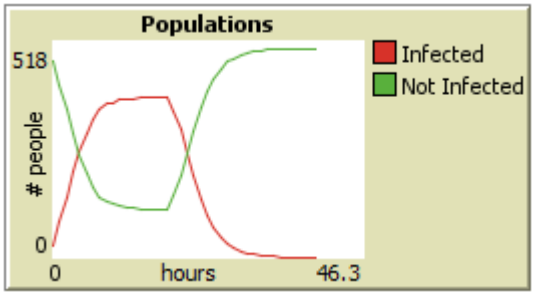
Screenshot 22

This screenshot shows that as the simulation ends, all individuals got recovery.



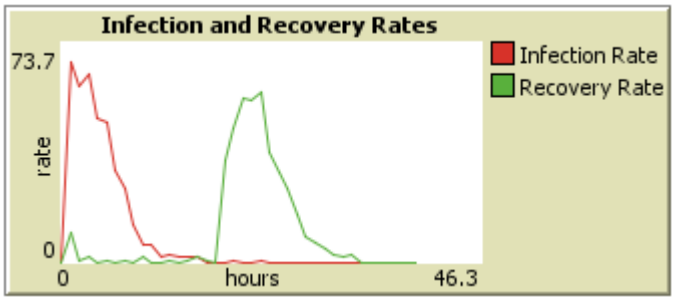
Graph 16

This graph plots the total percentage of individuals who have ever been infected or recovered.



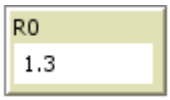
Graph 17

This graph plots the number of people with or without the disease.



Graph 18

This graph plots the estimated rates at which the disease is spreading.

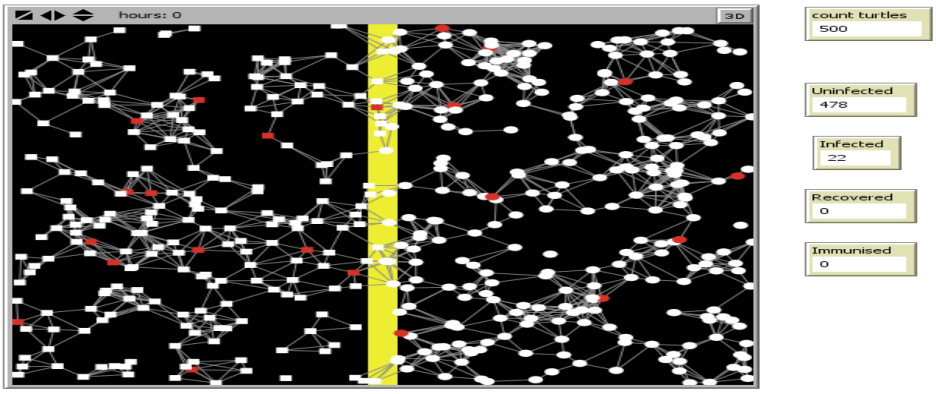


By vaccinating vulnerable individuals can likewise help in diminishing number of the infected individuals [19].

Flu emergence among high density of the populace is likewise identified with social networks and travelling parameter of individuals.

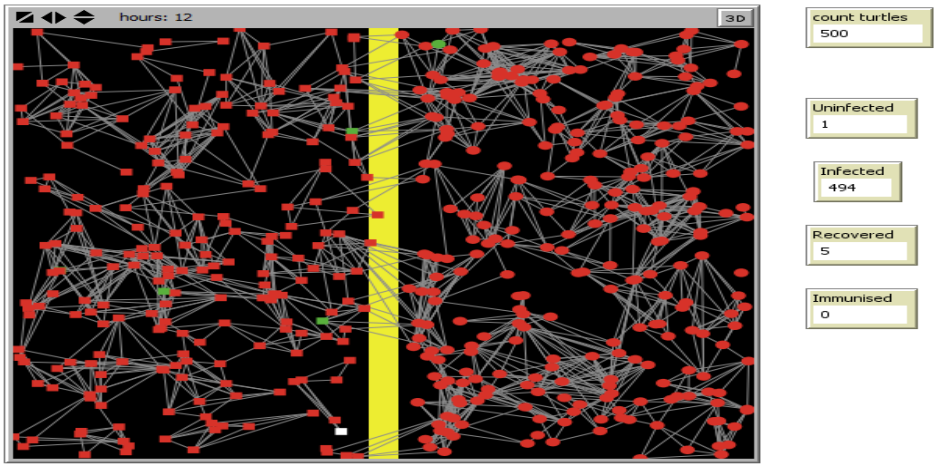
Test case no. - 7
To test the impact of social linking parameter on the influenza spread.

Initial individual =500
Contagion- probability=25
Recuperation - probability=50
Average-recuperation-time=150
When links on



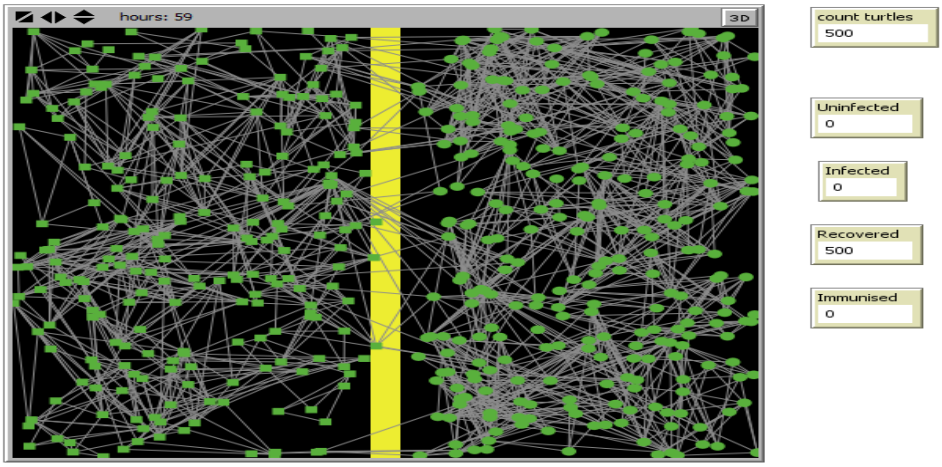
Screenshot 23

This screenshot shows that as the simulation begins, there are very few infected individuals and social networking has also been established.



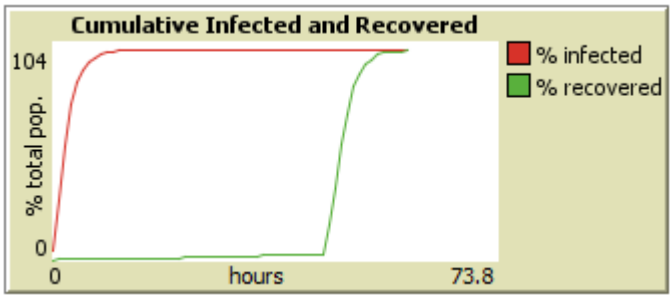
Screenshot 24

This screenshot shows that as the simulation progresses, infected individuals grow due to social networking.



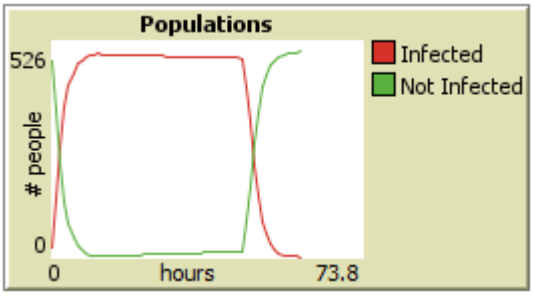
Screenshot 25

This screenshot shows that as the simulation ends, all individuals got recovery.



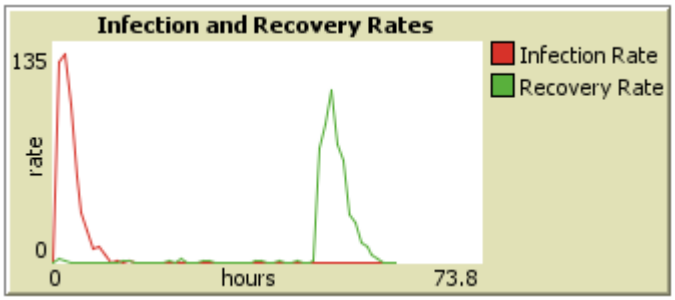
Graph 19

This graph plots the total percentage of individuals who have ever been infected or recovered.



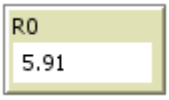
Graph 20

This graph plots the number of people with or without the disease.



Graph 21

This graph plots the estimated rates at which the disease is spreading.

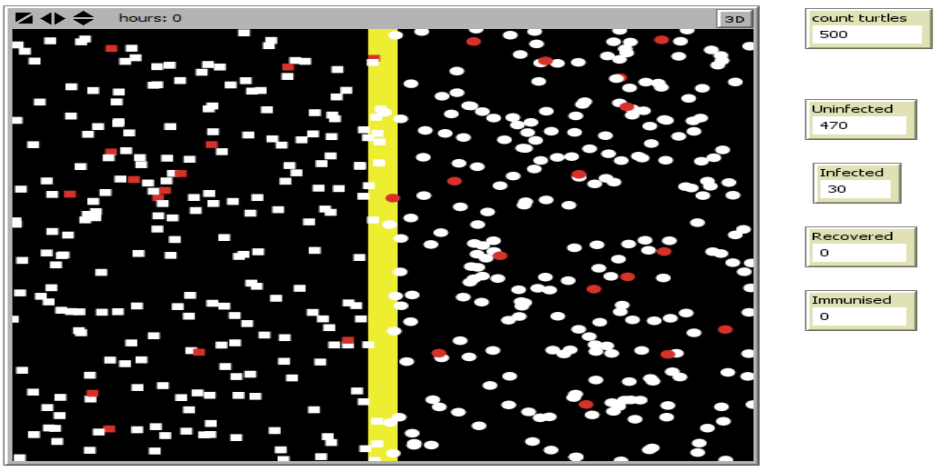


The results demonstrate that the infected rate in the early hours is greater than the rate in the late hours, and infected rate has a tendency to be smoothness, the count of infected people develops gradually.

The reasons for slow growing infected rate is that individual tends to talk with the one have social relationships, and individuals have social relationships are prior to sit together. During the early hours, incubation individuals rapidly infect their acquaintance through talking nearby, and during the later hours, incubation individuals hardly to infect other ones have no social relationships. Hence, the infected rate slows down [16, 17].

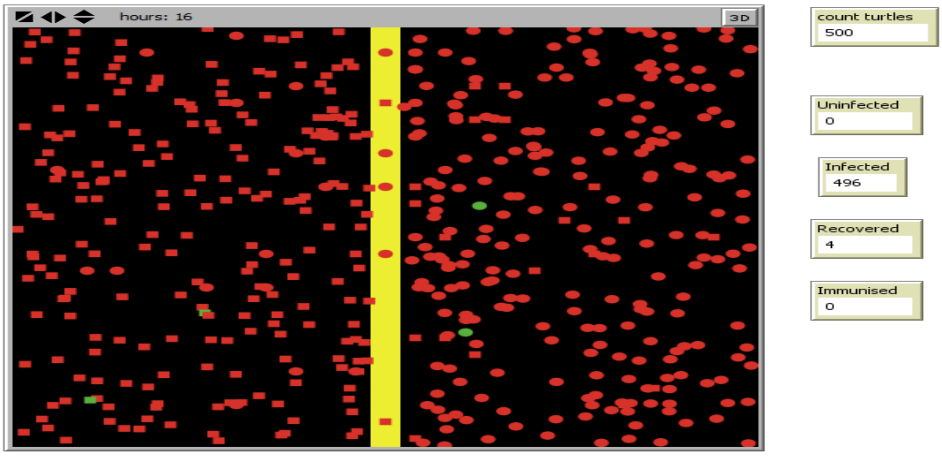
Test case no. – 8
To test the impact of travelling parameter on the influenza spread.

Initial individual =500
Contagion- probability=25
Recuperation - probability=50
Average-recuperation-time=150
When travel on



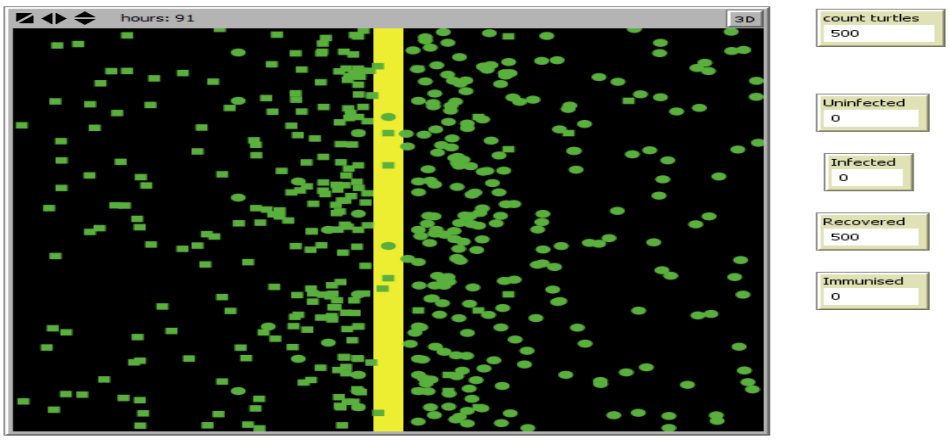
Screenshot 26

This screenshot shows that as the simulation begins, there are very few infected individuals and mixing of individuals around border.



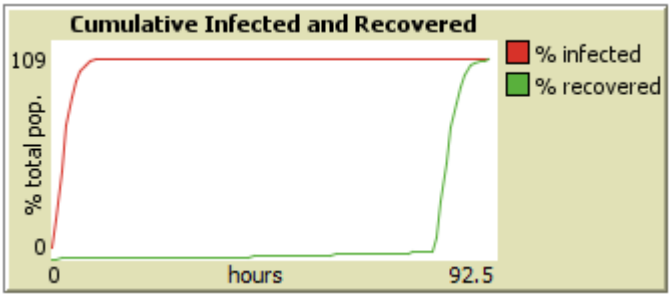
Screenshot 27

This screenshot shows that as the simulation progresses, infected individuals grow rapidly due to travelling.



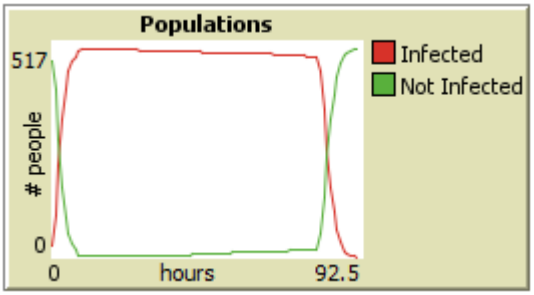
Screenshot 28

This screenshot shows that as the simulation ends, all individuals got recovery.



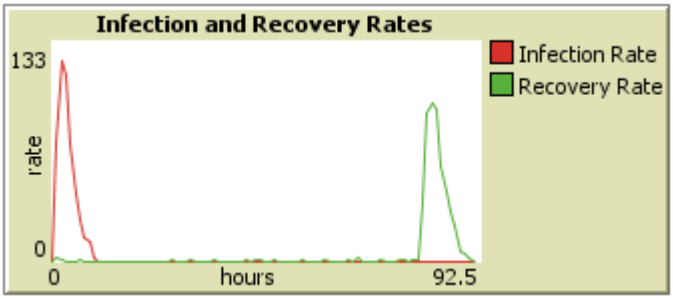
Graph 22

This graph plots the total percentage of individuals who have ever been infected or recovered.



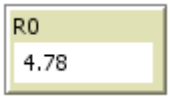
Graph 23

This graph plots the number of people with or without the disease.



Graph 24

This graph plots the estimated rates at which the disease is circulating.



It demonstrates that by adding travelling parameter, the influenza spreads widely as infected people migrate from one region to the other.
Basic transportation principles are utilized to mimic people's travels, taking into account the disease spread during a voyage since contagion is just conceivable upon contact with a tainted person [18].

When initial population is assumed to be 500-

Test case No.	Contagion-probability	Recuperation-probability	Average-recuperation-time	Average-segregation-propensity	Average -clinic-moving-propensity	Emergency-vehicles	Immunization-probability	Links	Travel	Time to recover (in hours)
1	25	50	150	-	-	-	-	No	No	84
2	25	50	200	-	-	-	-	No	No	149
3	25	60	150	-	-	-	-	No	No	22
4	25	50	150	20	-	-	-	No	No	47
5	25	50	150	-	10	2	-	No	No	32
6	25	50	150	-	-	-	20	No	No	39
7	25	50	150	-	-	-	-	Yes	No	69
8	25	50	150					No	Yes	91

Table1-Comparison of various different strategies

In test case no.2 when the average-recuperation-time is increased i.e. from 150 to 200 with respect to test case no.1,we find that individuals take more time to recover from the infection and in test case no.3 when the recuperation-probability is increased i.e.from 50 to 60 with respect to test case no.1, we find that individuals take less time to recover from influenza.

Individuals get faster recovery due to control parameters such as average-segregation-propensity, average-clinic-moving-propensity and immunization as these parameters help in limiting the spread of influenza. Among these, hospitalization seems to be very effective as it takes less time to recover that can be seen from test cases 4, 5, and 6.

Due to social linking i.e. cordial relationships among people (indicated by test case 7) and travelling (indicated by test case 8) parameters, influenza spread widely and thus requires more time to recover from flu, even after assuming average-recuperation-time and recuperation-probability as same.

CHAPTER 7 – CONCLUSION AND FUTURE WORK

The objectives of this research are to look at the spread of an epidemic and approaches to control it. An agent-based model is developed to examine the ability to control the epidemic utilizing segregation, quarantine, and immunization.

This simulation model helps clients for comprehending new illness spread progression in connection with the adjustments in control measures, travel, and versatility and furthermore observes the way R_0, i.e. Reproduction number, speaks as far as possible for the epidemic and comprehend the connection to integrals and subordinates.

The proposed model does not simulate real data. Future work will focus on the acknowledgment of bigger scale simulation model like city and even the country. Additional work at proposed model incorporates: operators with extra traits that permit a better reasonable model (e.g., Temperature, ages, sexual orientation, and so on), and in addition finding an ideal mix of control methodologies to deal with the epidemic outbreak.

REFERENCES

[1] G. Ch. Sirakoulis, I. Karafyllidis, and A. Thanailakis. "A cellular automaton model for the effects of population movement and vaccination on epidemic propagation." Ecological Modelling 133(2000): 209-223.

[2] U.Wilensky.(1999). *NetLogo*. Evanston, IL: Northwestern University, Center for Connected Learning and Computer-Based Modeling. Retrieved from ccl.northwestern.edu/netlogo.

[3] J.D.Murray, Mathematical Biology I: An Introduction. 3rd edition. New York: Springer, 2002.

[4] D.J.Daley, J.Gani. Epidemic Modeling: An Introduction. Cambridge: Cambridge University Press, 1999.

[5] M.Roberts, et al. Conceptualizing a model: a report of the ISPOR-SMDM Modeling Good Research Practices Task Force—2.Med Decis Making. 2012;32(5):678–89.

[6] U.Siebert, et al. State-transition modeling: a report of the ISPORSMDM Modeling Good Research Practices Task Force—3. MedDecis Making. 2012;32(5):690–700.

[7] SC .Bankes, Agent-based modeling: a revolution? Proc Natl AcadSci USA. 2002;99(Suppl 3):7199–200.

[8] SY Kim, SJ Goldie. Cost-effectiveness analyses of vaccination programmes. Pharmacoeconomics. 2008;26(3):191–215.

[9] RM Anderson, RM May. Contagious diseases of humans, vol. 1. Oxford: Oxford University Press; 1991.

[10] TC Schelling. Models of segregation. Am Econ Rev.1969;59(2):488–93.

[11] M .Gardner. Mathematical games: the fantastic combinations of John Conway's new solitaire game ''Life''. Sci Am. 1970;223(4):120–3.

[12] E. Bonabeau. Agent-based modeling: methods and techniques for simulating human systems. Proc Natl Acad Sci USA. 2002;99(Suppl 3):7280–7.

[13] Rey, A M. Del, S.H. White, and G. R. Sanchez. "A Model Based on Cellular Automata to Simulate Epidemics Diseases." Google Scholar (2006) 304-305. Jan 2008 <http://www.springerlink.com/index/k0g181177x6q6532.pdf >.

[14] Beauchemin, Catherine. "Probing the effects of the well-mixed assumption on viral infection dynamics." Journal of Theoretical Biology 242(2006): 464-477.

[15] E.Ahmed, H.N. Agiza, and S. Z. Hassan. "On Modeling Hepatitis B Carrying Using Cellular Automata." Journal of Statistical Physics 92(1998): 707-712.

[16] Ge, Yuanzheng, et al. "Agent based modeling for H1N1 influenza in artificial campus." Emergency Management and Management Sciences (ICEMMS), 2011 2nd IEEE International Conference on. IEEE, 2011.

[17] K. M. Khalil, M. Abdel-Aziz, T.T. Nazmy and A.M. Salem, "An agent- based modeling for epidemic influenza in Egypt," available online at: http://arxiv.org/abs/1001.5275.

[18] Rakowski, Franciszek, et al. "Influenza epidemic spread simulation for Poland—a large scale, individual based model study." Physica A: Statistical Mechanics and its Applications 389.16 (2010): 3149-3165.

[19] Mei, Shan, et al. "Quantitatively evaluating interventions in the influenza A (H1N1) epidemic on China campus grounded on individual-based simulations." Procedia Computer Science 1.1 (2010): 1675-1682.

[20] J. Wang, J. Xiong, K, et al, 2010 "Use of GIS and agent based modeling to simulate the spread of influenza," in Proc. 18th Int. Conf. Geoinformat., pp. 1–6.

[21] G.Chowell, M.A. Miller, et al. "Seasonal influenza in the United States, France, and Australia: carrying and prospects for control." Epidemiol. Infect (2007): 1-13.

[22] J.D.Murray. Mathematical Biology . 2nd edition. New York: Springer, 1993.

[23] Feng, Zhilan, W. Huang, et al. "Global behavior of a multi-group SIS scourge model with age structure." Journal of Differential Equations 218(2005): 292-324.

[24] Allen, Linda. An Introduction to Mathematical Biology. Upper Saddle River, NJ: Pearson Prentice Hall, 2007.

[25] A.Ramani, A.S. Carstea, R. Willox, B. Grammaticos. "Oscillating epidemics: a discrete-time model." Physica A 333(2004): 278-292.

[26] RM Anderson, RM May. 1982. The logic of vaccination. *New Scientist* November 1982, pp. 410-415.

[27] Grimm, Volker, S. F. Railsback. Individual-based Modeling and Ecology. Princeton: Princeton University Press, 2005.

[28] CM Macal, MJ North. Agent-based modeling and simulation: ABMS examples. In: Proceedings of the 40th winter simulation conference. Miami, FL, USA; 2008.

[29] SF Railsback, V.Grimm. Agent-based and individual-based modeling: a practical introduction. Princeton: Princeton University Press; 2011.

[30] JJ Grefenstette, et al. FRED (a framework for reconstructing scourge dynamics): an open-source software system for modeling contagious diseases and control stmeasuregies using censusbased populations. BMC Public Health. 2013;13:940.

[31] P.Callan ,Ebola quarantine is perfectly legal.CNN. 2014. http://www.cnn.com/2014/10/06/justice/callan-law-on-quarantine/.Accessed 6 Oct 2014.

[32] J.Koopman.Controlling smallpox.Science. 2002;298(5597):1342–4.

[33] H.Rahmandad , J.Sterman. Heterogeneity and network structure in the dynamics of diffusion: comparing operator-based and differential equation models. Manag Sci. 2008;54(5):998–1014.

[34] F.Stonedahl, U.Wilensky. NetLogo virus on a network model. Center for Connected Learning and Computer-Based Modeling. Evanston: Northwestern University; 2008.

[35] U.Wilensky. NetLogo: Center for Connected Learning and Computer-Based Modeling. Evanston: Northwestern University;1999.

[36] U.Wilensky. NetLogo small worlds model. Center for Connected Learning and Computer-Based Modeling. Evanston: Northwestern University; 2005.

[37] AH.Briggs, et al. Model parameter estimation and uncertainty analysis: a report of the ISPOR-SMDM Modeling Good Research Practices Task Force Working Group—6. Med Dec Making. 2012;32(5):722–32.

[38] BG.Koerkamp, et al. Uncertainty and patient heterogeneity in medical decision models. Med DecisMaking. 2010;30(2):194–205.

[39] KM.Kuntz, MC.Weinstein. Modelling in economic evaluation. In: Drummond M, McGuire A, editors. Economic evaluation in health care: merging theory with practice. Oxford: Oxford University Press; 2001.

[40] A.O'Hagan , M.Stevenson, J.Madan. Monte Carlo probabilistic sensitivity analysis for patient level simulation models: efficient estimation of mean and variance using ANOVA. Health Econ. 2007;16(10):1009–23.

[41] JJ.Kim, et al. Modeling cervical cancer prevention in developed countries. Vaccine. 2008;26:K76–86.

[42] N.Ferguson, D.Cummings, C.Fraser, J.Cajka, P.Cooley, D.Burke. (2006) Strategies for mitigating an influenza epidemic. Nature 442(27):448–452

[43] N.Ferguson, DA.Cummings, S.Cauchemez, C.Fraser, S.Riley, M.Aronrag, S.Lamsirithaworn, D.Burke. (2005) Strategies for containing an emerging influenza epidemic in Southeast Asia. Nature 437(7056):209–214

[44] A.Flahault, E.Vergu , P.Bo¨elle (2009) Potential for a global dynamic of influenza a (h1n1). BMC Infect Dis 9(129):1–11

[45] C.Fraser, C.Donnelly (2009) Epidemic potential of a strain of influenza A (H1N1): early findings. Science 324:1557–1561

[46] T.Germann, K.Kadau, I.Longini, C.Macken. (2006) Mitigation strategies for epidemic influenza in the United States. PNAS 103:5935–5940

[47] J.Ginsberg, M.Mohebbi, R.Patel, L.Brammer, M.Smolinski, L.Brilliant, (2009) Detecting influenza epidemics using search engine query data. Nature 457(19):1012–1015

[48] R.Glass, W.Beyeler, H.Min (2006) Targeted social distancing design for epidemic influenza. Emerg Infect Dis 12(11):1671–1681

[49] M.Gojovic, B.Sander, D.Fisman, M.Krahn, C.Bauch (2009) Modelling mitigation strategies for epidemic (H1N1) 2009. CMAJ 181(10):673–680

[50] H.Guo, F.Santiago, K.Lambert, T.Takimoto, D.Topham (2011) T cell-mediated protection against lethal 2009 epidemic H1N1 influenza virus infection in a mouse model. J Virol 85(1):448–455

[51] N.Halder, J.Kelso, G.Milne (2010) Developing guidelines for school closure interventions to be used during a future influenza epidemic. BMC Infect Dis 10(221), pp 1–14

[52] M.Halloran, N.Ferguson, I.Longini, C.Macken (2008) Modeling targeted layered containment of an influenza epidemic in the United States. PNAS 105(12):4639–4644

[53] E.Kenah, D.Chao, L.Matrajt, M.Halloran, I.Longini (2011) The global carrying and control of influenza. PLoS One 6(5):1–10

[54] W.Liu, Z.Li, F.Tang, M.Wei, Y.Tong, L.Zhang, Z.Xin, M.Ma, X.Zhang, L.Liu, L.Zhan, C.He, H.Yang, C.Boucher, J.Hendrik, W.Cao (2010) Mixed contagions of epidemic H1N1 and seasonal H3N2 viruses in one outbreak. Clin Infect Dis 50(10):1359

[55] M.J.North, N.T.Collier, & J.R.Vos. (2006). Experiences creating three implementations of the repast agent modeling toolkit. *ACM Transactions on Modeling and Computer Simulation, 16(1),* 1-25.

[56] S.Luke, C.Cioffi-Revilla, L.Panait, K.Sullivan, and G.Balan. (2005). MASON: A Java multi-agent simulation environment. *Simulation: Transactions of the Community for Modelling and Simulation International, 81(7),* 517-527.

[57] Germann, C.Timothy, K. Kadau, Jr.I. M. Longini, and C. A. Macken. "Mitigation Strategies for epidemic influenza in the United States." PNAS Vol. 103 (15)11 Apr 2006 5935-5940. 28 Mar 2008 <www.pnas.org>.

[58] Ohkusa, Yasushi, and T. Sugawara. "Application of an individual-based model with real data for transportation mode and location to epidemic influenza." J Infect Chemother 139 Aug 2007 380-389.

[59] "U.S. Department of Transportation Bureau of Transportation Statistics." RITA. 08 Apr 2008. U.S. Department of Transportation. 9 Apr 2008 <http://www.transtats.bts.gov/>.

[60] Polio Vaccine What you need to Know. 1 Jan 2000. Center for Disease Control. 9 Apr 2008 <http://www.cdc.gov/vaccines/pubs/vis/downloads/vis-IPV.pdf>.

[61] Rothstein, A.Mark, M.G. Alcalde, N. R. Elster, M.A. Majumder, L.I. Palmer, T.H. Stone, and R. E. Hoffman. "Quarantine and Isolation: Lessons Learned from SARS." Nov 2003. Center for Disease Control. 9 Apr 2008 <http://www2a.cdc.gov/phlp/docs/Quarantine-Isolation-Lessons-Learned-from-SARS.pdf>.